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Bird diversity and psychological wellbeing: A comparison of green and coastal blue space in a neotropical city

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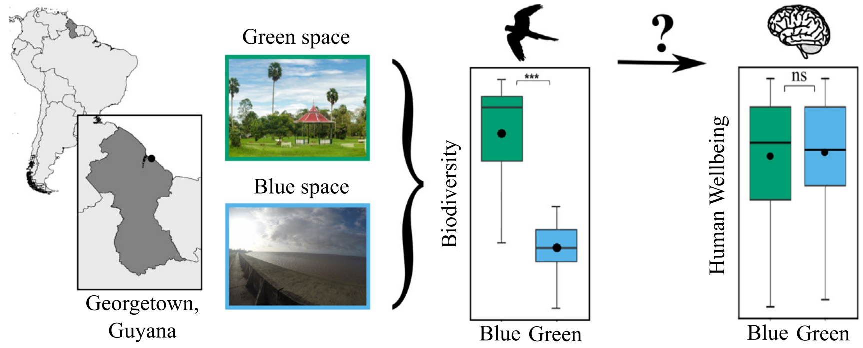
HIGHLIGHTS

- Urban green and blue space are important for biodiversity and human wellbeing.
- We examined bird diversity and human wellbeing in the neotropical Global South.
- Bird surveys and questionnaires were conducted across green and coastal blue space.
- Bird diversity did not relate to wellbeing, implying other factors have a role.
- City planners should conserve green and blue space for both people and wildlife.

GRAPHICAL ABSTRACT



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ABSTRACT

Accelerating rates of urbanisation are contributing to biodiversity declines worldwide. However, urban green (e.g. parks) and blue spaces (e.g. coast) provide important habitat for species. Emerging evidence also shows that green and blue spaces can benefit human psychological wellbeing, although few studies originate from the Global South and it is unclear whether more biodiverse spaces offer greater wellbeing gains. We examine how bird diversity (abundance, species richness, Shannon diversity, and community composition) in green and coastal blue space in Georgetown, Guyana, is associated with people's wellbeing (positive and negative affect, anxiety) *in situ*, using point counts and questionnaires. Bird community composition differed between green and coastal sites, and diversity was significantly higher in green sites. Positive affect and anxiety did not differ between green and coastal sites, but negative affect was higher in coastal sites. Mixed-effect models showed no associations between biodiversity and wellbeing, implying other features are contributing to people's positive wellbeing. Despite no association between biodiversity and wellbeing, both green and coastal blue sites are important for wellbeing and supporting different bird communities. City planning authorities and public health professionals should ensure these social and environmental needs are met in developing cities in the Global South.

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1. Introduction

Urbanisation rates are increasing globally, with urban landcover forecast to triple between 2000 and 2030 (Angel et al., 2011), and 60% of people around the world will live in urban areas by 2030 (UN, 2018). Residing in towns/cities can be detrimental to human wellbeing, as the prevalence of mental health issues (e.g. anxiety, depression) is greater than in rural regions (Peen et al., 2010; WHO and CBD, 2015). The scale of urbanisation also places significant pressure on biodiversity (Güneralp and Seto, 2013) and, consequently, ecosystem functions that provide critical services to humanity (Cardinale et al., 2012). However, biodiversity can thrive in towns and cities (Ives et al., 2016), with urban green spaces (e.g. parks, gardens) providing a refuge for some species (Fontana et al., 2011; Baldock et al., 2015). Additionally, there is substantial evidence showing that visits to urban green spaces can benefit people's psychological wellbeing (Keniger et al., 2013; Lovell et al., 2014). The planning, design and management of urban areas is therefore important for both biodiversity conservation and public health services.

Emerging literature also highlights the importance of blue spaces (e.g. rivers, coast) for psychological wellbeing. Indeed, while often subsumed within the definition of green spaces (van den Berg et al., 2017; Coldwell and Evans, 2018; White et al., 2019), some research suggests stronger positive associations are apparent when blue spaces are considered independently. For instance, studies using national survey data show that people living near visible salt or freshwater experience lower psychological distress than those near visible green spaces (Nutsford et al., 2016), and a more pronounced reduction in the prevalence of anxiety and mood disorders associated with the availability of blue over green space (de Vries et al., 2016). Likewise, experimental evidence demonstrates people prefer viewing scenes containing water, rather than just greenery, and perceive them as more restorative (White et al., 2010). Suggested explanations for this include the specific characteristics of water, such as its visual properties (e.g. vastness, movement) and sounds (e.g. breaking waves) (White et al., 2010; Völker and Kistemann, 2015). A review of blue spaces, health and wellbeing by Gascón et al. (2017) demonstrates that a diverse array of psychological outcome measures have been studied to date (e.g. psychological distress, minor psychiatric morbidity), but that psychological wellbeing is rarely a focus. With over one third of the world's population living near a coastline (Neumann et al., 2015), there is considerable potential to develop a stronger evidence-base around how coastal blue spaces could influence psychological wellbeing.

Several theories are proposed to substantiate the link between improved human psychological wellbeing and urban green/blue space. Attention Restoration Theory (ART) states that time spent in green or blue space restores concentration and the ability to focus attention, improving memory retention, problem-solving, and information-processing (Kaplan and Kaplan, 1989; Kaplan, 1995). Stress Reduction Theory (SRT) suggests that natural environments can ameliorate physiological and psychological stress, by influencing emotive reactions and subsequent behavioural and cognitive responses (Ulrich et al., 1991). Others posit that people are 'biophilic', affiliated with 'nature' through evolved genetic adaptations to natural environments, which lead to positive or negative responses to specific stimuli (e.g. a snake, running water) (Kellert and Wilson, 1993). The explicit role of biodiversity in these theories, including what taxa or metric to measure biodiversity, is rarely considered. However, there is increasing interest as to whether experiencing a more biodiverse green or blue space may result in greater wellbeing gains, supported by the empirical evidence that is emerging on the subject (Lovell et al., 2014; Botzat et al., 2016; Aerts et al., 2018).

Disentangling the impacts of green and blue space for psychological wellbeing, particularly where they co-occur, is important to identify effective land-use management/policy strategies (Higgins et al., 2019). Achieving this requires a better understanding of which specific characteristics of green and blue spaces enhance or detract from wellbeing. Specifically, teasing apart the role biodiversity plays in human-nature relationships would be valuable for decision-makers tasked with improving environmental quality for people and species alike. Current empirical evidence to support the contribution of biodiversity to psychological wellbeing is equivocal. For instance, greater afternoon bird abundance has been associated with lower stress, depression and anxiety, but these relationships did not hold when species richness was used as the biodiversity metric (Cox et al., 2017). Conversely, other studies have found greater bird species richness to be associated with higher psychological wellbeing (reflection, place identity and place attachment) (Fuller et al., 2007; Dallimer et al., 2012), and higher life satisfaction across Europe (Methorst et al., 2021a).

No research has quantitatively examined the link between biodiversity in blue spaces and psychological wellbeing in situ, although there is qualitative and ex situ evidence that blue space biodiversity has a positive effect. In a laboratory setting, viewing videos of coastal bird flocks and charismatic species resulted in positive moods, compared with other wildlife (White et al., 2017). In an aquarium, higher Shannon diversity of aquatic fish was, similarly, related to higher self-reported mood and interest (Cracknell et al., 2016). Garrett et al. (2019) found that people in Hong Kong were more likely to visit blue spaces if they felt there was wildlife to see.

There are also major geographical gaps in where biodiversity-wellbeing research has taken place, with a paucity of studies from the Global South (Keniger et al., 2013; Lovell et al., 2014; Botzat et al., 2016). Global South nations are urbanising extremely quickly, with urban landcover expected to grow 315% between 2000 and 2050 (UN, 2018; Angel et al., 2011). Simultaneously, there is a lack of urban conservation research and action which could help alleviate associated biodiversity loss (Shwartz et al., 2014). The largest urban expansion into biodiversity-rich ecosystems by 2030 is predicted for South America, with a ~3.5 fold increase in urban landcover (Güneralp and Seto, 2013), where cities are characterised by extreme social and economic inequality (Pauchard and Barbosa, 2013). Despite the presence of green spaces in South American cities, urban planners have yet to fully acknowledge their importance as key habitats for species, or the benefits they may provide to human wellbeing (Pauchard and Barbosa, 2013).

Here, we explore bird diversity and psychological wellbeing in Georgetown, Guyana. Birds were chosen as a model taxa as they are highly visible, inexpensive to monitor, and are indicators/providers of ecosystem functions (Herrando et al., 2017). Moreover, given its proximity to the Guiana Shield Amazonian forest, Georgetown contains more than 10% of Guyana's known bird species, found throughout the city's urban green and coastal blue space in differing levels of diversity (Hayes et al., 2020). By comparing sites within green and coastal blue space, we subsequently hypothesise that this observed variation in bird diversity will relate to variation in human psychological wellbeing (positive affect, negative affect, and anxiety). This study addresses important knowledge gaps, relating biodiversity to wellbeing in green versus coastal blue space in the Global South.

2. Methods

2.1. Study design

Georgetown, the capital of Guyana in northern South America (Fig. 1a–b), has a human population of 119,000 (Bureau of Statistics, 2012). Once a wetland, the city sits below sea level, protected from flooding by a sea wall (Edwards et al., 2005). There are many managed green spaces throughout the city, with two large public parks (National Park and Botanical Gardens), cemeteries, several smaller neighbourhood parks, and University of Guyana grounds.

We collected both questionnaire and bird point count survey data across Georgetown. First, sites were randomly selected (see Hayes

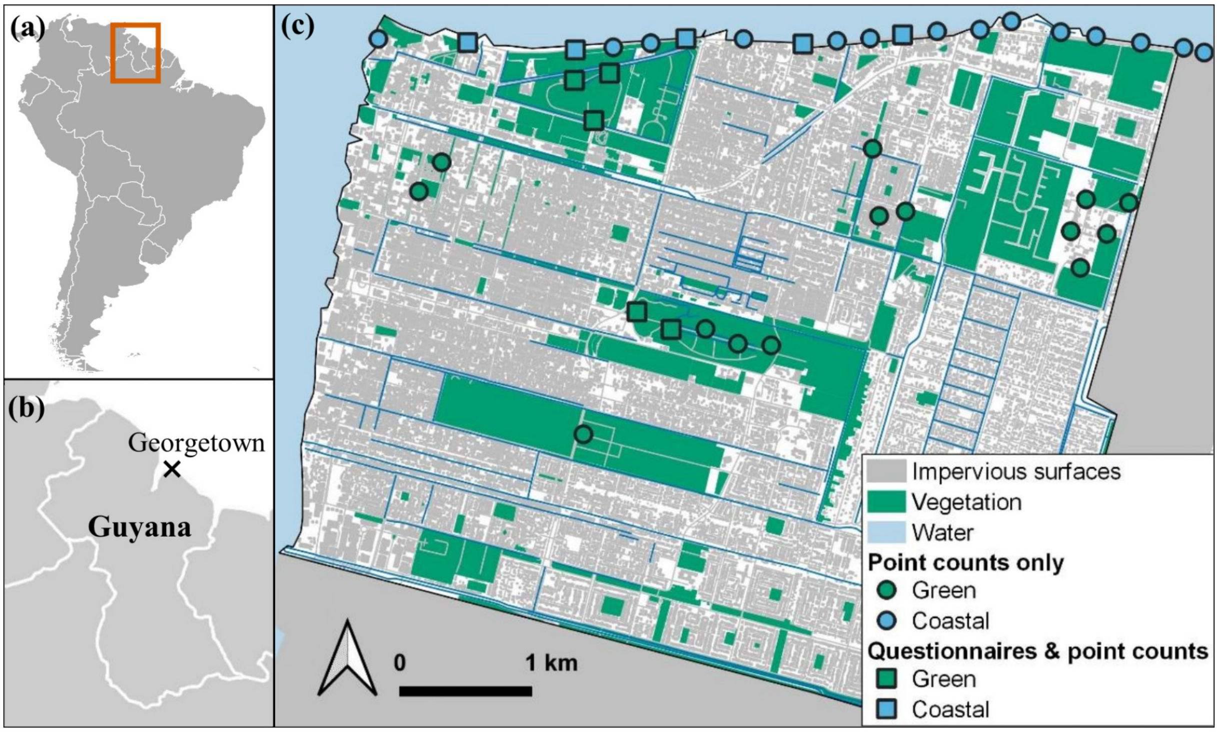

Fig. 1. (a) Guyana, in northern South America, (b) Georgetown, along the north coast of Guyana and (c) sites in Georgetown ($n = 19$ green sites, $n = 19$ coastal sites) used for bird surveys (circles), and used for both bird surveys and questionnaires (squares) ($n = 5$ green sites, $n = 5$ coastal sites), and the distribution of the three environmental variables (impervious surfaces, vegetation, and water) across the city. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

et al., 2020 for full details) within green space (green sites, $n = 19$) and coastal blue space along the sea wall (coastal sites, $n = 19$). Sites were at least 250 m from one another to ensure spatial independence (Silva et al., 2015).

The green and coastal blue sites were defined and ground-truthed according to the predominant percent ground cover of a number of environmental variables within a 50 m radius of the site centre. This radius reflected the search area of the bird point count surveys, and the area participants were asked to consider when completing the questionnaire (see Supplementary material Fig. S1 for examples). The recorded environmental variables comprised impervious surfaces, vegetation (tree canopy, shrub, grass) and water (ocean, drains, pond, canals) (see Supplementary material Table S2 for descriptions). As we were matching site-level biodiversity with people's momentary wellbeing, we delivered the questionnaire in 10 ($n = 5$ green sites, $n = 5$ coastal sites) of the 38 point count survey sites where people were known to visit (Fig. 1c).

2.2. Questionnaire development and delivery

We invited participants to respond to a questionnaire about 'how people feel in Georgetown'. Three initial questions explored visit patterns that could affect momentary wellbeing, including how often they visit the site (visit frequency), who they were visiting with (type of company), and the reason for visiting on this occasion (visit motivation). These questions were asked first to reduce response bias (Robson and McCartan, 2016). To measure visit frequency, we asked: '*How frequently do you come past this spot*?' with five response options (daily, weekly, monthly, less than monthly, yearly), and '*Who are you with today*?' with six response options (children, friends, partner, parents, alone, other) to record type of company. These were followed by an open-ended question to gauge visit motivation: '*What is the main reason you are here today*?'.

Momentary psychological wellbeing was measured as positive affect, negative affect and anxiety, using existing validated scales commonly used in nature-wellbeing research (e.g. Cracknell et al., 2016; Wolf et al., 2017; Marselle et al., 2016). We asked participants to '*rate how you feel at the present moment in this spot*'. They were specifically and repeatedly asked to consider only a 50 m radius around them, to correspond with the area of the bird point count surveys. The Positive and Negative Affect Schedule (PANAS) asked participants for 10 positive and 10 negative emotions, on a five-point scale (1 = *not at all*, 2 = *slightly*, 3 = *moderately*, 4 = *quite a bit*, 5 = *extremely*) (Watson et al., 1988) (Supplementary material Table S3a). Scores for each set of 10 emotions are summed to create a continuous measure (10 to 50) of positive and negative affect. The six-item State Trait Anxiety Inventory (STAI) (Marteau and Bekker, 1992) measures anxiety using the same stem question as for PANAS (Supplementary material Table S3b). We modified response options from the original four-point to a five-point scale in keeping with PANAS, to reduce potential participant confusion. Negative items in STAI were reverse scored, then all scores were added together and multiplied by 3.33 to generate total in the range of 20–100 (Marteau and Bekker, 1992). Cronbach's α was used to check for internal consistency in each scale (Cronbach, 1951).

Using questions from the most recent Guyanese census (Bureau of Statistics, 2012), we collected sociodemographic data on gender and age to ascertain whether our sample was representative of the Georgetown population. The questionnaire was piloted with 20 members of the public from varying demographic backgrounds. One adjustment was made to the original PANAS, replacing 'jittery' with 'uneasy' as participants found this easier to understand. Show cards were used to display response options from which participants selected answers, reducing the chance of skipped questions (OECD, 2013) and acting as a literacy aid. Questionnaires were delivered face-to-face to every third passer-by above the age of 18 during daylight hours (07:30–18:30) every day of the week, including weekends. Ethics approval was gained from University of Kent's Faculty of Social Sciences Research Ethics Advisory Group for Human Participants (Ref. No. 0511617).

2.3. Bird surveys

Bird point counts were conducted at green ($n = 19$) and coastal sites ($n = 19$), with one survey undertaken per site (see Hayes et al., 2020 for full details). Point counts took place on clear days, between 05:30 and 08:30, with each survey lasting 15 min. All birds seen within 50 m of the point count centre, including those flying no more than 25 m above the highest structure, were recorded to species level. Anything flying higher than this threshold was deemed a flyover.

2.4. Analyses

Statistical analyses were performed using R version 3.5.0 (R Core Team, 2020). Differences in the ground cover of environmental variables (impervious surfaces, vegetation and water) between green and coastal sites were compared using non-parametric two-sample Wilcoxon rank sum tests. Bird abundance, species richness, and Shannon diversity were also calculated for each of the 38 sites using the 'Vegan' package (Oksanen et al., 2018). No spatial autocorrelation was evident between sites (see supplementary text for details). Non-metric multidimensional scaling (NMDS) was used to visualise the composition of bird communities in green and coastal sites (see supplementary text for details), using '*metaMDS*' (Oksanen et al., 2018), and statistical differences quantified with Analysis of Similarities (ANOSIM), using '*anosim*' (Oksanen et al., 2018). Sites where questionnaires were delivered ($n = 5$ sites per landcover type) contained bird communities representative of each type of landcover, with 80% falling inside each of the green or coastal NMDS minimum convex polygons (see supplementary text for details). Comparisons between green and coastal sites where questionnaires were conducted were made using Wilcoxon rank sum tests.

The qualitative reasons for participants visiting a site (e.g. 'passing through') were coded iteratively by two authors (JCF, KNI) into codes ($n = 27$), themes ($n = 9$) and domains ($n = 5$) (Supplementary material Table S4), based on a previously developed typology (Irvine et al., 2013). Chi-squared tests were used to compare differences in visit frequency, type of company and visit motivations between green and coastal sites. Analyses for visit motivations were conducted at domain level to overcome sample size limitations. A G-test was used to investigate if the sample population was representative of Georgetown.

Using the 'lme4' package (Bates et al., 2015), we created bivariate general linear mixed-effect models to assess initially whether levels of biodiversity could predict wellbeing, using 'site' as a random effect to control for independence. We used log-gamma error distributions for non-normal residuals for all wellbeing response measures. We also used an interaction term between the two NMDS axes from our bird community analysis (a measure of how the composition of species differs) as a fourth predictor in the bivariate models. Next, we produced adjusted general linear mixed-effect models that contained biodiversity measures alongside demographics (gender and age) and visit patterns (visit frequency, type of company, visit motivation) to see if these covariates were influencing the association between biodiversity and wellbeing. To improve power, we collapsed visit frequency categories into 'Daily', 'Weekly', and 'Monthly or Less', and visit company into 'Alone', 'Family', and 'Friends'. Numerical variables were centred, and we checked for multicollinearity using variance inflation factors, finding no issues. Checks for model fit, overdispersion and homoscedasticity were carried out prior to analysis (Zuur and Ieno, 2016; Harrison et al., 2018).

3. Results

Both green and coastal sites contained a similar percentage ground cover of impervious surfaces ($W = 17.5$, $p = 0.313$) (Fig. 2; Supplementary material Table S5). Coastal sites were predominantly characterised by water ($W = 25$, $p < 0.05$) and green sites by vegetation ($W = 0$, $p < 0.001$).

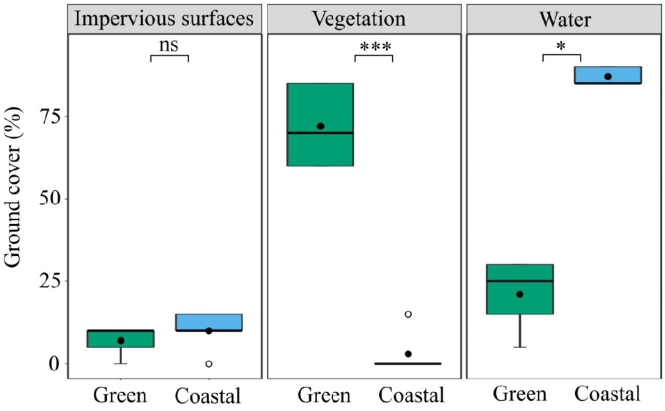

Fig. 2. Percentage ground cover for the three environmental variables (impervious surfaces, vegetation, and water) across green and coastal sites where questionnaires were delivered ($n = 5$ per landcover type). Boxplots show range (whiskers) of data about the median (bold horizontal line), with the coloured box depicting the 25th and 75th quartiles. Hollow circles denote outliers, filled circles denote means. Star notation indicates significance level of analysis with Wilcoxon rank sum tests (ns = not significant; $^{*} = p < 0.05$ $^{***} = p < 0.001$). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Across the 10 sites where questionnaires were conducted, 306 individuals participated (response rate = 70%), with 169 and 137 in green and coastal sites respectively. Overall, 58% of participants were women, and age ranged between 18 and 65+ years old. Although sample demographics were not representative of the wider Georgetown population, they were broadly similar between green and coastal sites (Supplementary material Tables S6–7). The frequency of visits to green and coastal sites was significantly different ($X^2 = 12.053$, df = 4, $p = 0.012$), with coastal sites visited more on a daily basis (41%) compared with green sites (30%), which had a higher percentage of yearly visits (23%) than coastal sites (59%) (Supplementary material Tables S8–S10). For additional visit pattern outcomes, there were no significant difference between green and coastal sites (type of company: $X^2 = 6.689$, df = 4, $p = 0.153$; visit motivation at domain level: $X^2 = 6.625$, df = 4, $p = 0.157$), with almost half of all participants (47%) visiting both landcover types alone, and the majority (66%) visiting for physical activity.

All three scales measuring momentary psychological wellbeing showed good internal consistency (Cronbach's α: positive affect = 0.85; negative affect = 0.85; anxiety = 0.70). There were no significant differences in positive affect ($W = 11{,}396$, $p = 0.814$) or anxiety ($W = 21{,}067$, $p = 0.931$) between green and coastal sites. A significant difference in negative affect was identified ($W = 9810.5$, $p = 0.014$), whereby negative affect was lower in green space (Fig. 3; Supplementary material Table S5).

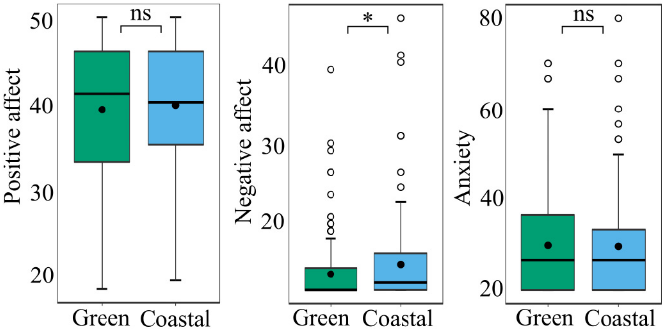

Fig. 3. Momentary wellbeing measures (positive affect, negative affect, and anxiety) for visitors to green ($n = 169$ respondents, $n = 5$ sites) and coastal sites ($n = 137$ respondents, $n = 5$ sites) in Georgetown, Guyana. Boxplots show range (whiskers) of data about the median (bold horizontal line), with the coloured box depicting the 25th and 75th quartiles. Statistical significance level of analysis with Wilcoxon rank sum tests (ns = not significant; $^{*} = p < 0.05$). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

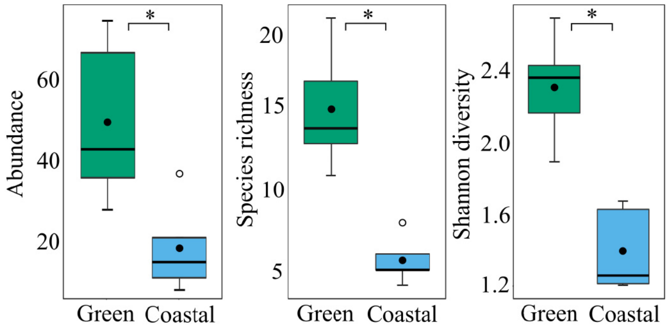

Fig. 4. Measures of bird diversity (abundance, species richness, and Shannon diversity) measured from green sites ($n = 5$) and coastal sites ($n = 5$) where both point counts and questionnaires were delivered in Georgetown, Guyana. Boxplots show range (whiskers) of data about the median (bold horizontal line), with the coloured box depicting the 25th and 75th quartiles. Hollow circles denote outliers, filled circles denote means. Star notation indicates significance level of analysis with Wilcoxon rank sum tests ($^{*} = p < 0.05$). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

A total of 1298 individual birds were identified to species level during the point counts, with 72 and 26 species recorded at green and coastal sites respectively. Sampling effort was deemed adequate, based on species accumulative curves for green and coastal sites respectively (Supplementary material Fig. S2). All measures of bird diversity were significantly higher in green compared to coastal sites (abundance: W = 25, $p < 0.05$; species richness: W = 25, $p < 0.05$; Shannon diversity: W = 23, $p < 0.05$) (Fig. 4; Supplementary material Table S5).

There were significant differences between the bird communities of green and coastal sites (ANOSIM: $R = 0.79$, $p = 0.001$) (Fig. 5).

There was a statistically significant association between bird community composition and positive affect in green sites when tested with bivariate general linear mixed-effect models (Supplementary material Table S11), which did not hold when adjusted for demographic covariates and visit patterns (Table 1). There were no associations between any other measures of momentary psychological wellbeing and bird diversity in the bivariate or adjusted models.

4. Discussion

Globally, the fastest rate of urbanisation into biodiversity-rich ecosystems is forecast for South America (Güneralp and Seto, 2013). Yet, the role of urban biodiversity in the provision of ecosystem services such as human wellbeing has yet to be fully acknowledged in this region (Pauchard and Barbosa, 2013). Here, we provide novel evidence from the Global South that bird diversity (abundance, species richness, Shannon diversity, and community composition) is not associated with momentary psychological wellbeing (positive affect, negative affect, and anxiety). This concurs with findings from Germany, where bird abundance had no association with mental health (Methorst et al., 2021b), and from the UK, where bird species richness had no association with depression, anxiety and stress (Cox et al., 2017). Nonetheless, our findings from Georgetown contradict other evidence from Europe that found bird species richness was positively related to wellbeing (continuity with the past, place attachment, Fuller et al., 2007; continuity with the past, place attachment, reflection, Dallimer et al., 2012; positive affect, reduced anxiety, Wolf et al., 2017; life satisfaction, Methorst et al., 2021a), as well as research from UK and Australia showing higher bird abundance relates to lower depression, anxiety, and stress (Cox et al., 2017), and to greater life satisfaction in a neighbourhood (Luck et al., 2011). Altogether, making comparisons between studies is complicated, not only because of their different geographical locations around the world and variable use of biodiversity metrics, but also due to the various measures of psychological wellbeing used and the context they are set within (e.g. back garden, neighbourhood). For example, Wolf et al. (2017) use STAI videos of birds in a laboratory setting to explore associations between biodiversity and anxiety, whereas Cox et al. (2017) use the Depression, Anxiety and Stress scale with bird point counts in a neighbourhood. Therefore, making generalised, overarching conclusions about associations between biodiversity and wellbeing remains difficult, but could be remedied by using comparable methods and psychological instruments.

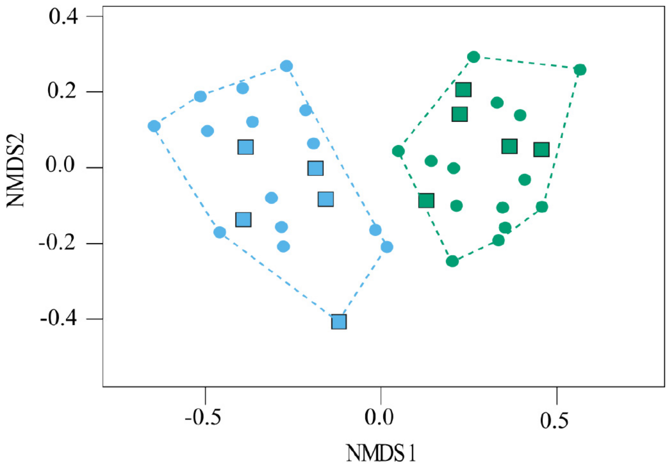

Fig. 5. NMDS two-dimensional plot of bird assemblages from 38 sampled sites (19 coastal = blue circles and squares, 19 green = green circles and squares). Of these, questionnaires were delivered at 10 sites (5 coastal = blue squares, 5 green = green squares). A stress value of 0.16 was calculated. Green and coastal sites are grouped by their minimum convex polygon (dotted lines). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Momentary psychological wellbeing differed little between green and coastal sites. These findings contradict studies that report significantly higher levels of wellbeing associated with blue rather than green space (White et al., 2010; Nutsford et al., 2016; de Vries et al., 2016). As our findings suggest that bird diversity was unrelated to wellbeing, other features are likely to be driving the high positive affect and low anxiety observed. Attributes specific to coastal blue spaces, like crashing waves and oceanic smells, are reported as therapeutic (Bell et al., 2015), as well as vast panoramas and easy orientation, which relate to psychological wellbeing (Finlay et al., 2015; Völker and Kistemann, 2015). More research is needed into what factors of blue space influence psychological wellbeing, and their relative importance, to understand the higher levels of negative affect we found in coastal as opposed to green sites. Indeed, certain green space attributes like lighting, cleanliness, and tree abundance, as well as people's perceptions of attributes such as naturalness, comfort and beauty are known to influence wellbeing (Ayala-Azcárraga et al., 2019; Zhang et al., 2013; Francis et al., 2012; Akpinar, 2016). In Georgetown, higher levels of negative affect could also be explained by concerns for personal safety, which has been shown to directly increase negative affect in the city's public outdoor spaces (Fisher et al., 2021a). Moreover, safety concerns have been shown to negatively influence patterns of green and coastal blue space use in Georgetown (Fisher et al., 2021b), synonymous with other cities in South America (Moran et al., 2020; Wendel et al., 2012).

Disparity exists between how people's perceptions map onto objective reality, particularly in terms of biodiversity (Pett et al., 2016). This has been shown in studies looking at the effects of actual and perceived biodiversity on psychological wellbeing, where actual bird species richness was incorrectly estimated and unrelated to wellbeing, but greater perceived species richness was associated positively with wellbeing (Fuller et al., 2007; Dallimer et al., 2012). This phenomenon has also been observed in Georgetown, Guyana, although only when green spaces were perceived as restorative (Fisher et al., 2021a). Human perceptions could be affected by specific species evoking positive or negative reactions based on cultural significance or childhood experience (Bell et al., 2019). For example, people have positive associations with

Table 1
Coefficients and 95% confidence intervals (CI) for log-gamma regression models testing whether three measures of psychological wellbeing (positive affect, negative affect and anxiety) can be predicted by four different measures of bird diversity (species richness, abundance, Shannon diversity, and community composition) across all sites (full questionnaire dataset; $n = 306$), green sites ($n = 169$ respondents, $n = 5$ sites) and coastal sites ($n = 137$ respondents, $n = 5$ sites). All models are adjusted for demographic covariates (age and gender) and visit patterns (visit frequency, type of company, and visit motivation at the domain level).

		Positive affect		Negative affect		Anxiety	
		Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Full dataset ($n = 306$)	Species richness	0.000	−0.006, 0.007	−0.006	−0.018, 0.005	−0.002	−0.015, 0.010
	Abundance	0.001	−0.000, 0.003	0.000	−0.003, 0.004	−0.001	−0.003, 0.000
	Shannon diversity	−0.027	−0.083, 0.028	−0.059	−0.141, 0.023	−0.017	−0.108, 0.073
	Community composition	−0.714	−2.036, 0.608	−0.597	−3.228, 2.035	−1.866	−4.049, 0.316
Green ($n = 169$)	Species richness	0.012	−0.003, 0.026	0.002	−0.019, 0.023	−0.014	−0.039, 0.010
	Abundance	0.050	−0.106, 0.206	0.027	−0.145, 0.199	−0.075	−0.003, 0.000
	Shannon diversity	−0.053	−0.132, 0.026	−0.001	−0.096, 0.094	0.017	−0.110, 0.144
	Community composition	−1.132	−3.836, 1.573	−0.378	−3.655, 2.899	−1.766	−5.803, 2.271
Coastal blue ($n = 137$)	Species richness	−0.018	−0.042, 0.007	0.015	−0.059, 0.090	−0.014	−0.116, 0.087
	Abundance	−0.002	−0.005, 0.001	−0.001	−0.006, 0.004	−0.008	−0.018, 0.003
	Shannon diversity	−0.003	−0.073, 0.080	−0.125	−0.261, 0.012	−0.126	−0.260, 0.007
	Community composition	−0.186	−0.903, 0.530	−0.385	−2.339, 1.569	−1.723	−3.575, 0.130

culturally important songbirds (Clucas et al., 2015; Brock et al., 2017), and negative associations with local wildlife thought to be dangerous (Schuttler et al., 2019). These studies indicate that people's wellbeing experiences could relate to particular species or combinations of species present at that time (Bell et al., 2017; Palliwoda et al., 2017), and could explain why people's negative affect was significantly lower in green compared to coastal sites. Disparity between objective and perceived measures of biodiversity may also reflect the familiarity people have with local wildlife (Ratcliffe et al., 2018; Schuttler et al., 2019). For example, by assessing the identification skills of urban riparian green space visitors, Dallimer et al. (2012) showed that knowledge of birds was related to how accurately people estimate levels of biodiversity around them, with species common to domestic gardens more accurately recognised. In summary, patterns in objective versus perceived species richness in biodiversity-wellbeing research can be very different, pointing towards the need to collect and compare both types of information.

Bird diversity measures of abundance, species richness, and Shannon diversity of birds were much greater in green sites than at the coast, and the community composition was different between the two landcover types. The green spaces of Georgetown have been shown to contain sufficient tree cover and vegetation to support a high diversity of birds (Hayes et al., 2020), consistent with other studies in South American cities (Reynaud and Thioulouse, 2000; Pauchard et al., 2006; Reis et al., 2012). These findings emphasise the conservation value of green and coastal blue spaces in urban areas. Given evidence that cities can offer important habitat for threatened species (Ives et al., 2016), efforts should be made by urban planners to protect these spaces for both wildlife, as well as people.

5. Conclusion

As cities strive for sustainability, there are growing demands to simultaneously satisfy economic, social, and environmental needs (UN, 2018). To meet these multiple demands, interdisciplinary studies are critical to highlight where co-benefits can be derived from particular land-use planning interventions (Hartig and Kahn, 2016; Botzat et al., 2016). This study provides novel evidence regarding how wellbeing might be linked, or not, with biodiversity, comparing green and coastal blue space within the same Global South city. Our evidence suggests that there is no direct association between bird diversity and wellbeing for people in Georgetown. It is likely that features specific to green and coastal blue space, as well as people's perceptions of these sites, are contributing positively to wellbeing, which require further work to uncover. Nonetheless, we suggest that conserving bird diversity and encouraging visits to Georgetown's green and coastal blue space could benefit the human and avian populations alike. The research is important for city planning authorities, conservationists and public health professionals who seek to manage urban environments to conserve wildlife, while improving the quality of life for people in rapidly developing cities.

CRediT authorship contribution statement

Jessica C. Fisher: Conceptualization, Methodology, Formal analysis, Visualization, Writing – original draft. **Jake E. Bicknell:** Methodology, Supervision. **Katherine N. Irvine:** Conceptualization, Methodology, Validation, Writing – review & editing. **William M. Hayes:** Investigation, Writing – review & editing. **Damian Fernandes:** Resources, Methodology, Supervision. **Jayalaxshmi Mistry:** Methodology, Supervision, Writing – review & editing. **Zoe G. Davies:** Conceptualization, Methodology, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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