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Range expansion, density, and population estimates of an introduced population of Red-vented Bulbuls (*Pycnonotus cafer*) in Houston, Texas (USA)

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ABSTRACT

The Red-vented Bulbul (*Pycnonotus cafer*) is native to southern Asia and is an established invasive species in several tropical Pacific islands, parts of the Middle East, Spain, and Houston (Texas, USA), the focal region presented herein. Here, we assess recent range expansion, density, and population size. We used locality databases and the Map Maker program to measure bulbul range expansion. The range expanded from 589 km^2 before June 2012 to 4,606 km^2 during the following decade. By counties, there were 215 bulbul reports in Harris County before June 2012 (and none in surrounding counties), and 6,543 in the following decade, along with nearly 50 records in adjacent counties. Mean distance of outliers from the central population doubled from 27 km before June 2012 to 53 km during the following decade. To estimate minimum density and population size we conducted transect surveys for bulbuls January—March 2024 at four sites, repeating each transect 10 times. We estimated a mean population density of 8.77 bulbuls/km^2 and a total population of 466 (range = 144–955) individuals within the 53.18 km^2 core area. Although range size of the Houston bulbul is indeed expanding, it is not expanding rapidly, growing at approximately 400 km^2/year. Additionally, recent outliers have appeared as far as 68 km from the center of the bulbul's range, suggesting that expansion trajectories are continuing. Natural barriers (e.g. rivers, intracoastal waterways) and some highways appear to inhibit continued bulbul range expansion, as additional records are absent beyond these features.

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Expansión de rango, densidad y estimaciones poblacionales de una población introducida de Bulbul Ventrirrojo (*Pycnonotus cafer*) en Houston, Texas (EE.UU.)

RESUMEN

El Bulbul Ventrirrojo (*Pycnonotus cafer*) es nativo al sur de Asia y es una especie invasora establecida en varias islas tropicales del Pacífico, partes del Medio Oriente, España y Houston (Texas, EE.UU.), la región focal presentada aquí. Evaluamos su reciente expansión de rango, densidad y tamaño poblacional. Usamos bases de datos de localidades y el programa Map Maker para medir expansión de rango. Su rango expandió de 589 km^2 antes de junio de 2012 a 4,606 km^2 durante la

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siguiente década. Por comarcas, hubo 215 reportes de *Pycnonotus cafer* en la comarca Harris antes de junio de 2012 (y ninguno en comarcas vecinas), y 6,543 en la siguiente década, además de casi 50 registros de comarcas vecinas. La distancia media de puntos extremos (a distancias extremas de la población central) se duplicó de 27 km antes de junio de 2012 a 53 km durante la siguiente década. Para estimar la densidad mínima y el tamaño de población, realizamos búsquedas de *Pycnonotus cafer* en cuatro transectos en enero–marzo 2024, repitiendo cada transecto 10 veces. Estimamos una densidad poblacional media de 8.77 individuos/km^2 y una población total de 466 (rango = 144–955) individuos dentro del área núcleo de 53.18 km^2. Aunque el tamaño de rango de *Pycnonotus cafer* está expandiendo en Houston, no está expandiendo rapidamente, creciendo a aproximadamente 400 km^2/year. Adicionalmente, puntos extremos han aparecido recientemente tan lejos como 68 km del centro del rango de *Pycnonotus cafer*, sugiriendo que las trayectorias de expansión continúan. Barreras naturales (e.g., ríos, canales intracosteras) y algunas rutas parecen inhibir la expansión de *Pycnonotus cafer*, porque registros adicionales son ausentes más allá de estos elementos.

Globally, invasive species can diminish native biodiversity through direct competition or predation, and alter native ecosystems. Each new invader can potentially disrupt ecosystems and the survival of numerous species (Lockwood et al. 2007). Case examples include the threats of: Burmese pythons (*Python bivittatus*) to native fauna in the Florida Everglades (Dove et al. 2011), spongy moths (*Lymantria dispar*) to American forests (Simberloff 2013), and Chinese tallow trees (*Triadica sebifera*) to coastal prairies (Lankau et al. 2004). These examples illustrate contemporary paradigms requiring catalyzed management of invasive species that are indeed a threat.

Red-vented Bulbuls (*Pycnonotus cafer*; hereafter bulbul) are medium-sized songbirds that primarily feed on fruits, vegetables, and flowers. They thrive in various habitats, particularly sparse secondary growth, urban vegetation, and other habitats shaped by human activity and modification (Islam and Williams 2020). They are native to southern Asia (Pakistan south to Sri Lanka, and east to south-central China). In the past nearly 75 years, the bulbul has become an established invasive species in various parts of the world, including several tropical Pacific islands, parts of the Middle East, Spain, and Houston, Texas, in the USA (Brooks 2013; Thibault et al. 2019, 2020; Islam and Williams 2020; Nowakowski and Dulisz 2022). In the continental USA, in addition to the Houston population of bulbuls, there is a small population reported infrequently (six observations in summer 2018, one each during 2021 and 2024) in east Los Angeles, California (approximately 2400 km west), but this population does not appear to be expanding (Fink et al. 2023). Despite having the fourth highest human population of any city in the USA, Houston has ample green space and high tree density. The extensive and diverse flora of Houston, especially in the neighborhoods occupied by bulbuls, provides ideal habitat for the bulbuls to thrive (Brooks 2013).

In many areas where bulbuls are invasive or introduced they are considered an environmental threat, although this is not always the case. In some regions bulbuls disperse noxious weedy seeds, damage flower and fruit crops, and outcompete native bird species (Brooks

2013; Thibault et al. 2019, 2020; Islam and Williams 2020). However, the Houston population of bulbuls is not currently deemed an ecological threat to native local biodiversity (Brooks 2013), similar to the situation in Fiji (Watling 1979). Reasons include their limited distribution and population size compared to native Asian populations, as well as bulbuls not depleting native plants or crops for consumption (Brooks 2013). However, continued research on the population is essential to understand their ongoing range expansion, density, and population dynamics, to better inform conservation planning. The study herein aims to investigate these three parameters, to aid in assessing whether bulbuls are currently ecologically harmful in Houston.

Methods

Range expansion

To assess range expansion of bulbuls in Houston in the decade following May 2012 (the final month for analyses in Brooks 2013), we analyzed data from two primary sources: the Texas Invasive Birds Project (TIBP 2024) and eBird (Fink et al. 2023). When combined, records from these two databases provide an especially robust dataset of Houston bulbul sightings. TIBP is a community science project that accumulates reports of invasive bird species in Texas from birdwatchers and other naturalists (Brooks 2013). We entered submitted reports into a database after going to the location and ground-truthing by confirming presence for the first 20, all of which confirmed bulbul presence, negating the need for additional confirmation. In addition to the TIBP data, we downloaded records of Houston bulbul sightings from eBird, filtered the data by date, and only included verified sightings confirmed by the regional reviewer. We then divided the TIBP and eBird data into two categories, (1) reports through May 2012 and (2) reports from June 2012 to May 2022, which permitted analyses of range expansion after a full decade.

We created distribution maps using Map Maker to illustrate range expansion before and after June 2012. The Map Maker program plots sightings using latitude/longitude coordinate data and generates a Minimum Convex Polygon (MCP) encompassing all sightings to define geographic ranges. Using the Map Maker geospatial analysis tools, we calculated the MCP areas (km^2), representing the boundaries of bulbul distribution before and after June 2012.

Additionally, we assessed the number of county records before and after June 2012 by summing the number of records/county for both databases. As a final way of measuring range expansion, we identified outliers as the farthest recorded sightings from the central population located at Houston Heights Reservoir (see below). We visually examined both range maps (before and after June 2012) and selected the most extreme outliers, measuring km from Houston Heights Reservoir using the Map Maker distance calculator.

Density

Houston Heights Reservoir and Lawrence Park/MKT Trail, located in the lower Houston Heights (Harris County, Texas) between White Oak and Little White Oak bayous (29°78'N, 95°40'W; Fig. 1A), have among the highest number of bulbul reports in Houston (Fink et al. 2023) and represent the center of bulbul distribution in the region. Located just west of

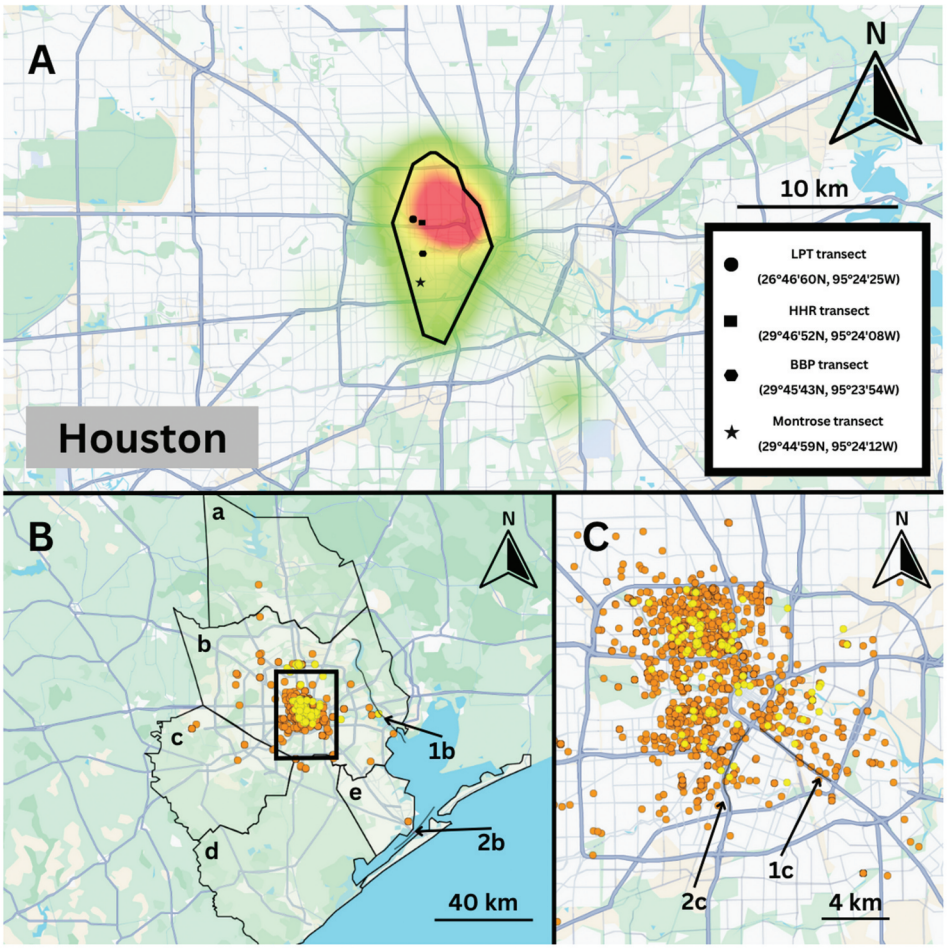

Figure 1. A) bulbul core area in Houston (Texas, USA) is bordered by the bold black polygon. The red area in the upper part of the polygon is the area with the highest concentration of bulbul records, the yellow area surrounding the red is the second-most concentrated area, and the green surrounding the yellow represents the third-most concentrated area. Transect locations are identified in the key. B) Counties with bulbul records (outlined in black) are: a, Montgomery; b, Harris; c, Fort Bend; d, Brazoria; e, Galveston. Examples of natural barriers inhibiting range expansion include the San Jacinto River (1b) and the Galveston intracoastal waterway (2b). C) expansion of the rectangle in map B. Examples of artificial barriers that appear to inhibit range expansion include highways I-45 (1c) and 288 (2c). Maps B and C show bulbul localities before (yellow circles) and after (orange circles) June 2012. Grey lines are major roads. Background shades of green indicate vegetated areas.

downtown Houston, Buffalo Bayou Park (29°45'43N, 95°23'54 W) and Montrose (29° 44'59N, 95°24'12 W; Fig. 1A), have fewer bulbul reports than the Heights but still contain high numbers relative to other areas around Houston (Fink et al. 2023; Fig. 1). We selected these four sites to perform transect surveys based on their high number of reports (Brooks 2013; TIBP 2024).

We established one linear transect route at each of the four sites, and surveyed each of these spatially independent transect routes for bulbuls 10 times between January and

March 2024 (Buckland and Handel 2006; Thibault et al. 2019). During each survey, we slowly walked while listening and watching for bulbuls within 25 m on either side of the transect. Bulbuls detected outside the 50 m swath were excluded from the survey. Transects ranged 1.7–2.0 km long. The bulbuls were conspicuous and made clearly distinct vocalizations; for this reason we assumed perfect detection within 25 m. We noted the number and spot-mapped location (to avoid double-counting) of bulbuls for each observation, as well as duration (min) of each survey (range: 29–45 min). We performed surveys beginning around 07:00–0730 h CST and ending by 07:30–08:00. We used the Google Earth box plotting feature to draw a rectangular area around each transect route, based on the total length and our detection width of 25 m on either side. Google Earth was then used to automatically convert the transect to a standardized quadrat (km^2). We calculated minimum density (number of bulbuls/km^2) for each site by dividing mean number of bulbuls observed on the transect (across 10 visits) by the total quadrat area (km^2).

Population estimate

After entering locations of all bulbul reports from the databases (June 2012 to May 2022), the geospatial analysis tool in Map Maker automatically generated a heat map of the bulbul population in Houston. We used Map Maker's drag and drop measuring tools to estimate the core area of the population by drawing a box around the darkest (representing highest density) parts of the heat map, thus calculating the core area to be 53.18 km^2 (Fig. 1A). To estimate bulbul population size in the core area, we took the mean density of bulbuls across the four surveyed sites and multiplied mean density × core area (53.18 km^2).

Results

Range expansion

The combined eBird/TIBP analysis indicated a substantial increase in the geographic range over which bulbuls were detected in Houston over the past decade (Fig. 2). The geographic range of detections expanded from 589 km^2 before June 2012 to 4,606 km^2 during the subsequent decade (June 2012 – May 2022). The combined dataset recorded 215 observations in Harris County, and no reports in other counties through May 2012. After May 2012, sightings in Harris County increased to 6,543, with new records in adjacent counties: 26 in Brazoria, 13 in Fort Bend, 4 in Galveston, and 1 in Montgomery (Fig. 1B). Citizen science platforms like eBird may experience a significant increase over time in the number of users and checklists submitted (Horns et al. 2018; Lourenço et al. 2024), which could inflate our assessment of range expansion. However, between 2003 and 2012, 72 bulbuls were reported in 30,935 Harris County eBird checklists (0.2%), and between 2013 and 2022, 5,694 bulbuls were reported in 160,033 Harris County eBird checklists (3.5%; Fink et al. 2023), an 18-fold increase in detections per checklist, which suggests true range expansion.

There were only two notable outliers from the central population before June 2012: 18 km north and 35 km east. Through May 2022 these increased to 57 km north and 41 km east, with additional outliers 68 km southeast and 45 km west. The mean distance of these outliers before June 2012 was 27 km, doubling to 53 km through May 2022.

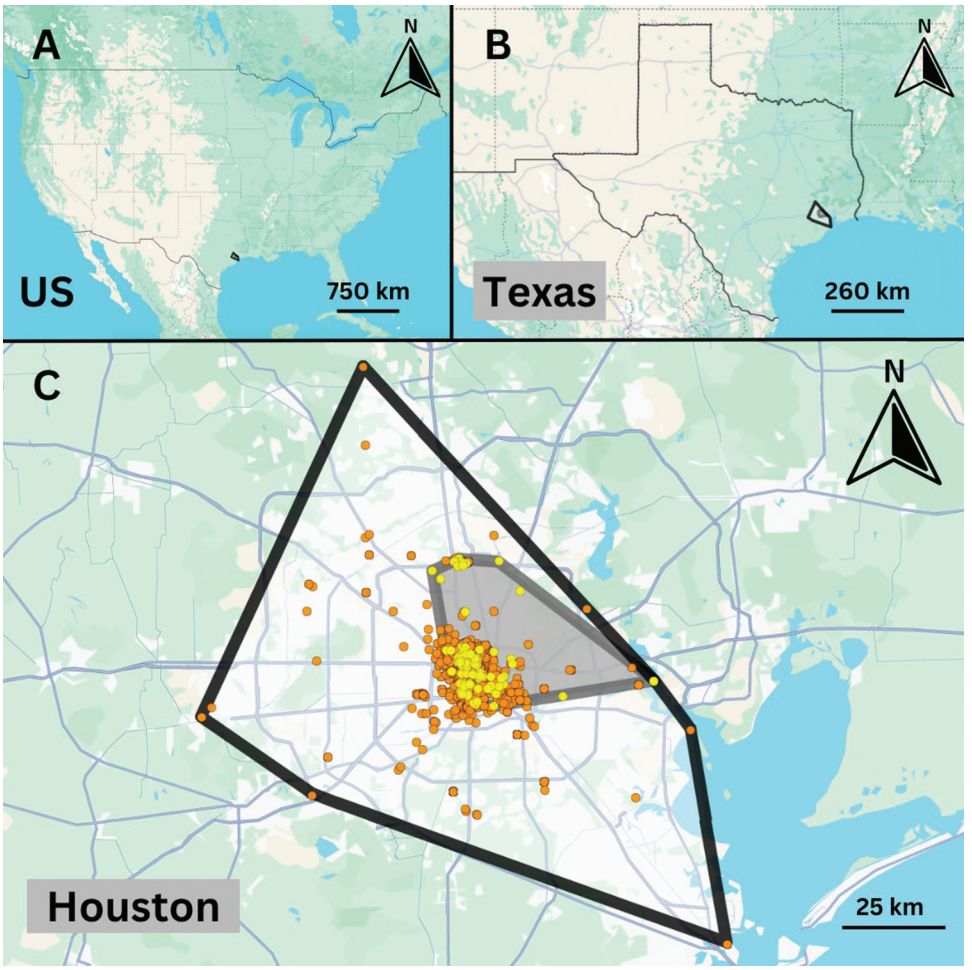

Figure 2. Bulbul expansion in Houston (Texas, USA). Maps A and B show the location of the study site in North America and Texas, respectively. Map C shows bulbul localities before (yellow circles) and after (orange circles) June 2012; known ranges are represented by the shaded and white polygons before and after June 2012, respectively.

Bulbul records are absent beyond natural barriers (e.g., San Jacinto River, Intracoastal waterway; Fig. 1B), which appear to impede continued bulbul range expansion, as bulbul records are absent beyond these features. Certain highways (e.g., Interstate 45, inner-loop State Highway 288) also appear to inhibit range expansion, with records absent from segments of highway (Fig. 1C).

Density

While conducting transect routes across the four sites, we observed a total of 29 bulbuls during 40 surveys ($n = 10$ surveys/site), covering 79.31 km total during 1,319 min. The mean density across the four transect surveys was 8.77 bulbuls/km^2 (Table 1).

Table 1. Summary of bulbul transect data at the four study sites: Houston Heights Reservoir, Lawrence Park/MKT Trail, Montrose, and Buffalo Bayou Park (Houston, Texas, USA).

Transect	Number of bulbuls/ km^2	Mean number of bulbuls/ survey	Transect length (km)	Quadrat (km^2)
Houston Heights Reservoir	17.95 (0–76.92)	1.4 (0–6)	2.0	0.078
Lawrence Park/MKT Trail	2.70 (0–27.03)	0.1 (0–1)	1.9	0.037
Montrose	7.87 (0–23.62)	1.0 (0–3)	1.8	0.127
Buffalo Bayou Park	6.56 (0–32.79)	0.4 (0–4)	2.1	0.061
Mean	8.77	0.73	1.95	0.076

Note: Data presented as: mean (range). $N = 10$ surveys of each transect.

Population estimate

A population of 466 bulbuls is estimated within the 53.18 km^2 core area, considering a mean density of 8.77 bulbuls/km^2. The population range is 144–955 bulbuls based upon the lowest (2.70 bulbuls/km^2 for the Lawrence Park/MKT Trail survey) and highest (17.95 bulbuls/ km^2 for the Houston Heights Reservoir survey) densities recorded (Table 1).

Discussion

Our results suggest that the Houston population of bulbuls is expanding, but not rapidly. Growth from 589 km^2 to 4,606 km^2 indicates a nearly eight-fold increase in the geographical range of detections over the past decade, approximately 400 km^2/yr. Harris County records grew 30 times since 2012, and the new records in surrounding counties suggest range expansion since June 2012. The mean distance of outliers doubled since 2012, also suggesting range expansion, although natural barriers and highways appear to inhibit bulbul range expansion to some areas.

Compared to other invasive vertebrates, the range expansion of approximately 400 km^2/ yr by the Houston population of bulbuls is extensive but not extremely alarming. European Starlings (*Sturnis vulgaris*) expanded in South America at a projected growth rate of 22.2 km/yr in 2016 after previously growing at a rate of 7.5 km/yr in 2005. Assuming isotropic radial spread, the rate of starling range expansion increased from approximately 177 km^2/ year to 1,548 km^2/year. This population explosion increased the starling range in the Pampas region of Brazil alone to over 65,000 km^2 (Stuart et al. 2023). Cane Toads (*Rhinella marina*) expanded in Australia at approximately 50 km/year (Department of the Environment, Water, Heritage and the Arts 2010). Assuming isotropic radial spread, the rate of toad range expansion was 7,850 km^2/year. These observations suggest that the bulbul's current range expansion is not overly alarming compared to other invasive vertebrates.

Bulbuls have spread to several regions around the globe, especially tropical Pacific islands. They are able to become well established in new regions because of their remarkable ecological plasticity. Bulbuls consume a broad range of fruit, nectar, insects, and garden plant material (Nowakowski and Dulisz 2022) and can easily nest in both natural vegetation and buildings (Zohaib et al. 2021). In some regions, their ability to dominate ecological competition in cities and agricultural areas, combined with their tendency to act aggressively around other species (Thibault et al. 2019), allow them to easily outcompete and displace native species. The main impacts of bulbuls include

destruction of cultivated crops in Hawaii (Walker 2008) and New Caledonia (Thibault et al. 2019), dispersing noxious seeds in Tahiti (Spotswood et al. 2012) and New Caledonia (Thibault et al. 2019), and outcompeting native species in New Caledonia (Thibault et al. 2019), American Samoa (Sherman and Fall 2010), and Tahiti (Blanvillain et al. 2003). While these impacts have not been observed in Fijian (Watling 1979) or Houston (Brooks 2013) bulbuls, it is important to continue monitoring these populations for potential changes.

We observed variation in bulbul minimum densities among the four transects (2.70–17.95 bulbuls/km^2). The ecologically harmful New Caledonian population had a density estimated to be orders of magnitude higher (204 bulbuls/km^2) in the epicenter of its range, with populations of 131–160 bulbuls/km^2 nearby, and dampening extensively to 31 bulbuls/km^2 at the range periphery 50 km away (Thibault et al. 2019). Assuming no sampling bias, the Houston population's lower density may be a primary mechanism explaining why bulbuls are not considered an ecological threat at this time (Thibault et al. 2019). However, a suite of factors (e.g., behavior, diet, habitat) likely influence the impact potential of introduced bulbul populations (Brooks 2013), in addition to density.

Several caveats need to be considered for this study. First, while the frequency of bulbul sightings in Houston has become much higher, their apparent range expansion could be an artifact of an increase in the number of eBird reports over time, rather than a true increase in range size. This is because an increase in effort from observers could potentially overestimate range expansions if such sampling bias occurs (Lourenço et al. 2024), as we tested for comparing percent of bulbuls/effort. Second, our modeling assumes perfect detection of bulbuls within a 50 m swath along our transects, and we were careful not to count bulbuls outside the 50 m swath. However, if we did not detect all birds within the 50 m swath, we would underestimate true density. Third, bulbuls in Houston might be experiencing a typical "lag-phase" growth, seen in many invasive species, where populations grow slowly over several years before experiencing a sudden rapid range expansion. This trend has been seen in European Starlings in Argentina (Stuart et al. 2023) and Common Mynas in Canberra (Grarock et al. 2012) for example. While our study population of Houston bulbuls is not currently considered a threat, continued monitoring of this population over time will be important to detect a population explosion, should one occur. Similar continued monitoring for population explosions was recommended for other invasive species in the region (cf, Callaghan and Brooks 2018).

The estimate of 466 bulbuls within the core area of 53.18 km^2 illustrates the significant presence of this invasive species in Houston's urban environment. Future studies should prioritize extensive transect monitoring across the bulbul's expanded and peripheral regions to permit calculating the total population estimate. A better understanding of bulbul population density is essential to estimate total numbers and assess dispersal ability. Additionally, it is necessary to explore the dynamics of bulbul reproduction, foraging, and interspecific competition to assess the ecological impact of their presence in Houston.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Generative AI

Generative AI was not used in the production of this manuscript.

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