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The Impact of Urbanization on Native and Invasive Species.
A Case Study of the Coexistence between *Anolis oculatus* and *Anolis cristatellus* in Dominica

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Introduction

The growth of urban environments has remarkably influenced the behavioral characteristics of animals (Wark et al., 2019). The altered behaviors are a response to urbanization and are diverse to enable the animals to navigate and survive while utilizing the available resources under selective pressures (Geng & Zang., 2020). Human activity significantly influences animal population-level behavioral changes, which necessitates species to respond adaptively. Urbanization has become a significant indicator of human activities globally. The United Nation's estimation posits an increasing percentage of urban dwellers worldwide likely to increase to about 70% of the world's population by 2050 (Wang et al., 2022). Additionally, in the future of human development is closely intertwined with the sustainable growth of cities and urban areas. Urbanization, however, has accelerated a series of ecological and environmental concerns, ranging from the overexploitation of energy and natural resources to the irresponsible generation and disposal of waste, as well as the unbridled broadening of construction land (Wang et al., 2022). The unprecedented and unchecked rate of urbanization imposes significant effects on landscapes due to the vast shifts in land use.

The disintegration of landscapes endangers biodiversity and negatively influences the productivity of the ecosystem through the deprivation of biomass and natural habitats. Consequently, the impacts of urban expansion alter the behavioral adaptations and traits in animals (Gaynor et al., 2018). The growth of urban environments has impacted the behavioral characteristics of animals (Wark et al., 2019). The altered behaviors are a response to urbanization and enable the animals to navigate and survive while utilizing the available resources under a different set of selective pressures (Geng & Zang., 2020). Human activity significantly influences behavior of animals at the population-level, which necessitates species to respond adaptively The ecosystem change in the urbanization process drives the impact mechanism and coordination of the relationship between urbanization and ecological conservation. The impact of this phenomenon results in the loss of species and escalates the symmetry of global biological homogenization (Putman & Tippie, 2020). The structural environment of urban habitats necessitates the evaluation of trait-environment relationships in native and invasive *Anolis* species.

The forest-shade species of *Anolis oculatus* occupies a diversity of microhabitats in Dominica while *Anolis cristatellus* is a mixed forest species that mostly occupies low trunk

habitats. The interpopulation differences in habitat use and morphology underscore the interspecific interactions in the species' distribution among populations (Barquero & Bolaños, 2018). The behavioral changes that species undergo arising from urbanization are not uniform when analyzed in different cities for the same or closely related species (Putman & Tippie, 2020). Examining the response of animals, especially, lizards to urbanization is pivotal to elucidating management decisions that target maximal biodiversity and sustaining an ecological balance in a growing urbanized world. According to Battles et al. (2018), the majority of Anolis species successfully reside in urban habitats. Urban anoles offer insights into the functional morphology and shifts in behavioral display in urban areas that drive their success in adapting to these environments.

Anolis lizards are good model to understand the ecological and evolutionary patterns resulting from urban environments. Notably, as Dufour et al. (2018) inferred, the responses of anoles inform the interactions between the invasive lizard *Anolis cristatellus* and the native *Anolis oculatus* in Dominica. Divergent morphological features related to habitat use are characterized by traits that include body size, toepad area, tail size, and limb dimensions (Prado-Irwin et al., 2019). The traits determine the abilities of the species to locomote in various microhabitats and evolve in response to environmental shifts and conditions. The evolutionary capacity of adaptation and morphological coherence posit anoles as a befitting taxon for analyzing urban adaptive changes. The invasive lizard *Anolis cristatellus* and the native *Anolis oculatus* differ in their behavioral traits. Lizards in human-populated habitats are bolder than those in other habitats in a standardized environment (Borden et al., 2022). The replication of behavioral differences in the ecology of lizards over time underscores the boldness of lizards in urban areas compared to others in semi-natural and natural populations. The coexistence between native species and invasive analogues is critical in addressing niche space and alleviating the impacts of invasive species and other disturbances.

The extent of the interactions between native and invasive species has intensified over time due to globalization and global change. The innate distribution of natural characteristics between species has subsequently been of concern in determining the outcome of these interactions. The biological invasions endanger the existence of numerous species and can eventually create negative ecological consequences (Avilés-Rodríguez et al., 2021). Species can compete for limited resources resulting in overexploitation and interference which ultimately threaten the species'

coexistence. The impacts of urbanization and the introduction of invasive congeners alter the interaction and interference of species and their coexistence (Borden et al., 2022). Invasive species compete with native species through interference and exploitation mechanisms for the available resources. *Anolis oculatus* species being the native species in Dominica was invaded by the Puerto Rican lizard *Anolis cristatellus*. The species share similar morphological features and ecological adaptations (Falvey et al., 2020). The two species have consequently shared behavioral interference as well as competition for resources which has affected the display behavior of the invasive congeners (Dufour et al., 2020)

The case in Dominica presents an excellent model for the exploration of species and their behavioral adaptations, integrating their aggressive behavior and the influence that invasive species have over native species in the initial phases of the biological invasion (Dufour et al., 2020). The behavioral response of *Anolis oculatus* indicates a repulsive attitude towards the invasive *Anolis cristatellus* conspecifics. Furthermore, *Anolis oculatus* displays certain species traits, such as morphology and recognition that enables it to discriminate the *Anolis cristatellus* and the conspecifics (Dufour et al., 2020). Moreover, Anolis *oculatus* shows the behavioral changes in sympatry that might affect the coexistence with *Anolis cristatellus*.

Fundamentally, to alleviate the impact of biological invasions, an in-depth understanding of behavioral mechanisms is critical to informing successful invasion of species.

Recent studies on the *Anolis* lizards illustrate contemporary progress in behavioral urban ecology (Lapiedra 2018). The *Anolis* lizards provide critical insight into the combination of behavioral traits that can enhance success in urban habitats such as foraging behavior, habitat use in urban areas as well as escape behavior differences (Lapiedra, 2018). Significantly, these species are pivotal to understanding how environmental shifts alter the evolutionary characteristics in anoles and their subsequent behaviors. Urbanization and global change have amplified the inherent distribution of species and the decline of biodiversity (Baxter-Gilbert et al., 2019).

The effects of urbanization and the introduction of an invasive congener is crucial in elucidating the responses of native species. Since species compete either directly or indirectly for the exploitation of resources, the focus is directed to whether the niche shifting occurs in anoles when subjected to varied environments or disturbances (Kolbe et al., 2021). The subsequent exploitation can result in competitive ostracism or lead to niche division to sustain the coexistence of species depending on the context of the interference. As Doufour et al. (2017) suggested, the

native lizard *Anolis oculatus* in Dominica tends to become more arboreal when encountering the invasive *Anolis cristatellus* which causes a co-occurrence of the species.

This study aimed to examine the impact of urbanization on the coexistence between the native *Anolis oculatus* and the invasive *Anolis cristatellus* species in Dominica. Furthermore, the study sought to answer the question below to determine the extent of the impact of urbanization on the Anolis species:

i. What are the significant behavioral traits that are linked to urbanization success across *Anolis* species?

We aim to test the impacts of urban environments on the coexistence of invasive and native *Anolis* species in Dominica. Moreover, the research will provide a more profound insight into the relationship between native and invasive species and habitat use in *Anoles* on the island of Dominica. Additionally, understanding how urbanization impacts the behavior of the two *Anolis* species is critical to understanding the interactions between native and invasive species and the role it has played in allowing the invasive *A. cristatellus* to get settle and disperse on the island.

Materials and Methods

Site and study species

From April 14 to June 26, 2022, four locations were assessed in Dominica namely Soufriere, Cabrits National Park, Capuchin, and Indian River. (Figure 1, Table 1). The presence of both *A. oculatus* and *A. cristatellus* was confirmed with transect observations at all sites (sympatric). Both disturbed and undisturbed areas were assessed within these locations, and the ecology and behavioral displays of the lizards were recorded (see details below).

Figure 1: Distribution of sites (Table 1) assessed across Dominica.

Table1: *Anolis* survey site information by Survey Area – Dominica 2022

Site	Site name	Site description	No. of lizards recorded	Date recorded
1	Cabrits National Park	small scale commercial area, cruise ship berth nature trails, dry scrub forest	*A.cristatellus* Males 23 Females 10 *A.oculatus* Males 11 Females 10	19/06/22 (disturbed) 31/05/22 (undisturbed)
2	Capuchin	Urban Park Waitukubuli National Trail segment 13, seasonal forest	*A.cristatellus* Males 1 Females 0 *A.oculatus* Males 31 Females 25	01/05/22 (disturbed) 26/05/22 (undisturbed)
3	Indian River	small scale commercial area Swamp forest, nature trail	*A.cristatellus* Males 9 Females 5 *A.oculatus* Males 28 Females 6	04/06/22 (disturbed) 06/06/22 (undisturbed)
4	Soufriere	Seasonal Forest, fumarole vegetation, Waitukubuli National Trail segment 2 Farms (livestock & agriculture), Residential areas	A.cristatellus Males 29 Females 22 *A.oculatus* Males 1 Females 1	14/04/2022 (disturbed) 27/05/22 (undisturbed)

Disturbance

A team of three people visually observed 107 lizards at four disturbed sites with varying degrees of disturbance (Figures 2.a, 2.b, 2.c, 2.d). These locations included urban parks, farms, and residential and commercial areas. There were 115 lizards found in undisturbed areas which included seasonal forest, dry scrub forest, swamp forest, and nature trails. (Figures 3.a, 3.b, 3.c, 3.d).

Figure 2.a: Cabrits National Park disturbed

Figure 2.b: Capuchin disturbed

Figure 2.c: Indian River disturbed

Figure 2.d: Soufriere disturbed

Figure 3.a: Cabrits undisturbed

Figure 3.b: Capuchin undisturbed

Figure 3.c: Indian River undisturbed

Figure 3.d: Soufriere undisturbed

Behavior Measurements

101 *A. cristatellus* and 121 *A. oculatus* were observed over a three-month period. The approach, flight, and final distances of each lizard, as well as the height and diameter of existing and available perches, were all measured to the nearest centimeter at each location using a Stanley Tylon five-meter measuring tape. Three behavioral variables related to lizard escape behavior were recorded: approach distance defined as the distance between the observed and the lizard when the lizard first ran, flight distance defined as the distance ran by the lizard, and final distance defined as the distance between the observed and the lizard when the lizard stopped fleeing.

Ecological measurements

The two ecological variables measured were: perch height defined as the distance from the ground to the surface where the lizard was originally spotted, and perch diameter defined as the size of the existing and available surface area. The GPS coordinates of each site and spotted lizard are recorded at each location. To avoid data resampling, a 200-meter transect was established at each location, and the sites were only visited once between 9 a.m. and 12 p.m.

Statistical Analysis

A MANOVA test was used to evaluate the main effects of species, sex, and site on disturbance. The test was used to take into account correlations between response variables to assess the difference in individual responses and enable a broader application of the information contained in the data. The analyses were performed using IBM- SPSS.

Results

Table 2 shows the results from the multivariate analysis MANOVA test. Determining the statistically comparing the effect of disturbance on site, sex,and species. Statistical significance is determined at $p<0.001$.

Wilks' Lambda P-Values for Variables

Effect	F Value	P-Value
Intercept	1639.345	0.002
Specie	2.575	0.914
Sex	1.970	0.933
Disturbance	1.655	0.943
Site	1.474	0.854
Specie * Site	1.344	0.140
Sex* Disturbance	1.033	0.409
Sex* Site	1.495	0.074
Specie * Sex	0.829	0.971
Specie * Sex* Disturbance	1.203	0.303
Disturbance*site	3.634	<0.001
Specie * Sex* Site	1.355	0.173
Sex* Disturbance* Site	0.917	0.568

As shown in Table 2, the only significant interaction was disturbance* site ($p < 0.001$). This show that there is a statistically significant interaction effect. The effect of disturbance on the dependent variables is not the same on different sites. The other interactions are not statistically significant as indicated in Table 2.

Test of effects:

There was a statistically significant interaction between species and site with disturbance. The species*disturbance ($p<0.021$) and disturbance*site ($p<0.001$) on log flight have $p<0.05$ indicating A statistically significant interaction between the species and site disturbance. To determine whether the one-way MANOVA was statistically significant, the statistically significant interaction informs the interpretation of the MANOVA test and the follow-up analyses required since $p < .0005$.

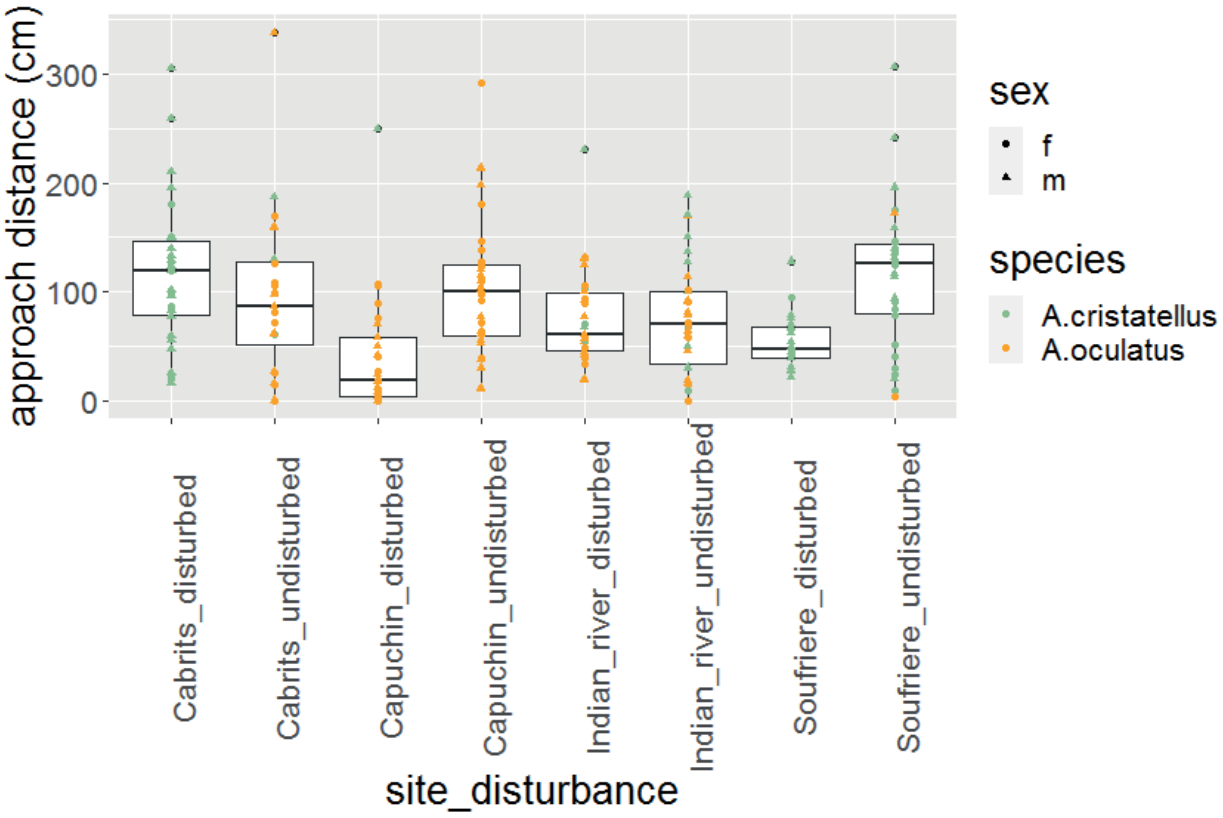

Figure 4: *Boxplot showing Site Disturbance and Approach Distance of Anolis cristatellus and Anolis oculatus species from disturbed and undisturbed sites (Dominica, 2022).*

In Soufriere disturbed environment, the invasive species *Anolis cristatellus* have a common approach distance compared to Cabrits disturbed and Soufriere undisturbed sites where the species depicts a varied/ diverse approach distance. The invasive species have a greater variability in the two sites. For the native species, *Anolis oculatus,* Cabrits undisturbed and Capuchin undisturbed site show variance in the species approach distance.

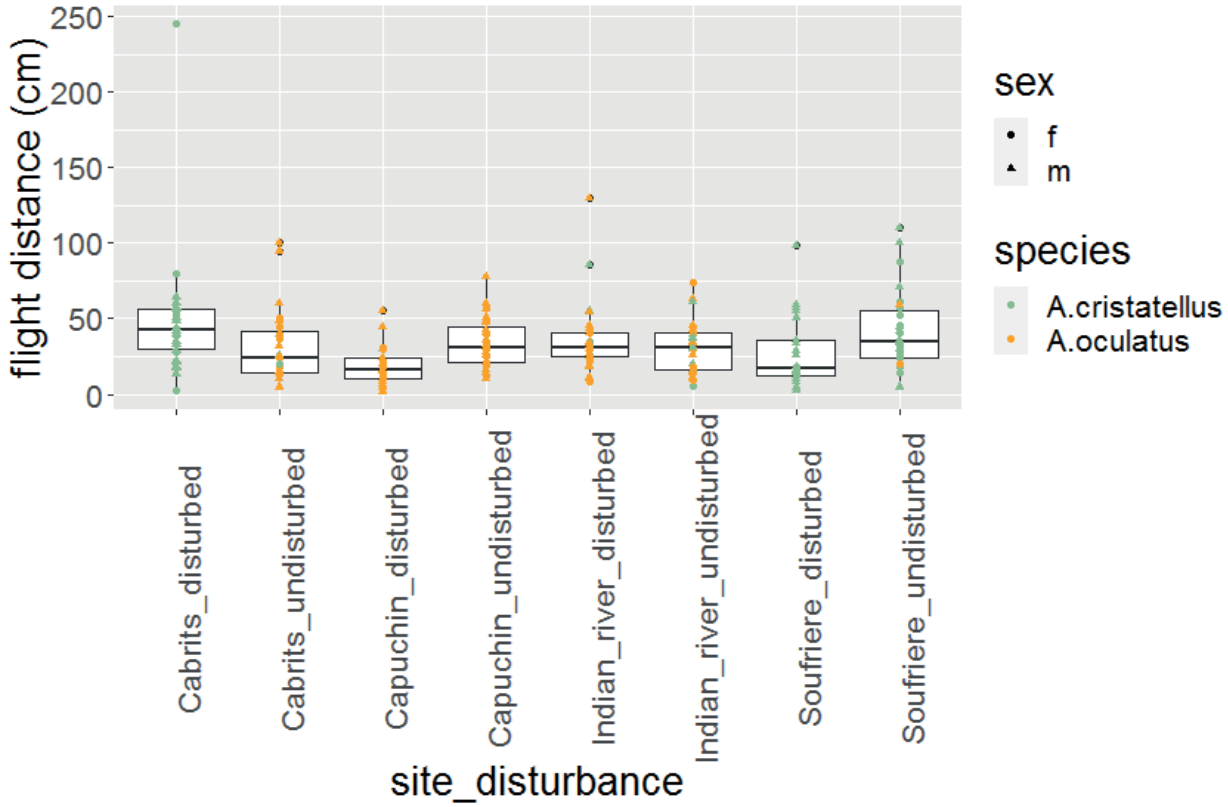

Figure 5: *Boxplot showing Site Disturbance and Flight Distance of Anolis cristatellus and Anolis oculatus species from disturbed and undisturbed sites (Dominica, 2022).*

In Figure 5, there are no disparities in the species flight distance. The median flight distance ranges from 30-50 for both species. Although for the invasive species we observed an outlier in Cabrits disturbed sites, this is not conclusive. More data needs to be collected.

There are also major disparities for the invasive species perch diameters in Cabrits disturbed and Soufriere undisturbed sites showing the species adapt differently in these environments.

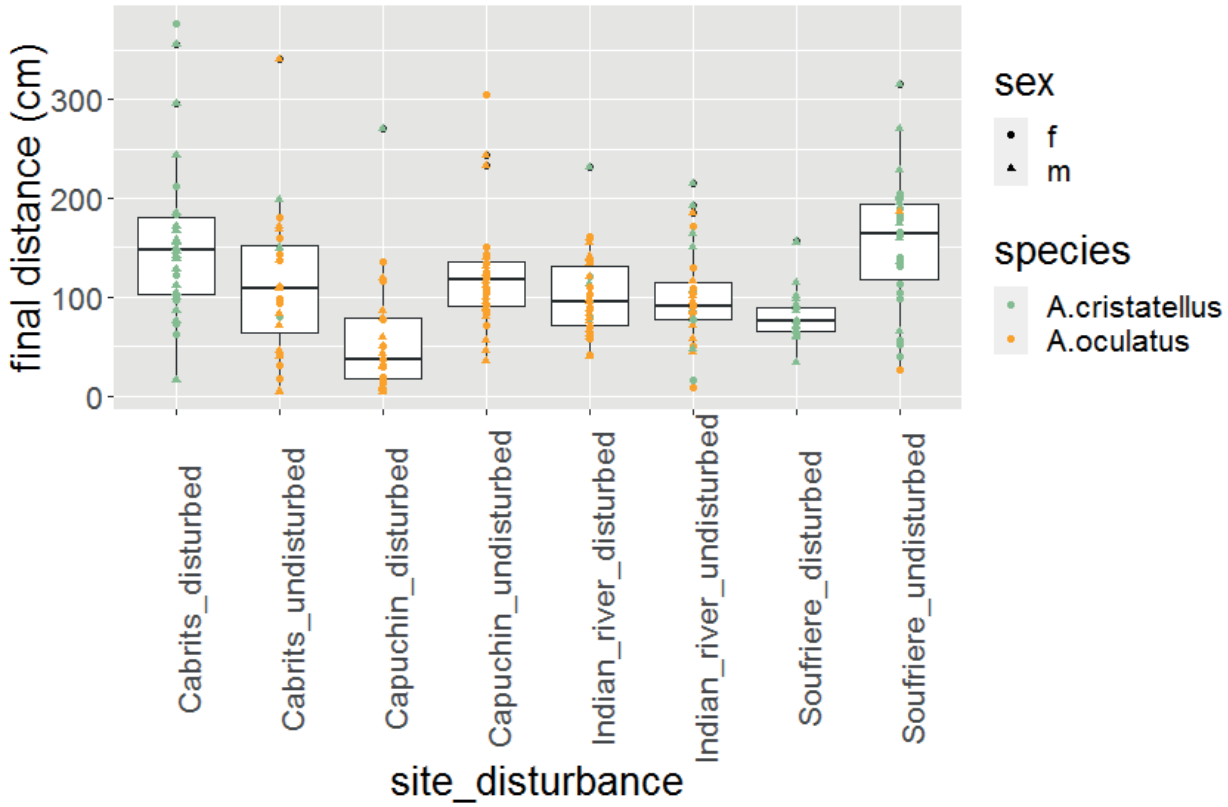

Figure 6: *Boxplot showing Site Disturbance and Final Distance of Anolis cristatellus and Anolis oculatus species from disturbed and undisturbed sites (Dominica, 2022).*

In figure 6, we see a predominance of the invasive species in 4 sites while the native species are thriving in three sites namely, Cabrits disturbed, Soufriere disturbed, and Soufriere undisturbed environments. In the three sites where the native species are dominant, we see high level non-disparities in the species final distance in Soufriere disturbed while the sites of Soufriere undisturbed and Cabrits disturbed sites the species experience varied final distance.

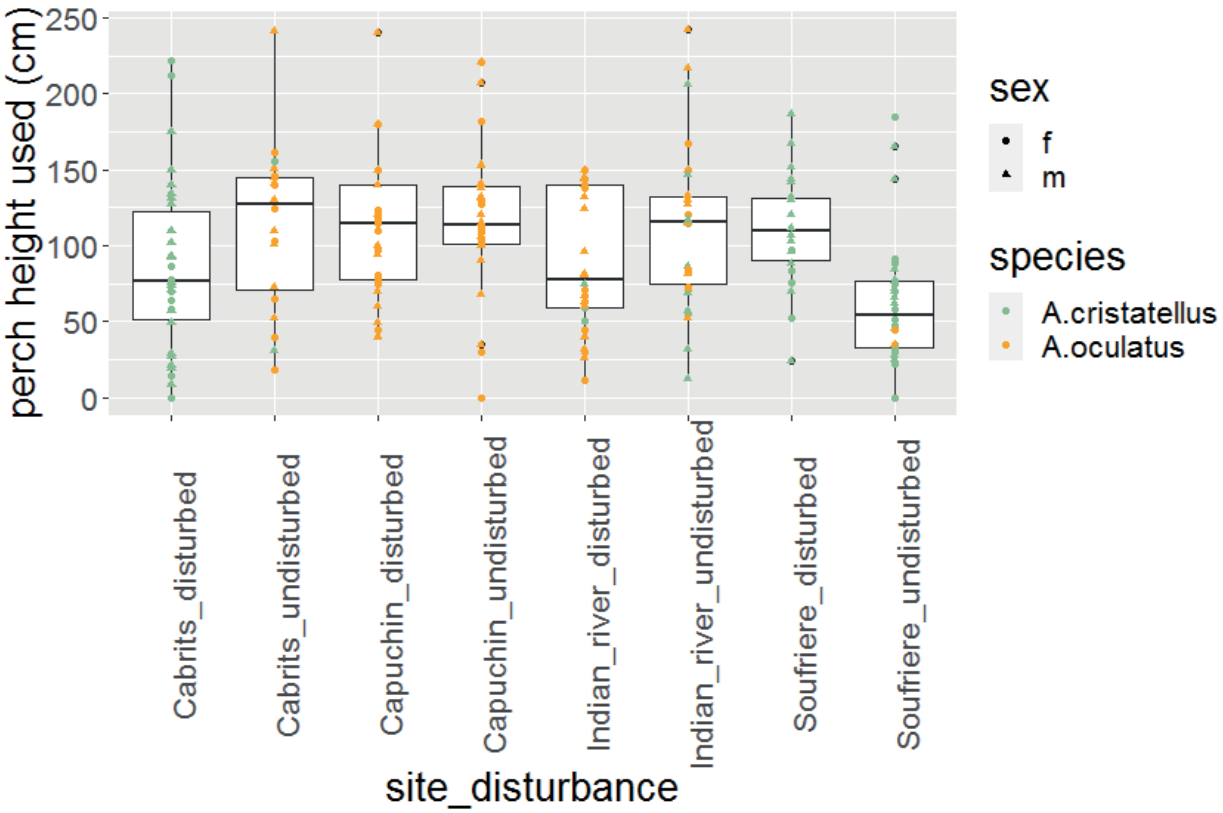

Figure 7: *Boxplot showing Site Disturbance and Perch Height of Anolis cristatellus and Anolis oculatus species from disturbed and undisturbed sites (Dominica, 2022).*

A species median height in all the sites depicts diversity in species adaptation from their perch height perspective. The native species generally have high median perch height at Cabrits undisturbed, Capuchin disturbed, Capuchin undisturbed, and Indian River undisturbed sites. The native species median height is low in Indian River disturbed site. However, at the sites where the invasive species adapts, they experience low perch height in Soufriere undisturbed site and high perch height variance in Cabrits disturbed site.

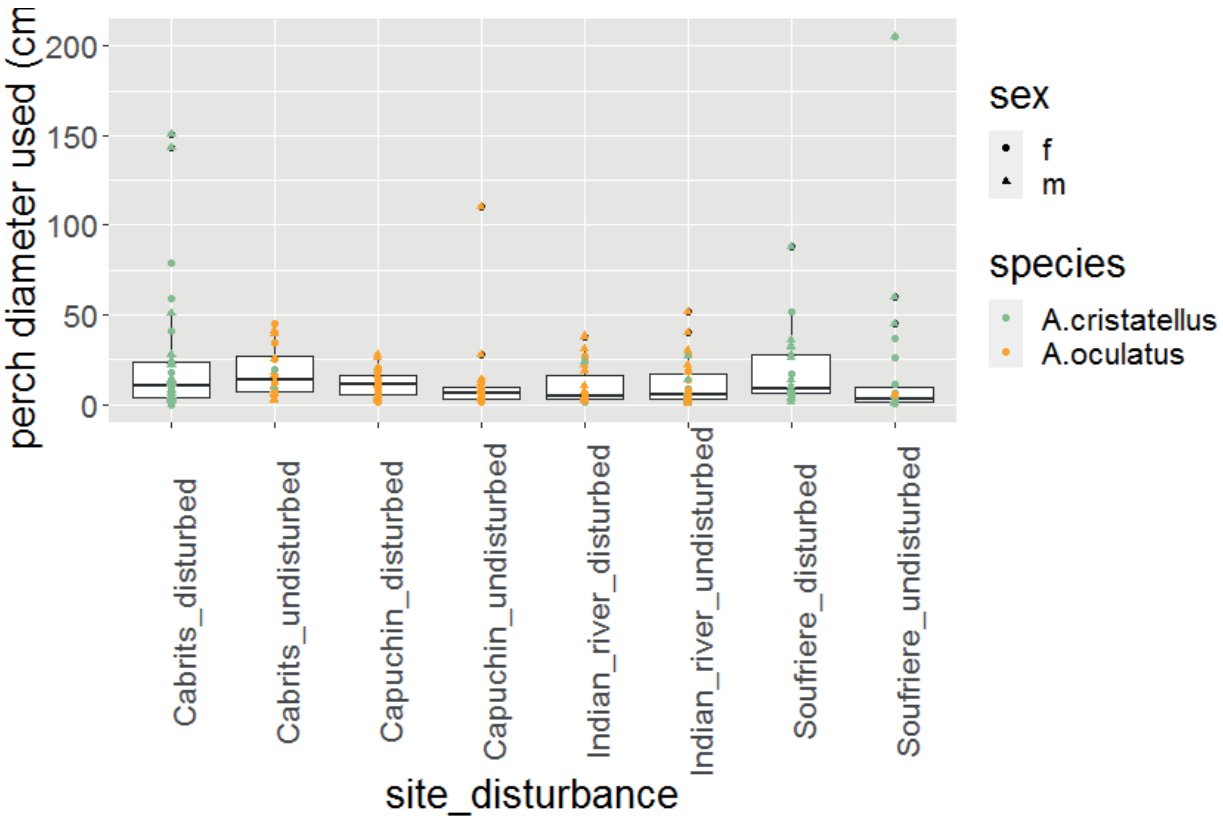

Figure 8: *Boxplot showing Site Disturbance and Perch Diameter of Anolis cristatellus and Anolis oculatus species from disturbed and undisturbed sites (Dominica, 2022).*

Figure 8 shows there are no major disparities in species perch diameter among the various sites. Outliers are visible for the invasive species in Cabrits disturbed and Soufriere undisturbed sites. In conclusion, species perch diameter is not highly impacted under different sites when comparing invasive and native species.

Discussion

Urban areas differ from natural habitats in structure. Urban habitats have reduced vegetation and trees while having numerous impervious facets compared to natural areas (Yuan et al., 2020). According to this study, urbanization has a significant impact on native and invasive species behaviour responses. We also show that varying degrees of disturbance creates ideal environmental conditions for the invasive *Anolis cristatellus*, which in some cases is in the process of displacing the native *Anolis oculatus.* We discovered a high density of invasives in agricultural and human activity areas (Soufriere and Indian River). We also discovered that many native species were more restricted to heavily forested and seldom visited areas (Cabrits and Capuchin). The discussion that follows looks at the potential role of species behaviour, ecology, and habitat use as explanations for differences in species' responses to urbanization.

The MANOVA test indicated significant interaction between species and site, indicating that the effect of species on behavior was not the same on different sites. As shown in the Soufriere disturbed environment, *Anolis cristatellus* had a different had a different approach distance compared to Soufriere undisturbed sites and Cabrits disturbed site. For A*nolis oculatus,* there was a variance in the approach distance observed in the Cabrits undisturbed and Capuchin undisturbed sites. The findings show a predominance of the *Anolis cristatellus* species in most of the sites. However, there was no significant disparities in fligh distance between the two species. *The findings also showed diversity in s*pecies median heights in perch heights. Specifically, the native species had high median perch height in four sites.

Species Behavior Responses and Ecology

The relationship between the invasive lizard *Anolis cristatellus* and the native lizard *Anolis oculatus* underpins the in-depth scrutiny of behavioural shifts between the species in Dominica. Ryan and Gunderson (2021) asserted that seeking an understanding of how invasive species effectively acclimatize in their new habitats and the subsequent impacts on the native species is fundamental to sustaining biodiversity and limiting the extinction of species. The initial years of the interferences between native and invasive species underscore the outcome of the interaction or competition (Dufour et al., 2018a; Thorpe et al., 2018). The divergence of perch use can cause the

rise of new microhabitat pressures or locomotory adaptations. Therefore, interspecific competition among anoles might structure their behavioral display.

The potential for ecological conservation in Dominica is momentous: to preserve the forest cover on the island which is over 60%, as well as protect the indigenous animals that occupy the vast remainder of the natural habitats (Dufour et al., 2019). Notably, reptiles and amphibians comprise the most prevalent herpetofauna in the Lesser Antillean archipelago (Borden et al., 2022). The Puerto Rican nonnative Anolis cristatellus lizard is a potential threat to the endemic *Anolis oculatus* species. Similarly, as Boronow et al. (2018) averred, the recent mushrooming of the invasive Anolis species has been propagated to highly populated areas with human activities such as in Cabrits National Park and Soufriere. The spread of the invasive species has rallied for monitoring to gauge the extent of the native species' presence in greatly impacted areas.

The data collected and the results obtained from the survey at various locations on the island showed the extent of the invasion from its initial contained area. However, as Culbertson and Herrmann (2019) mentioned, the invasion has been maintained in the human-disturbed areas and has hence, not permeated the densely forested regions. Despite research indicating that the *Anolis oculatus* has not decreased in range, the results stipulate that the *Anolis cristatellus* has increased in its range. Fundamentally, according to Borden et al. (2022), the expansion has been restricted to human-disturbed habitats such as parks where there is extensive farming, buildings, and other human activities. Notably, Dufour et al. (2018a) stated that the presence of the *Anolis cristatellus* was observed in wooden railings, rock piles, and telephone poles as well as in other forested edge areas close to the *Anolis oculatus*. The invasive anole exhibits more combative behavior compared to the native anole which may affect the existence of the *Anolis oculatus* in the scenario that the *Anolis cristatellus* encroaches on the natural forested habitats where the endemic species dwell.

The invasive anole was observed on the borderline between forested habitats and human-disturbed areas, such as the nature trail in the Indian River, but not in the densely forested areas lie Capuchin and Cabrits where there is a prevalence of the native anole. Crucially, the indigenous Dominican anole is an astute depiction of a morphologically diverse species which can remarkably adapt to varying habitats. The ecological assessment of the *Anolis cristatellus* suggested the preference of the Puerto Rican invasive to open woodlands contrary to the heavily forested habitats of the native *Anolis oculatus* (Dufour et al., 2018b). Measuring the pervasiveness of the Dominican

Anolis lizard species posits an augmented insight into the potential repercussions of the invasion of the Puerto Rican anole on the population of the native *Anolis oculatus.*

Overall, Thorpe et al. (2018), argued that the Puerto Rican anole and the indigenous Dominican species utilize varying segments of the urban habitat. The native species tend to utilize more of the indigenous portion of the urban environments, such as the swamp forest, whereas the *Anolis cristatellus* leans more toward the anthropogenic settings in the habitat (Lapiedra, 2018). Moreover, the elements of habitat discrimination by species in urbanized places with forested sites indicate that the native species perched higher than the invasive congener and preferred lower temperatures. The novel niche space that the *Anolis cristatellus* inhabit correlates to the artificial aspects of the urban habitats which are not occupied by the *Anolis oculatus*. The contemporary invasions of *Anolis* species in Dominica formulate a vital aspect in studying and understanding the evolutionary linkages by offering a natural experiment to examine the interspecific competition in the evolution of species.

The study might have been subject to potential limitations. Apart from previous research on the coexistence between native and invasive *Anolis* species, it is essential to understand the sequence of species evolution in response to urban activity. Moreover, inadequate time to research and measure the time of change and behavioral shifts in *Anolis* lizards posed a crucial constraint, which necessitates further studies and exploration into the behavioral adaptations of Anoles caused by urbanization (Falvey et al., 2020). Despite the study's deductions, the findings are not generalizable since they are limited to the *Anolis* species in Dominica.

References

Avilés-Rodríguez, K. J., Winchell, K. M., De León, L. F., & Revell, L. J. (2021). Phenotypic response to a major hurricane in Anolis lizards in urban and forest habitats. *Biological Journal of the Linnean Society*, *133*(3), 880-895.

Barquero, M. D., & Bolaños, F. (2018). Morphological and ecological variation of a tropical anoline lizard: Are agonistic interactions shaping ecomorphological relationships? *Biological Journal of the Linnean Society*, *124*(3), 350-362.

Battles, A. C., Moniz, M., & Kolbe, J. J. (2018). Living in the big city: Preference for broad substrates results in niche expansion for urban Anolis lizards. *Urban Ecosystems*, *21*(6), 1087-1095.

Baxter-Gilbert, J., Riley, J. L., & Whiting, M. J. (2019). Bold New World: Urbanization promotes an innate behavioral trait in a lizard. *Behavioral Ecology and Sociobiology*, *73*(8), 1-10.

Borden, J. B., Bohlman, S., & Scheffers, B. R. (2022). Niche lability mitigates the impact of invasion but not urbanization. *Oecologia*, *198*(1), 1-10.

Boronow, K. E., Shields, I. H., & Muñoz, M. M. (2018). Parallel behavioral divergence with macrohabitat in Anolis (Squamata: dactyloidae) lizards from the Dominican Republic. *Breviora*, *561*(1), 1-17.

Culbertson, K. A., & Herrmann, N. C. (2019). Asymmetric interference competition and niche partitioning between native and invasive Anolis lizards. *Oecologia*, *190*(4), 811-820.

Damas-Moreira, I., Riley, J. L., Carretero, M. A., Harris, D. J., & Whiting, M. J. (2020). Getting ahead: Exploitative competition by an invasive lizard. *Behavioral Ecology and Sociobiology*, *74*(10), 1-12.

Damas-Moreira, I., Riley, J. L., Harris, D. J., & Whiting, M. J. (2019). Can behaviour explain invasion success? A comparison between sympatric invasive and native lizards. *Animal Behaviour*, *151*, 195-202.

Dufour, C. M. S., Donihue, C. M., Losos, J. B., & Herrel, A. (2019). Parallel increases in grip strength in two species of Anolis lizards after a major hurricane on Dominica. *Journal of Zoology*, *309*(2), 77-83.

Dufour, C. M., Clark, D. L., Herrel, A., & Losos, J. B. (2020). Recent biological invasion shapes species recognition and aggressive behaviour in a native species: A behavioural experiment using robots in the field. *Journal of Animal Ecology*, *89*(7), 1604-1614.

Dufour, C. M., Herrel, A., & Losos, J. B. (2018). Ecological character displacement between a native and an introduced species: The invasion of Anolis cristatellus in Dominica. *Biological Journal of the Linnean Society*, *123*(1), 43-54.

Dufour, C. M., Losos, J. B., & Herrel, A. (2018). Do differences in bite force and head morphology between a native and an introduced species of anole influence the outcome of species interactions? *Biological Journal of the Linnean Society*, *125*(3), 576-585.

Falvey, C. H., Aviles-Rodriguez, K. J., Hagey, T. J., & Winchell, K. M. (2020). The finer points of urban adaptation: Intraspecific variation in lizard claw morphology. *Biological Journal of the Linnean Society*, *131*(2), 304-318.

Gaynor, K. M., Hojnowski, C. E., Carter, N. H., & Brashares, J. S. (2018). The influence of human disturbance on wildlife nocturnality. *Science*, *360*(6394), 1232-1235.

Geng, Y., & Zhang, H. (2020). Coordination assessment of environment and urbanization: Hunan case. *Environmental Monitoring and Assessment*, *192*(10), 1-18.

Huie, J. M., Prates, I., Bell, R. C., & de Queiroz, K. (2021). Convergent patterns of adaptive radiation between island and mainland Anolis lizards. *Biological Journal of the Linnean Society*, *134*(1), 85-110.

Kolbe, J. J., Moniz, H. A., Lapiedra, O., & Thawley, C. J. (2021). Bright lights, big city: An experimental assessment of short-term behavioral and performance effects of artificial light at night on Anolis lizards. *Urban Ecosystems*, *24*(5), 1035-1045.

Lapiedra, O. (2018). Urban behavioral ecology: Lessons from Anolis lizards. *Integrative and Comparative Biology*, *58*(5), 939-947.

Lyndon-Gee, F., & Jessop, T. S. (2020). Attenuated phenotypic responses of lizard morphology to logging and fire-related forest disturbance. *Evolutionary Ecology*, *34*(5), 841-853.

Ouyang, J. Q., Isaksson, C., Schmidt, C., Hutton, P., Bonier, F., & Dominoni, D. (2018). A new framework for urban ecology: An integration of proximate and ultimate responses to anthropogenic change. *Integrative and Comparative Biology*, *58*(5), 915-928.

Prado-Irwin, S. R., Revell, L. J., & Winchell, K. M. (2019). Variation in tail morphology across urban and forest populations of the crested anole (Anolis cristatellus). *Biological Journal of the Linnean Society*, *128*(3), 632-644.

Putman, B. J., & Tippie, Z. A. (2020). Big city living: A global meta-analysis reveals positive impact of urbanization on body size in lizards. *Frontiers in Ecology and Evolution*, *8*, 580745.

Ryan, L. M., & Gunderson, A. R. (2021). Competing native and invasive Anolis lizards exhibit thermal preference plasticity in opposite directions. *Journal of Experimental Zoology Part A: Ecological and Integrative Physiology*, *335*(1), 118-125.

Thorpe, R. S., Barlow, A., Surget-Groba, Y., & Malhotra, A. (2018). Multilocus phylogeny, species age, and biogeography of the Lesser Antillean anoles. *Molecular Phylogenetics and Evolution*, *127*, 682-695.

Tiatragul, S., Hall, J. M., & Warner, D. A. (2020). Nestled in the city heat: Urban nesting behavior enhances embryo development of an invasive lizard. *Journal of Urban Ecology*, *6*(1), juaa001.

Wang, W., Deng, X., Wang, Y., Peng, L., & Yu, Z. (2022). Impacts of infrastructure construction on ecosystem services in new-type urbanization area of North China Plain. *Resources, Conservation and Recycling*, *185*, 106376.

Wark, J. D., Cronin, K. A., Niemann, T., Shender, M. A., Horrigan, A., Kao, A., & Ross, M. R. (2019). Monitoring the behavior and habitat use of animals to enhance welfare using the ZooMonitor app. *Anim. Behav. Cogn*, *6*, 158-167.

Yuan, M. L., Jung, C., Wake, M. H., & Wang, I. J. (2020). Habitat use, interspecific competition, and phylogenetic history shape the evolution of claw and toepad morphology in Lesser Antillean anoles. *Biological Journal of the Linnean Society*, *129*(3), 630-643.

Abstract

Human disturbance such as urbanization has over the years could be a driver of species evolution and has created environments for nonnative species to invade and flourish. The purpose of this study was to examine the impact of urbanization on native and invasive species, focusing on *Anolis oculatus* and *Anolis cristatellus* in Dominica. This study utilized a quantitative methodology, employing the MANOVA test to evaluate the main and interaction effects of the invasive lizard *Anolis cristatellus* on the behavior of the native *Anolis oculatus.* The two species were observed for three months at 4 locations, with measuring their behaviors in terms of approach, flight, and final distances of each lizard. We also measured the height and diameter of perches at each location and established a 200-meter transect to prevent resampling. The findings indicated a significant interaction between disturbance* site ($p < 0.001$), suggesting that the effect of disturbance on the lizards' approach, flight, and final distances were not the same on different sites. There was also a significant interaction between species*disturbance ($p < 0.021$) and disturbance*site ($p < 0.001$), indicating that the lizards' species affected site disturbance. The findings are consistent with previous studies that have found a significant effect of urbanization on native and invasive species.

Les perturbations humaines telles que l'urbanisation ont, au fil des ans, pu être un moteur de l'évolution des espèces et ont créé des environnements permettant aux espèces non indigènes d'envahir et de prospérer. Le but de cette étude était d'examiner l'impact de l'urbanisation sur les espèces indigènes et invasives, en se concentrant sur *Anolis oculatus* et *Anolis cristatellus* en Dominique. Cette étude a utilisé une méthodologie quantitative, employant le test MANOVA pour évaluer les effets principaux et d'interaction du lézard invasif *Anolis cristatellus* sur le comportement de l'espèce indigène *Anolis oculatus*. Les deux espèces ont été observées pendant trois mois à 4 endroits, en mesurant leurs comportements en termes d'approche, de vol et de distance finale de chaque lézard. Nous avons également mesuré la hauteur et le diamètre des perchoirs à chaque endroit et établi un transect de 200 mètres pour éviter un nouvel échantillonnage. Les résultats ont indiqué une interaction significative entre la perturbation* site ($p < 0,001$), ce qui suggère que l'effet de la perturbation sur les distances d'approche, de vol et finale des lézards n'était pas le même sur les différents sites. Il y avait également une interaction

significative entre espèce*perturbation ($p < 0,021$) et perturbation*site ($p < 0,001$), ce qui indique que l'espèce des lézards affecte la perturbation du site. Les résultats sont cohérents avec les études précédentes qui ont trouvé un effet significatif de l'urbanisation sur les espèces indigènes et invasives.