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Article · June 2020

DOI: 10.22120/jwb.2020.118316.1115

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Journal of Wildlife and Biodiversity 4(3): 70-79 (2020)

(http://jwb.araku.ac.ir/)

DOI: 10.22120/jwb.2020.118316.1115

Research Article

Population densities and conservation assessment of three threatened agamid species in Horton Plains National Park, Sri Lanka

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Received: 28 January 2020 / Revised: 14 March 2020 / Accepted: 26 April 2020 / Published online: 11 June 2020. Ministry of Sciences, Research, and Technology, Arak University, Iran.

Abstract

Horton Plains National Park is home for three endemic and threatened agamid species in Sri Lanka; *Ceratophora stoddartii, Cophotis ceylanica and Calotes nigrilabris*. This study was conducted to estimate the population densities of these lizard species within HPNP in 2016 and 2017. Line transect surveys were carried out following the "Distance" method to obtain population counts. A total of 288 transects were surveyed in two different time periods of each year; Dry months and Wet months. The program "Distance 7.1" was used for density calculations. The highest population density was recorded for *Ce. stoddartii* in the wet months of 2016 and 2017 (32.91 ind/ha, n=77; 26.70 ind/ha, n=66). However, *Ce. stoddartii* density was relatively lower in the dry months of both years (2016: 19.79 ind/ha, n=58; 2017: 17.18 ind/ha, n=55). The lowest population density was recorded for *Ca. nigrilabris* in the wet season of 2017 (7.80 ind/ha, n=38). The population density of *Co. ceylanica* which did not show much fluctuation throughout all four sampling periods, was relatively lower when compared with other species. These results indicate that more conservation focus is required to protect these agamids that have low and declining populations when compared to past literature available. They are also facing the threat of illegal smuggling.

Keywords: *Agamidae*, cloud forests, conservation, distance method, lizard smuggling, threatened lizards

Introduction

Sri Lanka lies in the Indian Ocean is an island nation that has rich herpetofauna diversity (Myers *et al*. 2000, Bossuyt *et al.* 2004, De Silva 2007, Erdelen 2012) and a high level of endemism (Bossuyt *et al.* 2004, Bambaradeniya 2006). Of the 21 agamid lizards found in the island, 19 (90.4%) are identified to be endemic to the island. Several evolutionary factors (Bossuyt *et al.* 2004) have resulted in this endemism, especially in the low and high altitude wet zone region of the island. Furthermore, Sri Lanka, along with Western Ghats of India has been identified as one of the 35 biodiversity hotspots of the world (Myers *et al.* 2000) due to the high level of endemism as well as the higher number of species that are threatened and face the risk of extinction mainly due to habitat loss (BDS, MoENR 2009, MoMD&E 2016). As a result of increasing human populations and exploitation in the wet zone region, to which more than 75% of the endemic species are restricted, the remaining forest cover has diminished to a considerably low level of 4.7% (BDS, MoENR 2009, MoE 2012, MoMD&E 2016) of the total land area of the island. Moreover, these remaining natural habitats are also being fragmented, and the level of anthropogenic pressure is increasing rapidly in the forms of encroachment, overexploitation, pollution as well as ornamental trade (MoMD&E 2016).

Horton Plains National Park (HPNP) is one of the few remaining protected areas of the montane region of the island wet zone which facilitate several endemic fauna that are highly range restricted. HPNP is home for three endemic and threatened agamid lizard species in Sri Lanka; *Ceratophora stoddartii* Gray, 1835*, Cophotis ceylanica* Peters, 1861 *and Calotes nigrilabris* Peters, 1860 (De Silva 2007). These three species are restricted to a few localities in the montane region. They have specially adapted to live in the cold climatic conditions of the area (Manamendra-Arachchi and Liyanage 1994, Pethiyagoda and Manamendra-Arachchi 1998, Bahir and Surasinghe 2005, De Silva 2007, Somaweera and Somaweera 2009, Amarasinghe *et al.* 2011, Jayasekara *et al.* 2018a). The only population density estimation regarding an agamid in the HPNP has been carried out in 1988 (Erdelen 1988), estimating the density of *Ca. nigrilabris* as 220 individuals/ha. No data is available regarding the population of the other two agamids. Despite assessed by IUCN Sri Lanka as threatened (MOE 2012), IUCN international has not evaluated the status of these three lizard species yet, probably due to lack of required data. Therefore, this study was conducted to estimate the population densities of these three lizard species within HPNP, which is one of the most popular National Parks of the island with high visitor rates. This region has also been identified as an area highly sensitive to climate change (Fernando 2008, Pethiyagoda 2012). Results provided by this study will be necessary for the establishment of the status of these species and can be integrated into the conservation strategies to be implemented in these unique and invaluable montane habitats.

Material and methods

HPNP (Fig. 1, 2) comprises three main habitat types; Cloud forest habitat, Grassland habitat, and Cloud forest dieback habitat (Gunatilleke and Gunatilleke 1986, DWC 2007). Data collection for population estimation of *Ca. nigrilabris* (Figure 3a)*, Ce. stoddartii* (Fig. 4) and *Co. ceylanica* (Fig. 3b) was conducted covering all three habitat types. Since the distribution of each habitat type is approximately equal within the park, no stratification of sampling effort was considered. However, the area of the park was divided into 1 km^2 plots (using a grid in Arc GIS 10.4) to make sure most of the national park area was covered during the sampling. Of the 27 plots which were marked within the national park area, 24 plots were surveyed except three plots, which were difficult to access. *Ce. stoddartii* and *Co. ceylanica* are considered to be Cloud forest adapted species (Manamendra-Arachchi and Liyanage 1994, Pethiyagoda and Manamendra-Arachchi 1998, Bahir and Surasinghe 2005, De Silva 2007, Somaweera and Somaweera 2009, Jayasekara *et al.* 2018a, Jayasekara and Mahaulpatha 2018a) which are mostly found in the Cloud forest and dieback habitats whereas, *Ca. nigrilabris* is mainly observed in the Grassland habitat despite being present in the Cloud forests (Karunarathna *et al.* 2011, Bahir and Surasinghe 2005, Jayasekara *et al.* 2017).

Sri Lanka experiences four monsoonal seasons (Thambyahpillay 1958), which shapeup the island's climatic conditions. However, HPNP, which resides on the highest plains of the island, seems to be relatively less affected by the monsoon rains having unique requirements when compared to the rest of the island. In addition to the direct precipitation that is received mostly on the onset of South-west and North-east monsoon rains, this area experiences horizontal rainfall (cloud water recapture), which keeps the conditions wet and moist throughout the year (Pethiyagoda 2012). However, when overall precipitation data was considered, a prominent wet season and a dry season has been identified (DWC 2007, Pethiyagoda 2012). Therefore, this study was conducted focusing on those two time periods of the year, which was selected taking the rainfall data into account (Dry months - 56.8 mm mean rainfall; January, February, March, and Wet months 125.9 mm; September, October, November). We collected data from

January to March and September to November in 2016 and 2017 to represent both dry and wet seasons. Densities were estimated for each season in the two years considered to take out any bias that occurred due to stochastic environmental variables by sampling only in one particular year.

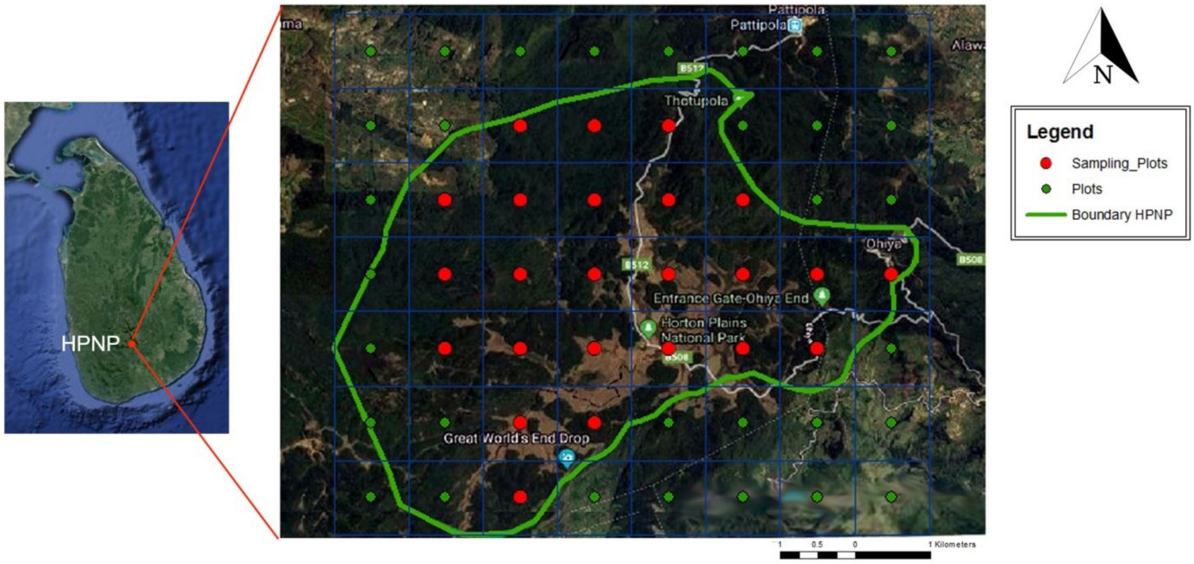

Figure 1. Location of Horton Plains National Park with the map showing the sampling plots and park boundary

Figure 2. View of the central region of HPNP from the top of Totupola mountain. Grassland habitat and Cloud forest habitats are visible with the backdrop of Kirigalpoththa and Agra mountain ranges

Distance sampling is a popular method for density estimates of different animals (Jenkins *et al.* 1999, Karsten *et al.* 2009) and recent literature includes several studies of chameleons (Jenkins *et al.* 1999; Karsten *et al.* 2009) as well as a few agamid density estimations (Venugopal 2010). The natural behavior of most agamid lizards, especially the species which are not fast-moving, helps to make accurate density estimations following the methods of Buckland *et al.* (1993, 2001). All three agamid lizard species considered in this study were arboreal, and none of them were burrowing or crevice dwelling species.

Relatively low canopy heights in most of the habitats also made the observations more possible, and based on past literature, and these agamids rarely ascend heights greater than 3 m in general (Somaweera and Somaweera 2009, Jayasekara *et al.* 2017, 2018a). Due to the threatened status of the species of concern, the mark-recapture method was estimated to be unsuitable because of the stress applied to the lizards during capturing, handling, and marking procedures. All these factors together make the distance sampling technique more suitable for density estimation of threatened agamid lizards in these montane habitats. To obtain higher encounter rates, the sampling was conducted coinciding with the periods when the lizard activity levels were high (Jayasekara *et al.* 2017, 2018a) Methods followed in this study adhered to the four main assumptions described by Buckland *et al.* (1993, 2001) for the distance sampling model; 1) survey transects are placed randomly concerning a species' distribution, 2) the detection rate for organisms that are zero distance from the transect line is 100%, 3) organisms are detected before any movement or disturbance caused by the observer, 4) perpendicular distances to the transect can be measured accurately. Randomly established 100m line transects were marked and traversed to identify and count the agamid lizards on either side of the line. The perpendicular distance to each lizard sighted was recorded using a measuring tape to 1 cm accuracy. There were no difficulties in the identification of species due to their distinct morphological differences, and the visibility of agamid lizards that were on the transect line was 100% (Karsten *et al.* 2009) based on our field experience. A total of 288 random transects were surveyed in two different time periods of each year. The program "Distance 7.1" was used for density calculations where the program applies a series of functions to the data and selects the best-fitting model for the available data using the Akaike Information Criterion (AIC) (Burnham and Anderson 2002, Karsten *et al.* 2009). The density was calculated as individuals per hectare. Additionally, Effective Strip Width (ESW) was provided by the software as a measure of distance in meters within which range the detection of a lizard is more accurate from the transect line.

Results

A total of 583 lizards (*Ca. nigrilabris* – 222, *Ce. stoddartii* – 256, *Co. ceylanica* – 105) were recorded during the study. *Ca. nigrilabris* was most abundant in the grassland habitat while the other two sympatric species, *Ce. stoddartii* and *Co. ceylanica* mostly preferred the Cloud forest habitat. *Ce. stoddartii* was never observed in the grassland habitat. *Ca. nigrilabris* was inhabiting all three habitat types.

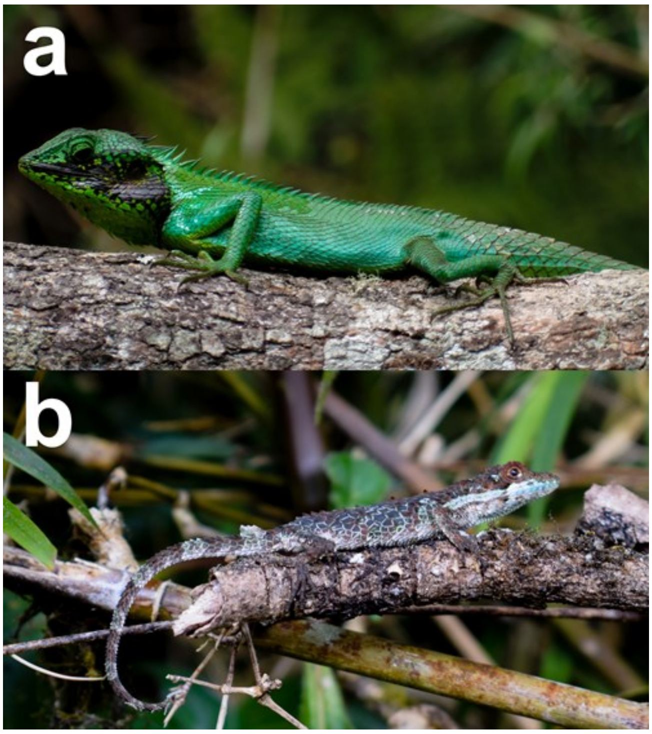

Figure 3. (a) An adult male *C. nigrilabris* (b) *C. ceylanica*

Figure 4. An adult *C. stoddartii* camouflaged in its preferred Cloud forest microhabitat

Population density during the dry and wet months of 2016 and 2017

As Table 1 indicates, during the dry seasons of the two years considered, *Ca. nigrilabris* densities were higher than their wet season densities. Densities of both *Ce. stoddartii* and *Co. ceylanica* were drastically lower during the dry seasons when compared to wet seasons. However, even in the dry season densities of *Ce. stoddartii* (2016: 19.79 ind/ha; 2017: 17.18

ind/ha) were higher than the rest of the species. Highest population density was recorded for *Ce. stoddartii* in the wet months of 2016 and 2017(32.91 ind/hec; 26.70 ind/ha). Lowest population density was recorded for *Ca. nigrilabris* in the wet season of 2017 (7.79 ind/ha, n=38) which was drastically lower than the densities in other three sampling periods. The population density of *Co. ceylanica* did not show much fluctuations throughout all four sampling periods (lowest: 9.71 ind/ha; highest: 11.20 ind/ha). However, the density of *Co. ceylanica* was relatively low when compared with the other two species.

The program also generated Effective Stripe Width (ESW) values for the species of concern, which gives an indication of the detection probability of each species. The average ESW for *Ca. nigrilabris* was 3.32 (±0.05) m. *Ce. stoddartii* and *Co. ceylanica* recorded lower ESW values, 1.90 (±0.28) m and 1.72 (±0.18) m, respectively.

Table 1. Population densities of the three lizard species during the time periods considered (Density given as individuals/ha, LCL-Lower Confidence Limit, UCL- Upper Confidence Limit, n- number of observations)

	2016 Dry months			**2016 Wet months**			**2017 Dry months**			**2017 Wet months**		
Species	Density	(LCL-UCL)	n	Density	(LCL-UCL)	n	Density	(LCL-UCL)	n	Density	(LCL-UCL)	n
Ca. nigrilabris	**13.33**	(7.84-22.69)	63	**12.33**	(7.22-21.05)	59	**13.14**	(7.72-22.38)	62	**7.8**	(4.14-14.73)	38
Ce. stoddartii	**19.79**	(14.99-26.12)	58	**32.91**	(24.27-44.74)	77	**17.18**	(12.7-23.26)	55	**26.7**	(19.26-37.04)	66
Co. ceylanica	**10.66**	(6.10-18.35)	29	**11.21**	(6.36-19.74)	25	**10.91**	(6.13-19.39)	25	**9.71**	(5.45-17.32)	26

Discussion

There was a clear pattern in the densities recorded for the dry and wet months of the two years considered. Fluctuations of densities were more related to the breeding seasons of each species. The cold loving *Ce. stoddartii* and *Co. ceylanica* were more abundant in the wet months which are also their primary breeding months (Jayasekara and Mahaulpatha 2018b). *Ca. nigrilabris*, which usually prefers higher temperatures, were more abundant during the dry months when their prominent breeding activity takes place. The reason for the higher densities generated on the onset of breeding seasons was due to the higher activity levels of lizards as they seek their mating partners. ESW value can be used as an essential indicator of the cryptic behavior of lizards. Lower ESW values indicate lower detection probabilities. Fittingly, *Ce. stoddartii* and *Co. ceylanica* accounted for lower ESW values due to their higher camouflage capabilities (De Silva 2007, Somaweera and Somaweera 2009, Jayasekara *et al.* 2018a) when compared to *Ca. nigrilabris*. However, the program distance becomes very useful which takes into account the detection probabilities in the density calculations (Karsten *et al.* 2009) in such scenarios. Therefore, we suggest that distance sampling method (Buckland *et al.* 1993, 2001) will be effective when estimating densities of lizards that are diurnal and arboreal/ground surface occupying in nature as the species of interest in this study. When it comes to crevice/dune-dwelling (Smolensky and Fitzgerald 2010) or highly cryptic species, the method should be implemented with caution. In this study, the high camouflage ability of particularly *Co. ceylanica* may have marginally affected the visibility, despite the excellent field experience of the observers.

Populations density data of the three threatened agamid species considered, have not been assessed in the recent past. In fact, the only population study regarding any of these agamids was conducted by Erdelen (1988) where *Ce. nigrilabris* density in the region (Nuwara-Eliya) was estimated to be 222 ind/ha. However, the present study generated contrastingly lower densities when compared to the records of Erdelen (1988). Therefore, it is interesting to look into the factors that may have caused this decline in population. It was in the 1980s when this area was declared a National Park, and the visitor rates have significantly increased since then, especially in the last two decades (MoMD&E 2016). With the increasing visitor rates, the invasive predators like *Corvus levaillantii* Lesson, 1831 (Jungle Crow) have attracted to the area mainly to feed on the garbage left by an unaware visitor. As the *C. levaillantii* population grew, the impact on native fauna was visibly significant (Karunarathna and Amarasinghe 2008, Chandrasiri *et al.* 2015).

When the other two agamid species are considered, their populations themselves are also in rather alarming levels when compared to the densities generated in similar studies elsewhere in the world (Rao and Rajabai 1972, Western 1974, Jenkins *et al.* 1999, Karsten *et al.* 2009, Smolensky and Fitzgerald 2010). Researchers who have conducted past work in the area also suggest a declining trend in agamid populations (De Silva, personal communication, January 2016). However, a deficiency of accurate past population density data acts as a barrier for a proper comparison with the current data. All three agamids considered in the study are endemic and have highly restricted geographical distributions (only within few localities in the montane region of the island) (Manamendra-Arachchi and Liyanage 1994, Pethiyagoda and Manamendra-Arachchi 1998), Bahir and Surasinghe 2005, De Silva 2007, Somaweera and Somaweera 2009, Amarasinghe *et al.* 2011, Jayasekara *et al.* 2018a). Therefore, high conservation priorities should be given to protect these lizard populations before they face catastrophic declines.

Ca. nigrilabris population density was recorded to be drastically lower in the wet season of 2017. Rather than natural factors, the reason for this sudden decline was the removal of invasive plant *Ulex eropaeus* L. from the park to which this lizard was highly adapted in the grassland habitat (Jayasekara *et al.* 2017, Jayasekara *et al.* 2018a, 2018b). It was a park management program carried out in early 2017 to eradicate the invasive *U. eropaeus*. This sudden loss of their preferred microhabitat may have possibly reduced their food availability and increased the predatory pressures. Therefore, the response of *Ca. nigrilabris* to this change in habitat condition needs further monitoring.

Conclusion

All three lizard species evaluated in this study have the potential of becoming targets for the illegal ornamental pet trade. Despite Sri Lanka having strict legislation against illegal trade of wildlife, there were several instances where these montane specific species were found being traded in the international ornamental pet market (Hettiarachchi and Daniel 2011, Hettige 2011, Altherr 2014, Auliya *et al.* 2016). Especially *Ce. stoddartii,* which is one of the unique lizard species in the world due to its "Rhino-horn" like a rostral appendage, faces a considerable amount of risk being targeted by smugglers. Even though the protection within the National Park is considerably higher than the peripheral areas, the populations' densities of the three species considered could be in even more critical levels outside the park due to the increasing anthropogenic activities. The rapid degradation of their natural habitats due to tea and other plantations combined with habitat fragmentation leaves a big question mark regarding the survival of these species. Immediate and applied conservation strategies should be implemented both within and outside the protected areas focusing not only on the species but also on their natural habitat as a whole. Furthermore, establishment of new protected areas or increment in the level of protection of native habitats of these lizards are highly recommended.

Acknowledgment

We appreciate the generous corporation of the Horton Plains National Park staff and the "Department of Wildlife Conservation" for granting permission (Permit No: WL/3/2/12/15, WL/3/2/9/16) to conduct this research. We would also like to express our gratitude to the University of Sri Jayewardenepura and the Department of Zoology for the facilities granted and providing financial support to conduct this research. We extend our appreciation to Dr. Anslem De Silva for providing valuable literature/insights and IDEA WILD for providing us field instruments that were of great value during field excursions. Dr. S. Chandrasiri, Chathuranga Dharmarathne, Dushantha Jayakody, and Prabhath Meegamage, who supported us in fieldwork, are also acknowledged. This work was supported by the University Grants (USJP) under the Grant [ASP/01/RE/SCI/2015/23].

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