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The avian cultural ecosystem services project:

quantifying the cultural ecosystem services provided by birds across South Africa's urban ecosystems

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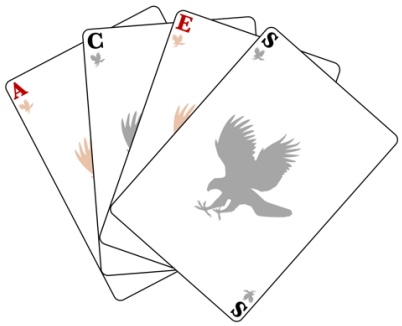

Submitted in fulfilment of the requirements for the degree Master of Sciences [2023-2024]

DECLARATION

I declare that this dissertation is my own, unaided work, and where necessary I have cited the literature used to develop and explain ideas in this study. It has been submitted in fulfilment of the requirements of a Master of Science at the University of the Witwatersrand. It has not been submitted before for any degree or examination to another university or similar institution.



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2068392

11 February 2025

REVISION DECLARATION

I further declare that the corrections for my MSc have been completed in full and represents my own, unaided work that has been approved by my research supervisor for the fulfilment of my Master of Science degree at the University of the Witwatersrand.



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23 July 2025

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For the 12-year-old boy with a dream.

Thanks for not giving up on me.

ABSTRACT

The “extinction of experience” suggests that human-nature interactions are declining with increased migration to urban environments. This decline is not experienced equally across all urban communities as socio-economic disparities exacerbate inequality in access to nature. The Luxury Effect shows this inequality, depicting that levels and access to biodiversity vary across urban and socio-economic landscapes where wealthier communities typically experience greater biodiversity. Existing literature highlights environmental injustices associated with urban biodiversity, which may influence human-nature interactions across different landscapes. While the use of biodiversity indices like species richness shows these injustices, there is limited understanding of how this may directly correlate to human well-being. In urban literature, there has been an increased focus on ecosystem service relationships to help understand this missing link. Because of a lack of standardised metrics, however, there is no clear understanding of how access to these services may vary across urban and socio-economic landscapes. Birds, being widely distributed and accessible, generally well-liked, and key urban ecosystem service providers, present an ideal taxon for evaluating this knowledge gap. Additionally, South Africa, because of its distinct urban and socio-economic landscapes and diverse culture and ecology, serves as an ideal model to address these gaps in knowledge. I focused specifically on cultural ecosystem services (CES) in this study as they offer insights to the personal and subjective values of different individuals of the birds in the environment. Using these services, I set out to assess patterns of avian cultural ecosystem services by assessing how and why individuals value different birds, and how urban and socio-economic development may influence the avian cultural ecosystem services that different individuals have access to.

In this dissertation, I collected quantitative and qualitative data on how likeable 36 bird species are across four South African provinces between September 2023 and January

2024. In Chapter II, I used this data to conduct a quantitative and qualitative assessment of cultural ecosystem services provided by birds in urban South Africa. I used participant ratings of how likeable birds are to generate likeability scores that showed birds are a generally well-liked taxon in urban environments, however, this varied at the species level. I then used open-ended sentiment responses associated with the likeability scores to qualitatively assess the reasons for likeability by training the large-language model, ChatGPT, to categorise responses into major themes. From eight major themes of likeability identified, I observed that people tended to like species for their aesthetics and emotional connectedness, but generally disliked non-native and aggressive species. I also used a factor analysis to create 'bundles of CES' from the eight major themes and found that some species values were associated more strongly with a single type of CES, whereas other species showed a synergy and were valued for offering multiple CES. I showed that birds were a generally well-liked urban taxon, however, specific CES from different species induced variability in value and perception.

In Chapter III, I developed a novel and spatially explicit cultural ecosystem services index (CES Index) to test for a Luxury Effect on access to avian cultural ecosystem services. My index combined the quantitative likeability scores with a measure of the probability of species occurrence derived from the Southern African Bird Atlas Project 2 (SABAP2). Mapping this novel index revealed that highly urbanised landscapes tended to have greater access to avian cultural ecosystem services. I then tested for a Luxury Effect using a linear mixed effects model and found that there was a strong positive correlation between socio-economic status and access to avian cultural ecosystem services. Interestingly, this analysis also showed that communities of lower socio-economic status were not influenced by urban cover, with the CES Index remaining consistently low. These patterns highlight that communities with lower socio-economic status have limited access to avian cultural

ecosystem services. My findings suggested that environmental injustices in South Africa are prevalent, with lower socio-economic communities often experiencing poorer access to avian cultural ecosystem services. This may suggest that these communities are experiencing a greater extinction of experience, with fewer opportunities to interact with nature because of inequitable distributions of biodiversity.

Overall, I showed that there was an inherent complexity that is associated with CES as individual subjectivity influences values of birds. Additionally, I showed that a possible driver for this may be the inequitable distribution and access to birds and the cultural ecosystem services they provide. From these findings, I suggest that it is important for sustainable urban development strategies to focus on nurturing biodiversity in lower socio-economic landscapes. Doing so will aid in mitigating prevalent environmental injustices by ensuring that access to biodiversity, and subsequently the ecosystem services they provide, can be equitably distributed.

Keywords: cultural ecosystem services, environmental injustice, extinction of experience, Luxury Effect, spatially explicit index, South Africa, urbanisation

CHAPTER I:

The Introduction

1.1. RATIONALE

Urbanisation is a defining feature of modern human development, shaping the landscapes we inhabit and altering the ecosystems we share with other species (Seto et al. 2011; McDonald et al. 2013). Rural-to-urban migration, spurred by economic and social drivers, has led to the transformation of natural ecosystems into built environments (Seto et al. 2011; Gu 2019; Byulegenova and Turemuratov 2023). These urban developments have led to habitat fragmentation, degradation, transformation and subsequently a loss of biodiversity, which has implications for ecosystem structure and function (McKinney 2006; Concepción et al. 2015; Elmqvist et al. 2015; de Lima Filho et al. 2021). Beyond the ecological consequences, urban developments also affect human-nature interactions, exacerbating the phenomenon known as the "extinction of experience" (Pyle 1978; Miller 2005). As natural habitats are replaced or diminished many urban residents, particularly younger generations and those in rapidly urbanising regions like sub-Saharan Africa, are suggested to be experiencing a greater disconnect from the natural world (Fox 2012; Cobbinah et al. 2015a; Soga and Gaston 2016; Saghir and Santoro 2018). This reduced exposure and interaction with biodiversity threatens human-nature interactions, and has greatly contributed towards a reduced concern for conservation among urban residents (Hedblom et al. 2017). These challenges posed by urbanisation highlight an urgent need to explore strategies that may mitigate the impacts of development on biodiversity and human experience.

Implementation of urban green infrastructure (UGI) has emerged as a possible solution to address these impacts of urbanisation (Baycan-Levent et al. 2009) by providing refuge to, and encouraging an increase in, biodiversity (Soga and Gaston 2016; Leong et al. 2018; Methorst et al. 2020). UGI also improves access to ecosystem services, which aids in improving human-nature interactions (Soga and Gaston 2016; Leong et al. 2018; Methorst et al. 2020). The challenge, however, is that UGI and its associated biodiversity tends to be

distributed inequitably across the landscape (Hope et al. 2003; Chamberlain et al. 2020; Reynolds et al. 2025). This is a phenomenon known as the "Luxury Effect" (Hope et al. 2003). The Luxury Effect hypothesises that wealthier urban landscapes often enjoy richer biodiversity as a function of the incorporation of more diverse, and well-managed, public and private UGI (Hope et al. 2003; Chamberlain et al. 2020). These spaces not only enhance biodiversity but also contribute towards promoting human well-being, and knowledge of the value of nature, by providing better access to ecosystem services (Reynolds and Howes 2023). Conversely, lower income landscapes are generally associated with poorly planned urban environments that often lack the implementation of UGI that would support diverse ecosystems (Leong et al. 2018). Hence, environmental and socio-economic disparities have contributed towards inequitable access to biodiversity and its benefits (Leong et al. 2018). Understanding this relationship between urbanisation and biodiversity is therefore crucial for sustainable urban planning to develop cities that will offer equitable access to biodiversity and its ecosystem services.

Among the diverse taxa present in urban environments, birds provide an excellent opportunity for understanding and addressing the shifts in human-nature interactions driven by urbanisation. In urban ecosystems, birds are a well-distributed taxon (Hedblom et al. 2017; Lees et al. 2022) and are recognised for providing a wide range of ecosystem services (e.g., pest control, pollination, nutrient cycling, and aesthetic and cultural value; Wenny et al. 2011; Whelan et al. 2015). Previous studies highlight that birds are a well-liked urban taxon (Belaire et al. 2015), however, their general value is quite complex. The value of birds may be influenced by (1) the types of services individuals can access in their environments, and (2) the ability of different communities to replace specific services offered by birds (Lapointe et al. 2019). For example, lower income communities tend to value the provisioning and regulating ecosystem services of birds more than wealthier communities as these

communities may lack the economic means to replace these service types (Lapointe et al. 2019). Comparatively, the cultural ecosystem services (i.e., the non-material benefits people derive from their experiences and interactions with nature; MEA 2005) of birds are largely influenced by individual perception of cultural values. For example, some studies highlight cultural value to be strongly influenced by physical and behavioural attributes of birds (e.g., Champness et al. 2023), whereas others show cultural value to be linked to personal emotional connectedness towards specific species (e.g., Donázar et al. 2016; Perry et al. 2020). The cultural value of birds can also be complicated by their 'ecosystem disservices', such as damaging property or the effects on other aspects of biodiversity, which may induce certain negative perceptions of the taxa (Belaire et al. 2015).

The complexity surrounding the value of cultural ecosystem services is shown to be largely associated with individual perceptions and experiences (Belaire et al. 2015), but may be affected by urban and socio-economic gradients (Chamberlain et al. 2019; Chamberlain et al. 2020; Reynolds and Howes 2023). While there is established research for these avian human-nature interactions, literature is largely limited to well-established Global North cities and suburbs (e.g., Clergeau et al. 2001; Belaire et al. 2015; Cox and Gaston 2015; Cox et al. 2017; Cox and Gaston 2018). Thus, there is a key gap in our knowledge for understanding the value of birds and their cultural ecosystem services in more recent and rapidly urbanising environments, such as sub-Saharan Africa. Furthermore, few studies have assessed how the perception of birds may vary with community exposure, experience, and access to different bird species along urban and socio-economic gradients.

To advance our understanding of urban biodiversity and its associated cultural ecosystem services, research is therefore required to understand how under represented landscapes, such as those in the Global South, value birds to ensure that findings are globally relevant and applicable. Additionally, more research is required to address the complexities

that are associated with cultural ecosystem services in general (Plieninger et al. 2013). This can be achieved by focusing on evaluating the roles and values of culturally significant taxa, such as birds. This will enable researchers to directly assess how humans and nature interact, especially across urban and socio-economic landscapes where access to biodiversity may vary (Hope et al. 2003; Leong et al. 2018; Chamberlain et al. 2020). Such studies will offer important insights that may aid in urban planning strategies to nurture avian biodiversity across different landscapes and may also contribute towards knowledge that is required to develop sustainable cities with equitable distributions of biodiversity.

1.2. LITERATURE REVIEW

The Urbanisation Framework

The rapid growth of the human population has prompted an increase in the development of the urban landscape (Seto et al. 2011). This process of urbanisation is largely driven by economic, social, and infrastructural developments aimed at benefitting human populations (Gu 2019; Byulegenova and Turemuratov 2023). As a consequence, global urbanisation has caused ecosystems to be reshaped, accounting for extensive rural-to-urban migrations of human populations (Godfrey and Julien 2005; Grimm et al. 2008; McGranahan and Satterthwaite 2014). Despite occurring globally, urbanisation does not occur at a uniform rate worldwide (Seto et al. 2011). In Europe, for example, urbanisation was initiated in the 11th century (~1800; Bosker et al. 2013), which has enabled these countries to incorporate and establish urban landscapes with well-integrated urban green spaces (Baycan-Levent et al. 2009; Kohout and Koop 2020). Conversely, the rapid population growth and increasing socio-economic pressures, has caused an exacerbated development of urban landscapes in Africa – particularly sub-Saharan African countries (Fox 2012; Cobbinah et al. 2015a; Saghir and Santoro 2018). As such, we are seeing the development of urban cities in these countries

where urban planning strategies are unable to sustainably meet the demands of the growing population (Cobbinah et al. 2015a; Cobbinah et al. 2015b). While these patterns of urbanisation are essential for human population development, there are consequences for ecosystem structure and the biodiversity in these systems (Taylor et al. 2013; McGranahan and Satterthwaite 2014; Kondratyeva et al. 2020; Zhang et al. 2020).

Increasing urbanisation results in the transformation of natural habitats into a built ecosystem (McKinney 2006), which causes increased fragmentation and subsequent loss and transformation of natural green spaces, and changes to biodiversity regimes (Concepción et al. 2015; Elmqvist et al. 2015; de Lima Filho et al. 2021). A key impact of urbanisation on biodiversity is the changes incurred for ecological niches (McKinney 2006; Faeth et al. 2011; Lowry et al. 2013; Concepción et al. 2015). Particularly, urban development alters the structure and function of ecosystems by altering climates through an urban heat island (UHI) effect, and by causing resources quality and quantity to be altered (Concepción et al. 2015; Elmqvist et al. 2015; de Lima Filho et al. 2021). Species that can adequately occupy these urban ecosystems tend to be limited to diet and habitat generalists (McKinney 2006; Ortega-Álvarez and MacGregor-Fors 2009; Lowry et al. 2013; Biard et al. 2017), as these species tend to be better capable of altering habits and morphology to suit the novelty of urban conditions (Finch et al. 2014; Møller et al. 2015; Santiago-Alarcon and Delgado-V 2017; Prokosch et al. 2019; Naidoo et al. 2024). This has resulted in a homogenisation of species diversity (e.g., Awoyemi et al. 2024a), but also, an increased abundance of generalist species, in urban landscapes (Campbell et al. 2022). Importantly, these ecological changes are not solely limited to biodiversity responses as there are also consequences for human-nature interactions, shaping how urban residents experience and connect with the natural world.

The Extinction of Experience

These patterns of urbanisation are further responsible for altering how humans interact with nature in urban ecosystems (Cox and Gaston 2016; Soga et al. 2016; Hedblom et al. 2017). Human-nature interactions have been prevalent for a large proportion of our existence, however, have declined in recent years, especially among younger generations (Soga and Gaston 2016). This phenomenon is known as the "extinction of experience" (Pyle 1978; Miller 2005), which shows a decline in human-nature interactions in urban ecosystems because of the general loss of, and lost access to, nature (Cox and Gaston 2016; Soga et al. 2016; Hedblom et al. 2017; Hoyle et al. 2019). For many urban residents, this loss of biodiversity has translated into a diminished connection to the natural world (Cox and Gaston 2016; Soga et al. 2016; Hedblom et al. 2017; Awoyemi et al. 2024b). The implications of this loss suggest a potentially weakened cultural, recreational, and aesthetic value for nature (Hedblom et al. 2017; Hoyle et al. 2019), but importantly, it also suggests that urban residents may be experiencing reduced concern for the protection and preservation of our natural resources (Cox and Gaston 2016; Soga et al. 2016). These patterns, however, may not be consistent among all urban residents as socio-economic disparities impact how different communities access and interact with nature.

The Luxury Effect

Distributions of biodiversity in urban landscapes are not equitable (e.g., Luck et al. 2009; Leong et al. 2016; Leong et al. 2018; Chamberlain et al. 2019; Chamberlain et al. 2020). In particular, the distribution of biodiversity in urban landscapes may vary based on the landscape management in different regions (Schwartz et al. 2013; Beninde et al. 2015; Leong et al. 2018; Chamberlain et al. 2019). For example, a poorly planned and managed urban ecosystems may experience a lower abundance, and homogenisation of, its biodiversity (Schwartz et al. 2013; Leong et al. 2018; Chamberlain et al. 2019; Mbiba et al. 2021). In

contrast, a well-designed and well-managed urban ecosystem may incorporate green spaces and biodiversity-friendly infrastructure (Tanner et al. 2014; Lundholm 2015; McPhearson et al. 2015; Hoyle et al. 2019) that may aid in supporting more, and a higher overall diversity, of plants and animals (Filazzola et al. 2019). Differences in how these urban landscapes are managed, however, may be affected by patterns of socio-economic status between different urban communities.

The "Luxury Effect" (Hope et al. 2003) is a global phenomenon that explains that patterns of urban biodiversity are impacted by an interaction between income levels and the urban landscape structure. Specifically, the Luxury Effect posits urban areas with higher income tend to have higher patterns of biodiversity compared with lower income areas (Hope et al. 2003; Leong et al. 2018; Chamberlain et al. 2020). This is a pattern that has been observed across numerous urban taxonomic groups, such as plants (e.g., Hope et al. 2003; Martin et al. 2004; Baldock et al. 2019), birds (e.g., Chamberlain et al. 2019; Chamberlain et al. 2020), and insects (e.g., Reynolds et al. 2025). The Luxury Effect can be explained by the ability of individuals across different urban landscapes, of different socio-economic status, to modify the environment to support varying levels of biodiversity (Leong et al. 2018; Chamberlain et al. 2020). In general, higher income landscapes can support higher biodiversity through the incorporation of more urban green spaces, such as parks and green roofs, or by developing diverse personal gardens (Troy et al. 2007; Grove et al. 2006; Leong et al. 2018). Additionally, some wealthier communities establish in pre-existing biodiverse landscapes, which offers opportunities to access and experience greater levels of biodiversity (Leong et al. 2018). These diverse green spaces and legacy effects provide an increase in resource diversity, which further illicit an increase in diversity of other taxa, resulting in overall higher biodiversity for wealthier communities (Lerman and Warren 2011; Luck et al. 2013; Chamberlain et al. 2019). Comparatively, lower income urban landscapes tend to have

limited resources and therefore do not have the ability to use the available resources to develop and manage diverse green infrastructure (Leong et al. 2018). Overall, the Luxury Effect shows us that there is inequitable distribution and access to biodiversity, which may further erode human-nature interactions. This is especially prevalent when considering how limited access to biodiversity may be affecting access to all the benefits nature provides in these landscapes (Reynolds and Howes 2023).

The Ecosystem Services Dilemma

The presence of biodiversity in human-inhabited ecosystems is crucial for the provision of ecosystem services. Ecosystem services are the benefits humans derive from the natural environment and its various components and processes (MEA 2005). The Millennium Ecosystem Assessment (MEA 2005) broadly categorises ecosystem services into four groups relative to the types of services and products humans receive from different aspects of the natural environment. The four groups of ecosystem services account for more tangible products, (e.g., food and material items) categorised as provisioning services. There are also intangible ecosystem services that may be categorised as regulating (e.g., pest control and water purification), supporting (e.g., nutrient cycling and decomposition), or cultural (e.g., aesthetic awareness, spiritual identity, or inspiration) services (MEA 2005). Collectively, these ecosystem services all form a crucial component of human well-being (MEA 2005; Shackleton et al. 2008; Layke et al. 2012).

Despite their importance, the decrease in biodiversity driven by urbanisation has caused a rapid degradation of ecosystem services across many ecosystems (Shackleton et al. 2008; Layke et al. 2012). Additionally, the inequitable distributions of biodiversity, suggests that access to ecosystem services is likely to also be distributed inequitably along the same urban and socio-economic gradient as biodiversity (Reynolds and Howes 2023). The

importance of these ecosystem services and the inequitable access has therefore prompted an increase in the evaluation of their different services nature offers and the value to society (Crossman et al. 2012; Plieninger et al. 2013; Boerema et al. 2017). Quantifications of ecosystem services are, however, somewhat challenging (Boerema et al. 2017). This is because we lack standardised methods to assess different ecosystem service types (Boerema et al. 2017). This lack of standardised methodology prevents us from being able to adequately quantify and qualify a broad array of ecosystem services in a manner that would ensure comparability and enable us to make more specific observations as opposed to broad assessments of patterns.

Though the challenge of quantifying ecosystem services extends across all service categories, cultural ecosystem services (CES) are recognised as the most challenging type to quantify (Plieninger et al. 2013). This is because of the intangible nature of these services paired with subjectivity among individuals in a society (Plieninger et al. 2013; Belaire et al. 2015; Hedblom et al. 2017; Tew et al. 2019). For example, pollination as an intangible regulating ecosystem service, can be similarly recognised and valued by most individuals for its role in enabling the growth and production of food resources (Hein 2009; Porto et al. 2020). Comparatively, cultural ecosystem service values of flora and fauna (e.g., aesthetic, or psychological benefits) are not as straightforward to quantify as not all individuals bear the same cultural values or beliefs for these components in their ecosystems (Plieninger et al. 2013; Belaire et al. 2015; Hedblom et al. 2017; Tew et al. 2019). This complexity has largely resulted in CES being excluded from broad-scale assessments aimed at quantifying ecosystem services (Plieninger et al. 2013). Hence, as a means to overcome the general complexity associated with CES, studies have focused on assessing specific taxa that contribute towards these service types (e.g., Clergeau et al. 2001; Belaire et al. 2015; Cox and Gaston 2015). Birds, as a widely distributed and ecologically significant taxon, offer an ideal

case study to explore and quantify CES, particularly in urban environments where their presence and services are both numerous and culturally impactful (Whelan et al. 2008; Wenny et al. 2011; Whelan et al. 2015).

Urban Birds: A Cultural Ecosystem Services Case Study

Across urban systems, anthropogenic effects on bird community structure (e.g., Aronson et al. 2014; Reynolds et al. 2021; Campbell et al. 2022; Xu et al. 2022), and on their ecology, adaptation, and evolution (e.g., Finch et al. 2014; Møller et al. 2015; Biard et al. 2017; Prokosch et al. 2019; Naidoo et al. 2024) has been well documented. Their role as ecosystem service providers in these urban systems, however, has been generally overlooked, (Hedblom et al. 2017; Gaston et al. 2018). Birds are recognised to provide key ecosystem services, which includes their role as a source of food and material (provisioning), pest control and pollination (regulating), nutrient cycling (supporting), and aesthetic values and inspiration (cultural; Whelan et al. 2008; Wenny et al. 2011; Whelan et al. 2015; Sekercioglu et al. 2016). While all these ecosystem service types have been assessed to some extent in urban literature, cultural ecosystem services have garnered increased interest in recent literature because of urbanisation effects on human mental and physical well-being, and the direct associations that these services have for aiding the improvement of this well-being (Hedblom et al. 2014; Belaire et al. 2015; Hedblom et al. 2017; Cheng et al. 2021).

Urban societies are in regular contact with birds (Fuller et al. 2012; Hedblom et al. 2017). This is largely because of the prevalence of birds in urban communities (Lees et al. 2022), as well as the increased efforts made by some people to connect with birds (Hedblom et al. 2017). For example, many urban residents are found to partake in birding activities (e.g., bird watching) by incorporating bird feeders and nest boxes in their gardens (Cox and Gaston 2015; Hedblom et al. 2017). These connections and interactions with birds suggest

that there are strong cultural associations with birds in urban environments (Hedblom et al. 2017). Studying these associations, however, remains quite complex as the cultural ecosystem services offered by birds are linked to an individual's value of specific service types (Belaire et al. 2015; Hedblom et al. 2017). For example, differences in upbringing, knowledge of nature, gender, age, and other lifetime experiences with nature affect how birds may be valued by different individuals (Belaire et al. 2015; Riechers et al. 2016; Hedblom et al. 2017; Hegetschweiler et al. 2022). Despite these factors, however, there have been attempts to quantify urban perceptions of avian cultural ecosystem services.

These studies have shown that birds are a generally well-liked and well-valued taxon (Clergeau et al. 2001; Belaire et al. 2015; Graviola et al. 2024), being among the most liked taxa in urban green spaces and built environments (Methorst et al. 2020). Largely, these studies have shown that residents tend to perceive birds favourably because of their service provisions linked to benefiting health and quality of life (Belaire et al. 2015). Quantification studies of avian cultural ecosystem services show that urban residents tend to favour birds for their aesthetic values, with smaller and more colourful birds being of higher value (Champness et al. 2023). Additionally, these studies also show that birds are well-liked for the emotional responses they elicit (Donázar et al. 2016; Perry et al. 2020), with many people having personal experiences with specific species that have contributed towards a higher value (Champness et al. 2023; Graviola et al. 2024). Importantly, some studies have recognised that the value of birds is also coupled with certain "ecosystem disservices" (Clergeau et al. 2001; Belaire et al. 2015). These disservices account for negative perceptions of birds in urban areas and can be highly correlated to a species' behavioural characteristics such as being noisy, intimidating, or causing damage to personal property (Belaire et al. 2015). While these existing studies provide valuable insights to understand urban perceptions of avian cultural ecosystem services, the patterns are limited to well-established urban

neighbourhoods of the Global North (e.g., Clergeau et al. 2001; Belaire et al. 2015; Cox and Gaston 2015; Cox et al. 2017; Cox and Gaston 2018).

The Avian Cultural Ecosystem Services Project

To address this knowledge gap, I set out to assess avian cultural ecosystem services quantitatively and qualitatively across an urban and socio-economic landscape in South Africa. South Africa provides a useful opportunity to conduct this study as it has a unique urban landscape created by the effects of the Apartheid-era spatial planning (Swilling 2010). Urban South Africa also has a distinct wealth imbalance, which has resulted in differences in the incorporation and management of green infrastructure in private and public regions (Swilling 2010). Subsequently, the diversity of birds across urban South Africa varies with socio-economic patterns across these landscapes (Chamberlain et al. 2019). By undertaking this study, I set out to quantitatively and qualitatively assess the value of the cultural ecosystem services provided by birds among urban residents of South Africa. Additionally, with this study, I aimed to test the Luxury Effect on access to avian cultural ecosystem services. This study will therefore contribute towards our growing knowledge of the value and importance of cultural ecosystem services provided by birds in our urban ecosystems. This information will be important for aiding in improving how we implement strategies towards nurturing biodiversity and develop urban landscapes that are both sustainable and have an equitable distribution of biodiversity for all urban residents.

1.3. OVERARCHING AIM AND OBJECTIVES

The broad aim of this study was to describe patterns in cultural ecosystem services provided by birds and evaluate access to these service types across urban and socio-economic landscapes of South Africa. To achieve this, I addressed two primary research objectives:

1. Use species likeability data and open-ended responses of South African residents to identify variations in the patterns of likeability, and themes of likeability, across different bird species.
2. Create a novel index of cultural ecosystem services to assess how this varies across the urban and socio-economic landscapes to test if there is a Luxury Effect on access to avian cultural ecosystem services across urban South Africa.

1.4. OUTLINE OF DISSERTATION

Increased urban development has prompted an increase in research targeted at understanding its effects on biodiversity (Seto et al. 2011). The role of birds as ecosystem service providers has gained traction as studies attempt to quantify the roles of these organisms in developing ecosystems (Hedblom et al. 2014; Belaire et al. 2015; Hedblom et al. 2017). Despite this, literature is largely limited, particularly in the Global South, surrounding a quantification of the cultural ecosystem services provided by birds, and how different landscapes may be affecting access to these service types. In this dissertation, I provide a novel quantification of the cultural ecosystem services provided by birds, as well as an assessment of socio-economic and urban landscape effects on access to these services in South Africa. Quantifying avian cultural ecosystem services, and the access to these services, in South Africa provides an opportunity to develop our knowledge of the value of biodiversity across different landscapes. This study highlights some critical development and urban planning requirements to target both environmental injustices and socio-economic imbalances that are affecting the distribution of biodiversity in the country.

This dissertation has been divided into four chapters, including an introduction, two data chapters (II & III) and a synthesis. The data chapters have been structured to facilitate the publication of the work. Hence, each data chapter may be recognised as a stand-alone

component, each comprising of an abstract, introduction, methods, results, and discussion section. There is some repetition of themes, ideas, and literature across these chapters in the introduction and methodology to the facilitate readability of each section. However, I have attempted to limit this as much as possible.

1.4.1. CHAPTER DESCRIPTIONS

Chapter I: The Introduction

In this current chapter, I have provided the foundational background of the study. This includes a literature review, description of the study area, and background on the selection of study species. The study area and selection of study species sections are applicable to both data chapters as it encompasses the data collection procedures used in both chapter analyses.

Chapter II: Cultural Ecosystem Services Provided by Urban Birds: A South African Perspective

In this chapter, I used scores of likeability to quantify how likeable different bird species are, and to assess the variation in likeability between species. I also used open-ended responses to explain why specific ratings were provided for the birds to qualitatively assess the major themes that describe species likeability – such as aesthetic, behavioural, or emotional value. Additionally, I use these themes to create bundles of cultural ecosystem services to describe the complexity of these services offered by birds. In doing so, I can identify bird species that are valued for only specific services, or if the perceptions are more complex, with some species valued across a multidimensional space.

Chapter III: A Test of the Luxury Effect in Urban South Africa: Assessing Access to Avian Cultural Ecosystem Services Along an Urban and Socio-economic Gradient

In this chapter, I generated a novel cultural ecosystem services index (CES Index) using the product of species likeability scores derived in Chapter II, and a measure of the probability of bird species occurrence derived from presence/absence data for each species from the Southern African Bird Atlas 2 Project. I used this score to assess landscape effects on the novel CES index and highlight a strong Luxury Effect on access to avian cultural ecosystem services.

Chapter IV: The Synthesis

In this chapter I synthesised the key findings of the study and provided recommendations to improve upon and address the limitations of my research questionnaire distribution.

1.4.2. STUDY AREA

1.4.2.1. The diversity of South Africa

South Africa is one of the most diverse countries in the world, with a broad ethnic, cultural, linguistic, and religious composition (Mino 2013). The country has a population of ~62 million individuals (comprised of ~81% Black, ~8% Coloured, ~7% White, and ~3% Indian/Asian; SA Census 2022). South Africa is also recognised as one of the most ecologically and biodiverse countries in the world (Egoh et al. 2009; Maphisa et al. 2016; Van Wilgen et al. 2020). Currently, South Africa ranks among the '18 megadiverse countries' because of its rich compositions of endemic species, which includes diverse terrestrial and aquatic plants, vertebrates, and invertebrates (Van Wilgen et al. 2020).

In addition to its social and ecological diversity, South Africa is also recognised for its diverse, and rapidly developing urban landscapes (Swilling 2010). South Africa is a densely populated country (Figure 1.1) and represents one of the most urbanised countries on the

African continent (Dewar 2003). Patterns of urbanisation in the country (Figure 1.2) increased with the abolishment of the Apartheid regime, which saw increased migration of populations into cities (Collinson et al. 2007; Todes et al. 2010; Statistics SA 2023). This migration drove an exacerbated development of the country's urban landscapes (Collinson et al. 2007; Todes et al. 2010; Statistics SA 2023) and have contributed towards approximately 68% of the South African population currently living in urban areas, with an increasing rate of ~2% per annum (O'Neill 2023; Statistics SA 2023; Figure 1.2). Historical legacies caused by racial segregation during the Apartheid regime (Dewar 2003) however, has contributed towards significant socio-economic disparities among South African urban communities (Totaforti 2021). In particular, socio-economic disparities are prevalent in the standards of living, relative to quality of life and accessibility to resources of different urban communities (Totaforti 2021).

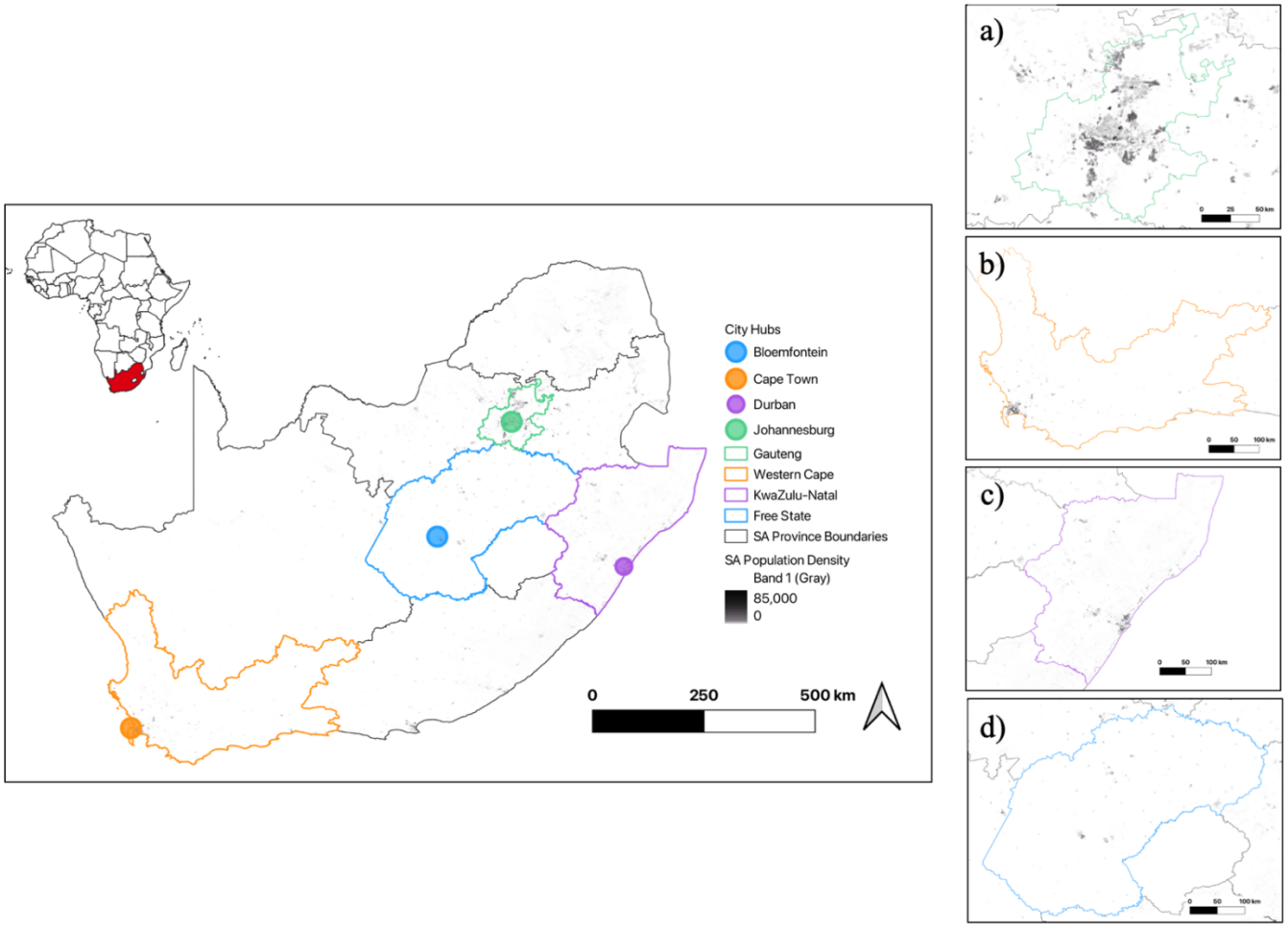


Figure 1.1: Map of South Africa depicting the grided population density in the year 2020 at a scale of 1km^2 across all provinces (WorldPop Data), with a focus on the population densities in my study provinces (a) Gauteng, (b) Western Cape, (c) KwaZulu-Natal, and (d) Free State. Regions presented in grey indicate more densely populated areas while regions presented in white represent less densely populated areas. Also depicted are the locations of the four main city hubs targeted for the distribution of the research questionnaires (Johannesburg, Cape Town, Durban, and Bloemfontein).

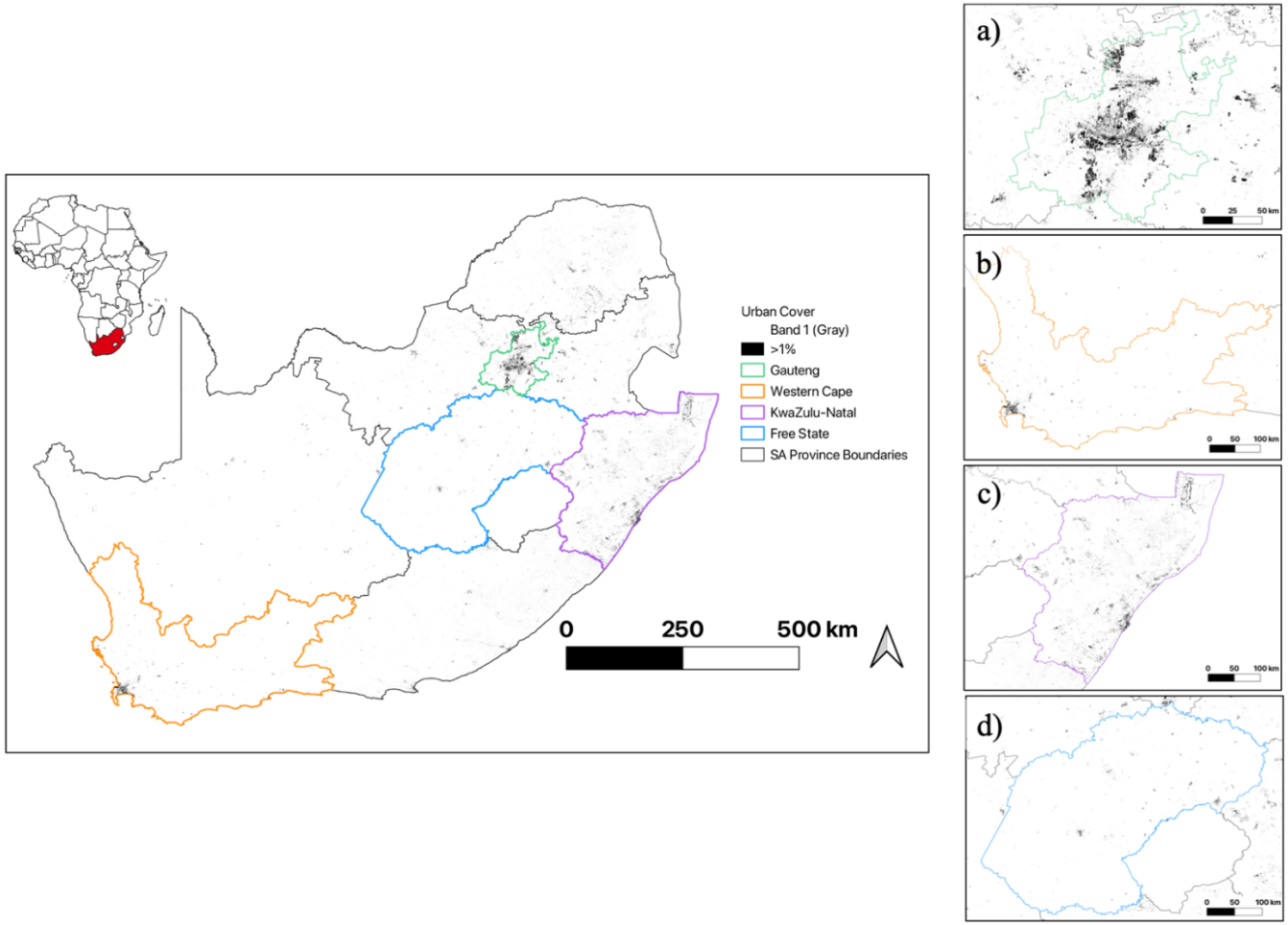


Figure 1.2: Map of South Africa depicting the distribution of urban landscapes (>1 % urban cover – comprised of built infrastructure across formal, informal, settlement, commercial, and industrial landscapes; in black) across the country, with a focus on the urban landcover in my study provinces (a) Gauteng, (b) Western Cape, (c) KwaZulu-Natal, and (d) Free State.

1.4.2.2. Using South Africa as a case study

Across South Africa's urban landscapes, studies have shown biodiversity to be richer and more abundant in higher income landscapes compared with lower income landscapes, which is somewhat mediated by urban cover (e.g., Davoren et al. 2016; Gwedla and Shackleton 2017; Chamberlain et al. 2019; Chamberlain et al. 2020). For example, the novelty of South Africa's more urbanised environments generally favours the success of introduced bird species, such as the Common Myna (*Acridotheres tristis*) and Rose-ringed Parakeet (*Psittacula krameri*), over native populations (Shivambu et al. 2020). However, differences in the socio-economic status of different urban communities have enabled wealthier communities to develop ecosystems that can support a greater diversity of bird species (Chamberlain et al. 2019; Chamberlain et al. 2020). This contributes towards different communities having greater access to different bird species, and subsequently the ecosystem services that they offer (Reynolds and Howes 2023). Furthermore, it can contribute towards different experiences and perceptions of these components of biodiversity in different urban and socio-economic landscapes.

Thus, South Africa presents a unique case study in urban ecology. The diverse ecological, urban, and socio-economic landscapes offer an opportunity to assess environmental inequalities and injustices to ascertain how access to avian biodiversity and the ecosystem services offered may vary across the country. For this study I opted to initially focus on the major cities, and economic hubs of South Africa (Johannesburg, Cape Town, Durban, and Bloemfontein) for selection of study species and distribution of research questionnaires. However, to understand the effects of large-scale urban and socio-economic diversity, I extrapolated my analysis to the urban landscapes across the four provinces in which these cities are located (i.e., Gauteng, Western Cape, KwaZulu-Natal, and Free State) to assess urban and socio-economic patterns on the value and access to cultural ecosystem

services provided by birds. Achieving this extrapolation was possible because of receiving responses to the questionnaires by individuals who lived beyond the bounds of each city but lived in the respective province. These additional responses provided an opportunity to assess patterns at the larger urban and socio-economic scale.

CHAPTER II:

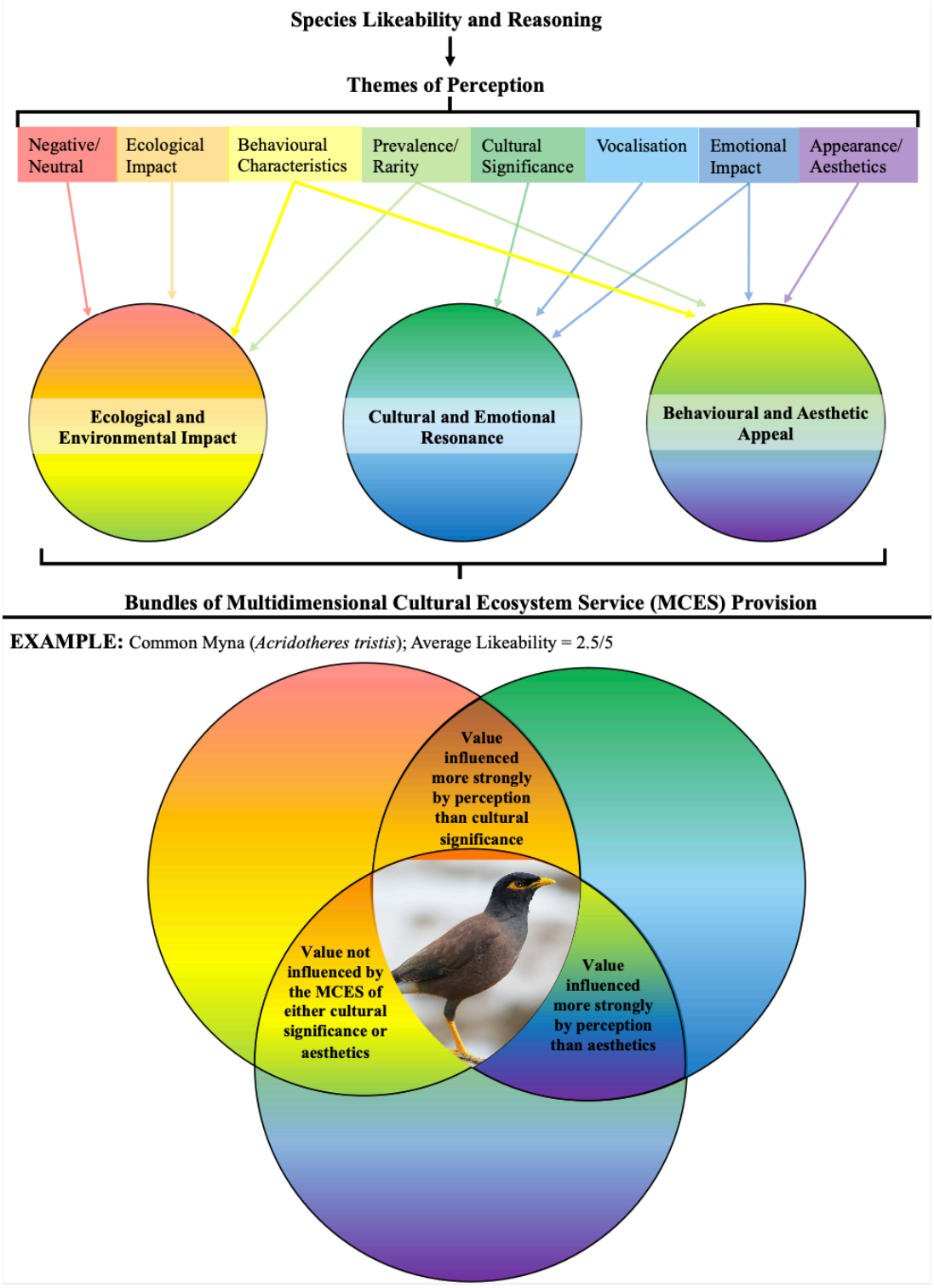
Cultural Ecosystem Services Provided by Urban Birds: A South African Perspective

ABSTRACT

Birds play a key role in providing cultural ecosystem services (CES) in urban landscapes, being appreciated for their aesthetics (e.g., size, shape, colour), emotional resonance, and behavioural appeal. Existing studies on urban birds' cultural value, however, often presents a spatially biased perspective, focusing predominantly on the Global North. To address this, I conducted a questionnaire across four South African cities, and their respective provinces, between September 2023 and January 2024, assessing the CES value of 36 bird species. A total of 1 994 questionnaires were completed, accounting for 1 994 individual responses for the quantitative, and ~70 000 individual responses for the qualitative analyses. I measured species likeability using scores and analysed the respondents reasoning for the scores given to different bird species. For a quantitative assessment, I asked participants to rate species likeability on a 5-point Likert scale, generating overall scores that revealed birds as a broadly well-liked taxon, with notable variations at the species level. For a qualitative assessment, I analysed ~71,000 open-ended sentiment responses associated with the quantitative scores by employing ChatGPT to thematically categorise the responses. Of eight major themes of likeability identified, species with high likeability scores were primarily valued for their aesthetics and emotional connectedness, whereas those with lower scores were often associated with negative traits, such as pest-like behaviours or non-native origins. I then used a factor analysis to group the eight themes into bundles of CES and show that some species value were more strongly associated with one bundle of CES whereas others showed a synergy between multiple bundles. These findings highlight the complexity of avian CES and demonstrate that species-level likeability was shaped by a combination of individual preferences and life experiences. This study highlights the multifaceted nature of human-bird interactions in urban settings, offering novel insights into cultural ecosystem service valuation in a Global South context.

Keywords: ChatGPT, cultural ecosystem services, multidimensional services, perception, personal experience, urbanisation

GRAPHICAL ABSTRACT



2.1. INTRODUCTION

Humans and nature exhibit an important two-way interaction, where human activity influences ecological processes, while nature provides benefits to human well-being in the form of ecosystem services (Cox and Gaston 2016). This relationship is well studied between humans and birds (e.g., Aronson et al. 2014; Reynolds et al. 2021; Campbell et al. 2022; Xu et al. 2022). Humans notably influence ecosystems that are available to birds, while birds are recognised as a provider of key ecosystem services for improving human well-being (Whelan et al. 2015). Birds provide services across all four major groups of ecosystem services, including provisioning (food and material), regulating (pollination and pest control), supporting (nutrient cycling and habitat creation), and cultural (aesthetic and educational value) services (Whelan et al. 2008; Wenny et al. 2011; Whelan et al. 2015; Sekercioglu et al. 2016).

Global urbanisation, however, rapidly transforms these relationships as urban ecosystems are expanding because of rural-to-urban migrations (Seto et al. 2011; Gu 2019; Byulegenova and Turemuratov 2023). These urban developments have led to the fragmentation of natural habitats and the creation of novel, built ecosystems (McKinney 2006; Concepción et al. 2015; Elmqvist et al. 2015; de Lima Filho et al. 2021). These changes have caused overall biodiversity to decrease, which subsequently affects ecosystem structure and functioning (Elmqvist et al. 2015; de Lima Filho et al. 2021). In urban environments, loss of biodiversity alters the existing human-nature interactions, which may influence how urban residents perceive and engage with nature (Belaire et al. 2015). Birds are an excellent taxon to study urban human-nature interactions because of their broad distribution and role as key ecosystem service providers (Belaire et al. 2015; Gaston et al. 2018). Despite the importance of this interactive relationship, our understanding of how birds are perceived in urban landscapes remains limited (Belaire et al. 2015).

Attempts to quantify the ecosystem services offered by birds have increased in the literature in recent years (e.g., Clergeau et al. 2001 in France; Belaire et al. 2015 in the United States of America; Cox and Gaston 2015 in the United Kingdom; Graviola et al. 2024 in Brazil). These studies show that some ecosystem services are generally easy to evaluate and quantify (Belaire et al. 2015). This includes the tangible provisioning and regulating services (such as food and pollination), which can be quantified based on its economic value or cost (Plieninger et al. 2013). In contrast, intangible service types, which highlight a perceived value of nature, are much more challenging to quantify (Wenny et al. 2011; Belaire et al. 2015). Cultural ecosystem services are defined as the "non-material, or intangible, benefits derived from nature" (MEA 2005). These services are important for improving the standard of living by enhancing the mental and physical well-being of human populations (Plieninger et al. 2013). Despite its importance, quantifying these service types has been shown to be complex (Boerema et al. 2017). This complexity pertains largely to the challenges associated with the intangible nature of the services but is also influenced by individual subjectivity and a lack of standardised approaches for assessing these service types (Chan et al. 2012; Boerema et al. 2017; Methorst et al. 2021). By focusing on specific, well-studied taxa such as birds, however, valuable insights for the quantification of cultural ecosystem services across different landscapes have been uncovered (Whelan et al. 2008; Wenny et al. 2011; Whelan et al. 2015; Cox and Gaston 2016; Sekercioglu et al. 2016).

In urban ecosystems, birds are a well-liked and well-valued taxon for their cultural ecosystem service provisions (Clergeau et al. 2001; Belaire et al. 2015; Cox and Gaston 2015; Graviola et al. 2024). These cultural ecosystem services may, however, vary across species as different birds offer distinct benefits (Lišková and Frynta 2013; Tisdell et al. 2015). For example, these services may be associated with species-specific traits, such as aesthetics, generating inspiration and knowledge, or providing spiritual values (Belaire et al. 2015;

Hedblom et al. 2017; Gaston et al. 2018). These cultural services all play a crucial role in influencing how individuals may value these different organisms in their environments (Belaire et al. 2015).

Studies have shown that the main influences of individual perception of birds in urban landscapes are associated largely with the aesthetic value and behavioural characteristics of different birds (Cox and Gaston 2015; Collins et al. 2021; Andrade et al. 2022; Champness et al. 2023). Birds that are smaller and more colourful, patterned, or have unique colours, for example, tend to be more positively perceived compared with larger and more simple birds (Collins et al. 2021; Andrade et al. 2022). Collins et al. (2021), for example, observed urban residents' preferred songbirds with unique colour schemes (e.g., blue, or black) over more common or simply coloured (e.g., yellow/orange) species. Comparatively, behavioural characteristics have also been used to describe negative perception of birds in urban environments (Perry et al. 2020; Champness et al. 2023). The Common Myna (*Acridotheres tristis*), for example, has frequently been regarded as an undesirable species in urban ecosystems (Champness et al. 2023), because of its negative behaviours towards other bird species.

These traits also contribute towards being more recognisable in the urban ecosystem, which further shapes individuals' perceptions of different birds (Donázar et al. 2016; Perry et al. 2020; Champness et al. 2023). Such recognisable species tend to elicit stronger personal and emotional connections (Champness et al. 2023; Graviola et al. 2024). These connections enhance the cultural ecosystem services provided by birds, leading towards more people participating in urban birding activities or learning more about species in their ecosystems (Belaire et al. 2015; Riechers et al. 2016; Hedblom et al. 2017; Hegetschweiler et al. 2022). Hence, these services improve mental and physical well-being by encouraging people to engage more with nature (Cox and Gaston 2015). This is particularly important for urban

residents where access to nature, and exposure to these service types, varies (Hope et al. 2003; Cox and Gaston 2016; Leong et al. 2018; Chamberlain et al. 2020). This can provide useful insights for planning and developing sustainable urban landscapes that can ensure both the preservation of bird diversity and delivery of their cultural ecosystem services across the landscape (Methorst et al. 2020; Methorst et al. 2021; Reynolds and Howes 2023).

Despite attempts to quantify these avian cultural ecosystem services, existing studies show a strong spatial and socio-economic bias. Most, if not all, previous literature that have quantified avian cultural ecosystem services are based on perceptions of individuals from the generally wealthier suburbs in the Global North. For example, studies that have evaluated the cultural ecosystem service values of birds have focused on neighbourhoods/towns, such as Rennes, Brittany (Clergeau et al. 2001), Cook County, Illinois (Belaire et al. 2015), Milton Keynes, Luton, and Bedford in London (Cox and Gaston 2015). Thus, there remains a limited understanding as to how urban residents in the Global South, or developing nations, perceive and interact with the birds in their environment. In this study, I set out to quantify and qualify the cultural ecosystem services provided by birds across urban landscapes in South Africa. This knowledge will aid in understanding how different bird species are valued in South Africa and may provide valuable insights for developing sustainable urban landscapes.

2.2. AIM AND OBJECTIVES

The aim of this chapter was to assess cultural ecosystem services in urban South Africa with a focus on quantitative and qualitative assessments at species level. To achieve this, I addressed the following objectives:

1. Quantitatively assess the likeability of birds in urban habitats of South Africa.
2. Categorise open-ended sentiment responses of perceptions of South African residents for different bird species into major themes of cultural ecosystem services.

3. Identify cultural ecosystem service bundles for different bird species based on the cultural ecosystem services they provide and that may influence their value to South African residents.

2.3. METHODS

2.3.1. Methods Overview

I used research questionnaires to quantitatively and qualitatively assess the value of different bird species across urban ecosystems in South Africa. I extracted scores of likeability for individual species from the questionnaires, based on 5-point Likert ratings provided by respondents, to quantify how likeable different bird species are. Additionally, I used the large-language model, ChatGPT, to thematically categorise open-ended responses and opinions of respondents into eight major cultural ecosystem services themes. I then used factor analysis to map these themes into bundles of cultural ecosystem services to understand the complexity and multidimensional nature of cultural ecosystem services provided by different bird species.

2.3.2. Species Likeability

Questionnaire design. I designed a research questionnaire in Google Forms, which was distributed across four major city hubs of South Africa (see *Study Area* section of Chapter I) to assess the quantitative and qualitative components of avian cultural ecosystem services in urban settings. Importantly, response to these questionnaires was not restricted solely to people living in the city as I accepted and included the responses of individuals who lived in the respective provinces. In total, I produced four questionnaires, one for each city hub, to specifically account for differences in the diversity of bird species across South Africa and the variation in bird species that occupy these different urban landscapes. An example of

one of the four questionnaires is provided in Appendix C, Section One, as all questionnaires had the same structure and questions, with the only difference being the selection of birds presented for each region.

Study Species Selection. I used the South African Bird Atlas Project 2 (SABAP2) database to select a stratified representation of birds that people may interact with across the four different cities. SABAP2 is an ongoing (2007-current) citizen science project that maps the distribution of birds across Southern African landscapes. Volunteer citizen scientists contribute to the SABAP2 database by recording birds detected within 5 x 5 minute longitudinal and latitudinal grid cells ('pentads', ~9 x 9 km; Brooks et al. 2022).

I focused my selection of study species on the regions surrounding the cities of Johannesburg, Cape Town, Durban, and Bloemfontein. I used the SABAP2 map, which records the number of atlas protocol cards submitted per pentad, to randomly select a pentad within the vicinity of the city centres of each hub. I then used the SABAP2 reporting rates (i.e., the frequency of how often individual species are recorded across sets of full protocol cards) to select bird species on a common-to-rare species observation gradient (Table 2.1). Species with the highest versus lowest reporting rates for each city are depicted in Figure 2.1. I included both native and non-native (or exotic) species in my selection to ensure that the full diversity of birds that occupy South African urban environments would be represented in the questionnaires. I selected 15 species per city to include in the respective questionnaire (Appendix A, Supplementary Table S1). In total, this accounted for 42 species as some species are more widely distributed across the country and occur in multiple cities (Appendix A, Supplementary Table S1).

Table 2.1: List of the South African Bird Atlas Project 2 (SABAP2) reporting rates (%) for selected study species included in the study analysis, for each research questionnaire in the cities of Johannesburg (JHB), Cape Town (CPT), Durban (DBN), and Bloemfontein (BLM) extracted from the randomly selected urban pentad used in species selection.

Species	Scientific Name	JHB	CPT	DBN	BLM
African Fish Eagle	*Haliaeetus vocifer*	-	32.3	-	0.8
African Harrier-hawk	*Polyboroides typus*	7.1	-	9.9	-
African Hoopoe	*Upupa africana*	33.5	-	-	-
African-paradise Flycatcher	*Haematopus moquini*	-	-	62.2	-
Amethyst Sunbird	*Terpsiphone viridis*	48.0	-	53.6	-
Bronze Mannikin	*Lonchura cucullata*	-	-	72.4	-
Black Sparrowhawk	*Accipiter melanoleucus*	-	47.8	-	-
Cape Bulbul	*Pycnonotus capensis*	-	94.8	-	-
Crested Barbet	*Trachyphonus vaillantii*	-	-	-	91.6
Crowned Eagle	*Stephanoaetus coronatus*	-	-	7.4	-
Common Myna	*Acridotheres tristis*	97.1	-	60.4	92.7
Cape Robin-chat	*Cossypha caffra*	87.3	-	-	96.0
Cape Sugarbird	*Promerops cafer*	-	3.9	-	-
Common Starling	*Sturnus vulgaris*	-	93.1	-	-
Cape White-eye	*Zosterops virens*	-	-	92.0	-
Mallard (Domestic Duck)	*Anas platyhynchos*	-	1.5	-	-
Egyptian Goose	*Alopochen aegyptiaca*	93.9	93.9	-	-
Grey Go-away-bird	*Corythaixoides concolor*	92.1	-	-	-
Green Twinspot	*Mandingoa nitidula*	-	-	9.6	-
Hadeda Ibis	*Bostrychia hagadash*	96.8	92.6	94.7	95.4

House Sparrow	*Passer domesticus*	-	-	46.4	92.4
Lanner Falcon	*Falco biarmicus*	-	-	-	2.3
Little Swift	*Apus affinis*	-	-	-	88.5
Malachite Kingfisher	*Corythornis cristatus*	-	45.5	-	-
Orange-breasted Sunbird	*Anthobaphes violacea*	-	4.3	-	-
Pied Crow	*Corvus albus*	79.8	90.4	-	-
Purple-crested Turaco	*Tauraco porphyreolophus*	-	-	95.7	-
Rock Dove	*Columba livia*	91.9	79.3	41.2	85.4
Rock Kestrel	*Falco rupicolus*	-	15.9	-	-
Red-knobbed Coot	*Fulica cristata*	-	-	-	70.9
Rose-ringed (Ring-necked) Parakeet	*Psittacula krameri*	73.5	-	-	-
Spotted Eagle-owl	*Bubo africanus*	38.8	-	-	-
Southern-masked Weaver	*Ploceus velatus*	-	-	-	92.6
Southern Red Bishop	*Euplectes orix*	-	-	-	64.8
Spotted Thick-knee	*Burhinus capensis*	59.3	-	-	73.2
Yellow-rumped Tinkerbird	*Pogoniulus bilineatus*	-	-	77.1	-

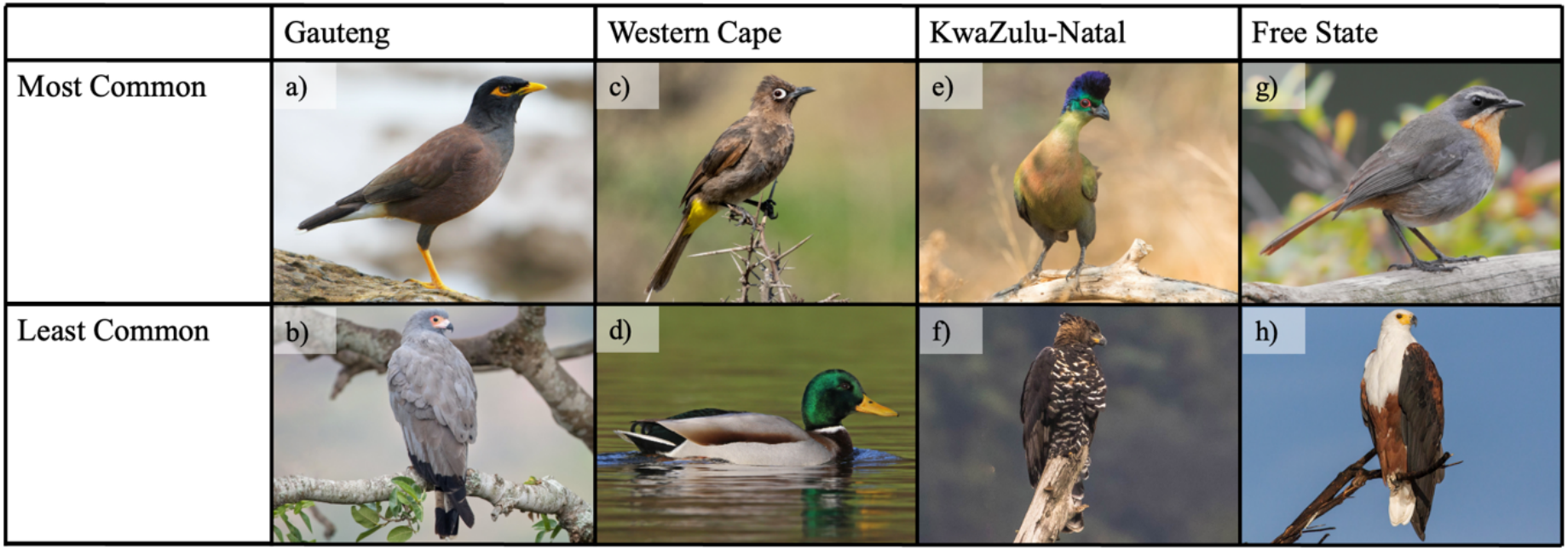


Figure 2.1: Depiction of the most versus least common species, based on reporting rates from the Southern African Bird Atlas Project 2 (SABAP2) for the randomly selected pentads in the four study provinces. Birds shown for each province, with the first indicating most common and second indicating least common, include: for Gauteng the (a) Common Myna (*Acridotheres tristis*) and (b) African Harrier-hawk (*Polyboroides typus*), for Western Cape the (c) Cape Bulbul (*Pycnonotus capensis*) and (d) Mallard (*Anas platyhynchos*), for KwaZulu-Natal the (e) Purple-crested Turaco (*Tauraco porphyreolophus*) and Crowned Eagle (*Stephanoaetus coronatus*), and for Free State the (g) Cape Robin-chat (*Cossypha caffra*) and (h) African Fish Eagle (*Haliaeetus vocifer*). Images of birds were all taken from the eBird website (https://ebird.org/home).

Data Processing. I removed two species per city questionnaire for the data analysis portion of this study (Appendix A, Supplementary Table S1,S2) to account for the inclusion of two coastal-based species in the Cape Town questionnaire (i.e., the African Oystercatcher (*Haematopus moquini*) and the Cape Cormorant (*Phalacrocorax capensis*)). The inclusion of these two species would have impacted the viability of the occurrence probability measures from occupancy modelling (Chapter III). To minimise confusion across the analysis of this dissertation, I reduced the study species sample size for analysis to 13 species per questionnaire. Hence, I analysed a total of 36 species across my four questionnaires, which included 11 species that were assessed in at least two questionnaires (Appendix A, Supplementary Table S2).

Questionnaire Structure. In the questionnaire (see example Appendix C, Section One), I first provided prospective participants with the background context of the study, alongside a request for their consent to participate in the study (Ethical Clearance Number: H23/06/29). I divided the questionnaire into three main sections.

In the first section, I asked participants to provide their background demographic information including age, gender, race, suburb, and dwelling type. This information was collected to assist in acquiring a broader demographic response, but I did not assess specifically how demographic differences influence species perception and CES value. Section two of the questionnaire was used to gather some information of interest regarding participants interactions with birds. In this section I asked questions such as “Do you believe birds add value to your environment?” and “Do you partake in any birding activities such as bird ringing or bird watching?”. Section three of the questionnaire was designed to acquire the primary quantitative and qualitative data to assess likeability and perception of bird species. Here, I provided participants with the common name and a single colour image of

the 15 bird species selected (selection of study species described above; Appendix A, Supplementary Table S1 & S2). The images used were taken from the eBird website and depicted the full body of the bird with clear display of any individual colours, patterns, and distinguishable traits, aiming to mitigate any bias in how a bird was "framed". To acquire data for the quantitative assessment, I asked respondents to rate the appeal of each bird, drawing on their response to the bird in the image and/or any personal experiences with the bird, on a 5-point Likert scale (1 = Strongly Dislike, 5 = Strongly Like). To acquire data for the qualitative assessment, I provided respondents with an open-ended question "What do you find appealing, or not, about [the bird in the image]?".

Questionnaire participants and distribution. The goal of the research questionnaire was to acquire responses from a diverse group of individuals, relative to the country's diverse people, economy, and living standards (Stats SA). I was interested in the response of the broader demographic of South Africa; hence the questions were designed so that anyone, not just avid birders, would be able to respond.

To acquire responses across the demographic population, I used several methods to distribute the questionnaires. Firstly, the questionnaires were posted across multiple social media platforms, including Instagram, Facebook, X, Threads, WhatsApp, and LinkedIn. The study and questionnaires were also promoted via a guest appearance on The Birding Life podcast (Season 8, Episode 2). These platforms provided a means to reach individuals across numerous demographic groups, including people of different ages, genders, or race.

The research questionnaires were also distributed via the email and the social media groups of various birding organisations and local birding clubs. This included BirdLife South Africa (BLSA) and its provincial subdivisions, as well as a promotion on the BLSA online bird identification game Birdle. While these distribution methods aided in reaching a larger

pool of respondents, I importantly recognise that distributing the questionnaires via birding groups did contribute towards a bias in the overall response population for the study as the questionnaires reached largely individuals who are avid birders. This also contributed to a wider demographic response bias, with a higher number of 'white' respondents. Despite this, questionnaires were also promoted by local nature reserves, such as Modderfontein Nature Reserve in Johannesburg and Friends of Franklin Nature Reserve in Bloemfontein to reach people who partake in outdoor recreation but may not be actively birding.

In Johannesburg, questionnaires were distributed to all students at the University of the Witwatersrand via the student email list and were promoted via posters and business cards with QR codes. These business cards were also given to various medical facilities, veterinary clinics, and animal parlours. These distribution methods contributed towards increasing the outreach of the research questionnaires for reaching a more diverse demographic population for the Johannesburg/Gauteng questionnaire.

Questionnaires were open for response for three months, starting on 29 September 2023 and ending on 11 January 2024 because of reduced engagement with the questionnaires. I recorded a total of 1 994 complete questionnaires upon closing the questionnaires. This accounted for 1 994 responses towards my qualitative (likeability) analysis, but over 70 000 responses towards my thematic qualitative analysis. Importantly, it was due to ethics limitations, that I was unable to conduct any in-person interviews/questionnaires in any of the four study regions, which resulted in a key gap in the demographic outreach of the questionnaire. In particular, I received fewer responses from lower income communities, and had a racial demographic bias in my respondents.

2.3.3. Qualitative Themes of Likeability

I used the open-ended rationale for each species to assess the key factors influencing species value. Given the open-ended, subjective nature of these responses, I opted to use a large language model (LLM) to analyse and categorise the data. This was largely to avoid introducing any personal biases when categorising the different responses or identifying different response types. It also accounted for the ~71 000 open-ended responses that were received across the four questionnaires for the 36 species. The LLM used for this analysis was ChatGPT 4.o (OpenAI 2024).

Sentiment analysis is typically used to identify opinions, sentiment, and emotion in text (Medhat et al. 2014). This includes sources such as social media posts, news reports, or in my case, open-ended responses (Wang et al. 2023). The capacity of ChatGPT to perform such analyses has been previously assessed (Wang et al. 2023). Wang et al. (2023) compared ChatGPT against the fine-tuned, small language model BERT (Bidirectional Encoder Representations from Transformers; Devlin et al. 2019), which is a commonly used baseline, reference model for performing sentiment analyses. Additionally, they tested ChatGPT against associated state-of-the-art (SOTA) models, which are typically developed with 'task-specific designs' (Wang et al. 2023). The study found ChatGPT to be a fair rival against the BERT model in performing these types of analysis but underperformed when compared with domain specific SOTA models in its capabilities (Wang et al. 2023). Despite its limitations, ChatGPT was a suitable, non-domain specific tool, which I could use to analyse the ~71 000 open-ended response data from my questionnaires to understand what reasons influence the value of different bird species.

Testing the abilities of ChatGPT. I assessed ChatGPT's capabilities to perform a sentiment analysis on data similar to the official questionnaires by prompting it to create a test, or 'dummy', dataset of 30 responses that would resemble the open-ended responses in

my questionnaires for three species – the Barn Owl (*Tyto alba*), White-eared Barbet (*Stactolaema leucotis*), and Sacred Ibis (*Threskiornis aethiopicus*). I prompted ChatGPT to categorise these dummy datasets into its major themes of CES. From the first attempt, ChatGPT was found to be capable of recognising and categorising the data into distinct categories. For example, the Barn Owl data was categorised as 'Beauty and Aesthetics', 'Hunting Skills and Predatory Nature', or 'Silent Flight'. While these are key characteristics and features that can be associated with themes of CES behind species value, I noted these themes to be too specific to be applied to all the species from the questionnaires. I repeated this with the White-eared Barbet, but instead I had ChatGPT produce a "step-by-step guide" on identifying major themes of CES value. This produced more generalised categories for CES value such as 'Appearance', 'Behaviour', 'Sound', 'Cultural Significance', and 'Personal Experience'.

I further prompted ChatGPT to fine-tune the categories, which involved using research participant responses to understand how ChatGPT would categorise the data. For example, in the questionnaire responses, a recurring point for the likeability scores received by the Common Myna was associated with its invasive provenance. Hence, I asked ChatGPT "what type of category (in terms of a broad theme) could there be if a lot of people were to say they gave a bird a rating because of its 'invasive nature'?". ChatGPT returned a new category of 'Ecological Impact' relating to "how the bird may be affecting the environment, other species, or human activities". I also tested ChatGPT's capabilities for identifying the responses that were contradictory/opposing to the major themes identified with the test dataset, which led to creating a category for 'Negative/Neutral' responses.

I then tested ChatGPT using a subset of data from the official questionnaires, using the responses to the Spotted Thick-knee (*Burhinus capensis*) from the Bloemfontein questionnaire. I provided ChatGPT with the simple prompt "This is a dataset of the opinions

of the Spotted Thick-knee, can you identify the major themes?". Based on the prompt provided, as well as previous prompts generated, ChatGPT adequately categorised the qualitative responses into seven distinct categories: 'Appearance', 'Behaviour', 'Vocalisations', 'Adaptability', 'Camouflage', 'Emotional Impact', and 'Neutral/Negative'. While 'Adaptability' and 'Camouflage' represented more specific categorisation, the general outcomes show that ChatGPT could categorise the qualitative themes similar to the training datasets used above.

Thematic categorisation of questionnaire responses using ChatGPT. I conducted a thematic analysis through ChatGPT to identify, analyse, and report the major themes of CES value related to my study species. To achieve this, I instructed ChatGPT to read and contextualise the content of the qualitative sentiment datasets to identify key points and recurring patterns. I provided ChatGPT with specific keywords that it could use when developing its code to assign thematic labels to different parts of the text. For example, when considering categorising responses that may be associated with the cultural significance of the bird, I gave ChatGPT keywords like 'culture', 'symbol', or 'iconic' to aid it in identifying similar responses in a broad theme associated with cultural value (Appendix C, Section 2). I also instructed ChatGPT to cross-check its categorisation to ensure suitable accuracy of the data into the necessary themes.

I identified the major themes/categories that would be most applicable to each species in the questionnaires using these example datasets and trial runs, as well as understanding ChatGPT's creation of the themes. The eight themes identified included 'Appearance/Aesthetics', 'Behavioural Characteristics', 'Ecological Impact', 'Cultural Significance/Symbolism', 'Emotional Impact (Personal Connection)', 'Vocalisation', 'Prevalence/Rarity', and 'Negative/Neutral' (see Appendix A, Supplementary Table S3 for

category descriptions). To conduct the final thematic assessment for the study species, I provided ChatGPT with the sentiment response dataset for each of the 36 species. These datasets were anonymised to contain only the open-ended responses from each respondent across every species. A detailed prompt (outlined in Appendix C, Section 2) was provided alongside the dataset to further aid ChatGPT in its categorisation of the responses. This prompt included a description of each theme and types of responses/keywords to consider when categorising responses. Importantly, the prompt specified that a single response could be categorised into more than one theme to ensure responses were fully represented under every suitable category. The prompt also included examples specific to each species dataset as to how and why they would be categorised into any of the above mentioned eight themes.

Troubleshooting ChatGPT's thematic categorisation. Because of the limited use and knowledge of ChatGPT for sentiment analyses, training ChatGPT to accurately recognise and categorise every response was not entirely plausible. Hence, it was important to recognise the shortfalls of this analysis. Across the 36 species, there was an average 'categorisation error rate' (i.e., responses that were not categorised into any of the 8 themes or were only categorised into one of multiple suitable themes) of 15.13 (± 5.52) %. I found that uncategorised rationales typically fell into two major themes, which were 'Appearance/Aesthetic' and 'Emotional Impact (Personal Connection)'. I found spelling and the use of numerous synonyms or phrases by different individuals to be the cause of aesthetic rationales being uncategorised. For example, birds like the Grey Go-away-bird (*Corythaixoides concolor*) and Purple-crested Turaco (*Tauraco porphyreolophus*) were well-liked because of the crest-like feathers on their heads. However, there were numerous synonyms or terms to describe the crest, such as "mohawk", "mane", or "kuif", but also several misspellings of these terms (e.g., "maine" or "mowhawk"). This variation in

terminology likely impacted how ChatGPT processed the content resulting in categorisation uncertainty.

Additionally, ChatGPT struggled with the recognition of 'emotion-based' responses (i.e., responses where individuals described a specific connection or appreciation of birds linked to their emotional state). This may suggest that ChatGPT experiences complications regarding underlying emotional contexts in text. Where responses are straightforward, expressing a direct emotional connection for the species, it was easy for ChatGPT to categorise it as an emotional response. For example, simply stating, "I love owls" or "It's a fish eagle! No need to say more" was recognised as emotional. Some responses were, however, more complex with an indirect suggestion of an emotional connection, and here ChatGPT had difficulty categorising responses as representing an emotional connection. For example, responses that used metaphors to describe how feelings related to certain behaviours, such as "Love the way they drift like leaves in my garden", or emotion-based references to specific characteristics individuals associate with the character of the bird, such as "Feisty characters and great mimics".

For the uncategorised rationales, I manually assessed and categorised them to ensure all responses were suitably themed, and to identify reasons for the shortfalls of ChatGPT's categorisation. Once datasets were processed and corrected, the counts of the number of responses in each category was recorded. This enabled us to rank the themes per species to identify which themes were most prominent for the responses provided for the different species.

2.3.4. Analytical Approach

Statistical Analyses. For the demographic response, I produced a chi-squared test to determine if there were any differences, or skews, in demographic patterns (i.e., gender, age,

race, or dwelling) between the provinces. Average likeability scores were computed for each species per questionnaire. Using these averages, I produced a heat map of the average likeability of each species per province using the ggplot2 package (v3.4.2; Wickham 2016). To assess whether there was a significant difference in likeability for the 11/36 species that were assessed in more than one research questionnaire, I used a simple ANOVA analysis where I tested the influence of the province on the raw likeability scores.

Counts of responses in each of the eight themes for every species was extracted from the ChatGPT outputs. I performed an exploratory factor analysis ('factanal' function in "nFactors" R package; v2.4.1.1; Raiche and Magis 2022) to understand correlation between themes that influenced likeability and to generate 'bundles of CES' associated with response themes that vary together. Three factors were extracted for interpretation based on outputs from a scree plot and parallel analysis. I used the factor analysis to understand the multidimensional nature of the provision of cultural ecosystem services by birds using the Spearman's rank correlation coefficients of the factor loadings. This involved assessing possible synergies (i.e., strong associations) between bundles of CES to describe the perception of different bird species. Additionally, I assessed if species were more strongly perceived for the provision of cultural ecosystem services associated with only one bundle of CES. This suggests an association where only one bundle of CES has strong influence in describing in the values of the bird. The methods used for this analysis were derived from Ament et al. (2017) where they assessed cultural values and associations of South African protected areas. In their study, Ament et al. (2017) explains that the factor analysis is a powerful statistical tool for such analyses, being able to explore patterns for bundling service-based data from research questionnaires without concerns of a priori hypotheses or effects of sample sizes for different categories.

All analysis were conducted in R Version 4.3.1 – “Beagle Scouts” (R Core Team 2024).

2.4. RESULTS

From the total of 1 994 complete questionnaires across the four cities and provinces, I noted that Gauteng had the most respondents (57.6 %; 1 149 respondents), followed by KwaZulu-Natal (21.5 %; 428 respondents), the Western Cape (18.9 %; 376 respondents), and the Free State (2.1 %; 41 respondents; Appendix A, Supplementary Table S4), respectively.

2.4.1. Demographic response

There was variation in the age, gender, race, and dwellings of the respondents (Figure 2.2; Appendix A, Supplementary Table S5). Results show that there was significant differences in the responses across all demographic categories within each province: gender (X^2 = 177.16, df = 9, p < 2.2e-16), age (X^2 = 185.19, df = 21, p < 2.2e-16), race (X^2 = 92.853, df = 18, p = 4.423e-12), and dwelling (X^2 = 57.38, df = 18, p = 5.384e-06). I received the most responses from individuals in the age category of 61-70 years old (20.6%; 410 respondents) and the fewest responses from individuals younger than 18 (0.8%; 17 respondents) years old (Figure 2.2a; Appendix A, Supplementary Table S5). Female respondents accounted for higher responses (59.9%; 1 195 respondents), followed by males (39.1%; 780 respondents), and then agender/non-binary individuals (0.7%; 13 respondents; Figure 2.2b; Appendix A, Supplementary Table 5). There was a distinct bias in the responses received regarding race, with majority of respondents identifying as ‘White’ (79.7%; 1 590 respondents; Figure 2.2c; Appendix A, Supplementary Table S5). The remainder of the respondents identified as ‘Indian’ (7.9%; 158 respondents), ‘Black’ (6.7%; 134 respondents), ‘Coloured’ (2.5%; 49 respondents), or ‘Asian’ (0.4%; 8 respondents; Figure 2.2c; Appendix

A, Supplementary Table S5). My respondents also occupied a diverse range of dwellings across the provinces, with the majority occupying stand-alone houses (56.9%; 1 135 respondents) and fewest occupying informal housing (0.3%; 6 respondents; Figure 2.2d; Appendix A, Supplementary Table S5).

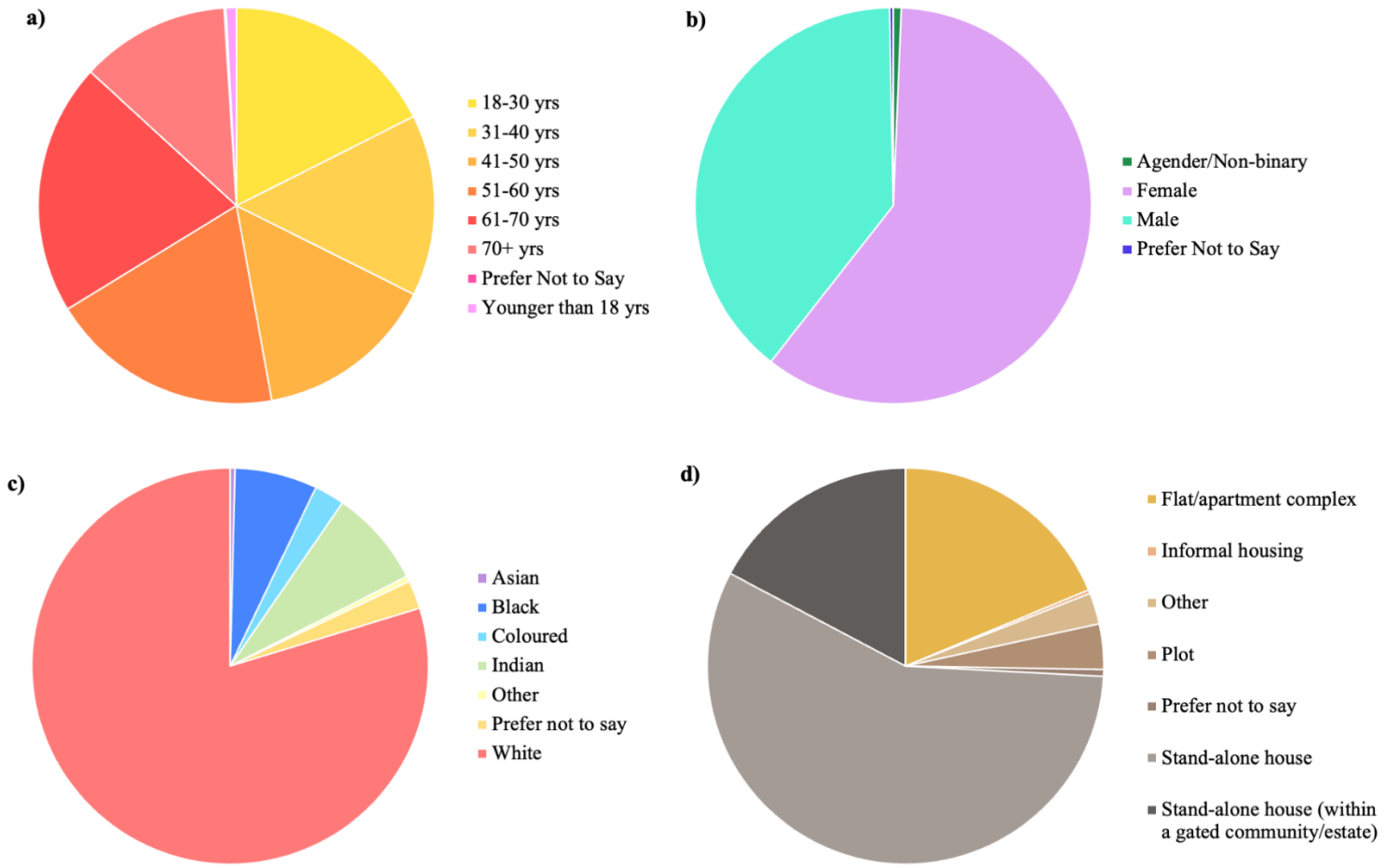


Figure 2.2: Breakdown of the demographic profiles of the respondents of the Avian Cultural Ecosystem Services project research questionnaires across the provinces of Gauteng, Western Cape, KwaZulu-Natal, and Free State in South Africa. Figures show the breakdown of respondents by (a) age category, (b) gender identity, (c) racial background in a South African context, and (d) dwelling type they occupy.

Responses further showed 98.2% of participants agree birds have, or add value, to the environment. Additionally, I recognised 64.7% of the respondents participate in some form of birding activity (such as bird watching or bird ringing).

2.4.2. Species Likeability

I observed variation in the likeability scores across the different bird species that were included in the questionnaires (Table 2.2 & Figure 2.3 for species averages by province with variance). The results showed that most birds are well-liked, with some species being more well-liked than others (Table 2.2 & Figure 2.3; Appendix A, Supplementary Table S2). Species that received higher likeability scores included colourful and appealing birds such as the Malachite Kingfisher (*Alcedo cristata*) and Orange-breasted Sunbird (*Anthobaphes violacea*), which received higher ratings (Table 2.2 & Figure 2.3b; Supplementary Table S2). Conversely, species that were more negatively rated included the Common Myna, Common Starling (*Sturnus vulgaris*) and Pied Crow (*Corvus albus*), which are generalist or non-native pest species in South Africa (Table 2.2 & Figure 2.3; Supplementary Table S1 & S2).

Table 2.2: Heat map displaying the diversity in average likeability of the 36 species that were assessed and included in the analysis. The colour scale represents the difference in the average likeability of a species based on all responses received for the species in the questionnaire, a darker colour suggests a more well-liked species. The first 11 species displayed were included in at least two of the research questionnaires. An asterisk (*) marks averages where there is a significant difference in likeability responses between the provinces where these species were assessed.



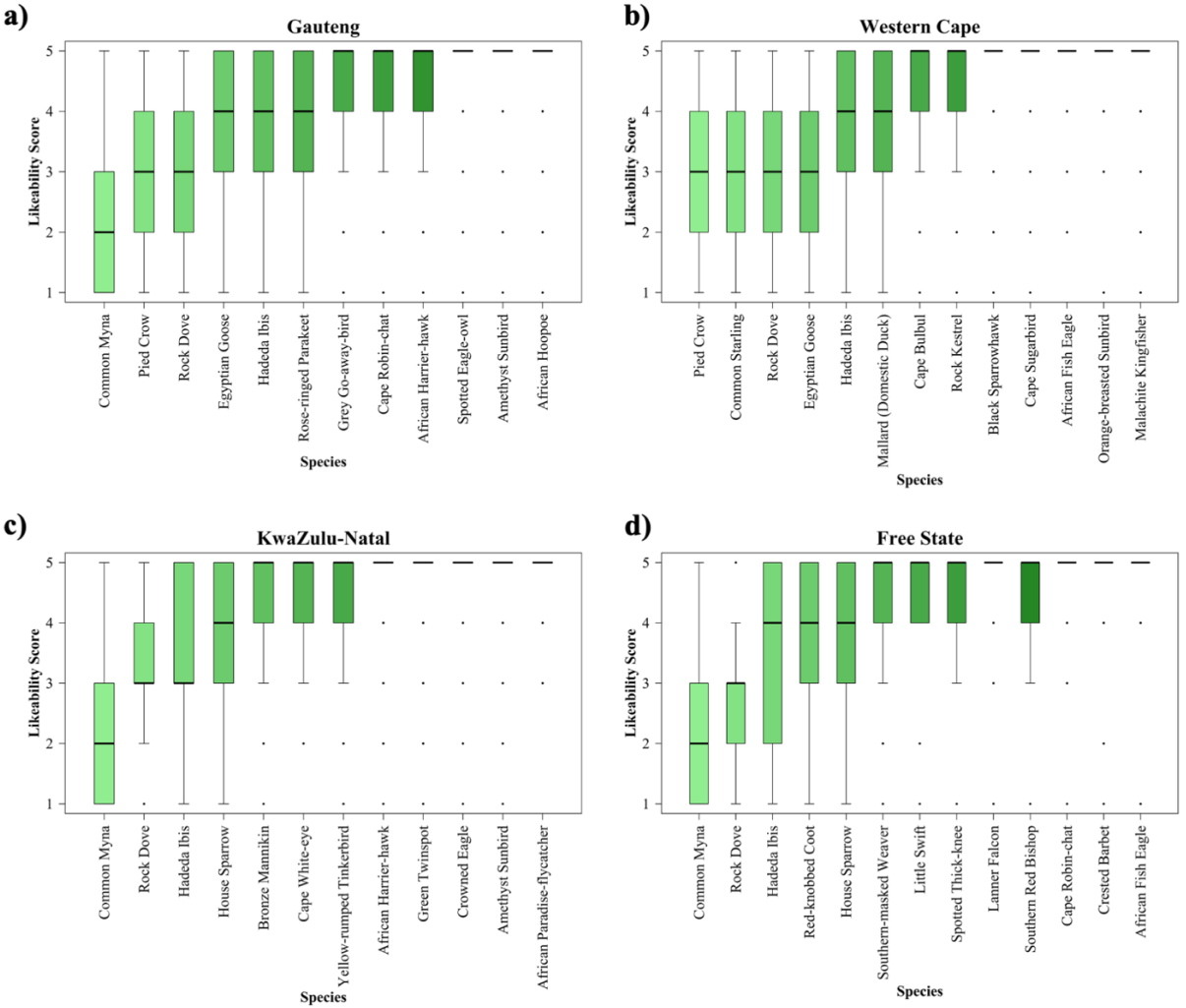


Figure 2.3: Likeability scores, with standard error, received by the 13 species presented in (a) Johannesburg, (b) Cape Town, (c) Durban, and (d) Bloemfontein questionnaires as rated by residents across the Gauteng, Western Cape, Kwa-Zulu Natal, and Free State provinces respectively. Bird species that show little-to-no variation in likeability scores (i.e., those on the far right) received a score of 5/5 from most questionnaire respondents.

I also observed variation in likeability for species that were assessed across different provinces (i.e., were included in at least two questionnaires; Table 2.2; Appendix A, Supplementary Table S2). The Hadeda Ibis (*Bostrychia hagadash*) showed no difference in likeability between provinces ($F = 0.236$, $p = 0.871$; Table 2.2). The Rock Dove (*Columba livia*), however, experienced significant differences in likeability ($F = 11.02$, $p < 0.001$), specifically between KwaZulu-Natal and the Western Cape, and between KwaZulu-Natal and Gauteng, being more positively perceived by KwaZulu-Natal respondents in both cases (Table 2.2). Both the African Harrier-hawk (*Polyboroides typus*; $F = 12.11$, $p < 0.001$) and the Amethyst Sunbird (*Chalcomitra amethystina*; $F = 11.57$, $p <0.001$) were more negatively perceived by Gauteng respondents compared with KwaZulu-Natal (Table 2.2). Conversely, the Egyptian Goose (*Alopochen aegyptiaca*) was significantly more positively perceived by Gauteng respondents compared with Western Cape respondents ($F = 11.43$, $p < 0.001$; Table 2.2).

2.4.3. Thematic Likeability Reasoning

From the open-ended questionnaire responses used for the thematic analysis, I recorded ~70 000 responses for the CES thematic ranking. Ranking the CES themes for each species showed some variation as to how different species were perceived or valued in the environment (Figure 2.4). Overall, I observed that 'Appearance/Aesthetics' tended to be the number one ranked theme for most species (Figure 2.4). This suggested that most species were "liked" based on their physical appearance. Traits linked to colour and pattern were predominantly appreciated in the selected species. 'Emotional Impact (Personal Connection) was also identified as a high-ranking theme for species (Figure 2.4). Personal experiences from exposure to birds during birding activities elicited emotional responses from some respondents, particularly towards the appeal of the selected raptor species. Some species

(e.g., Hadeda Ibis, Rock Dove, and Common Myna; Figure 2.4) were found to have 'Negative/Neutral' as the highest-ranking theme, associated with recognition of the problematic nature of these birds in urban environments.

General common terms that appeared in these negative responses included "loud", "messy", "invasive", and "bully". For other themes, there was generally no clear pattern observed across the species. However, I did note that the theme of 'Cultural Significance/Symbolism' tended to be the lowest ranked (i.e., had the fewest responses associated with it) for majority of the species (Figure 2.4). This indicated a possible low cultural significance or value for birds among my questionnaire respondents. The African Fish Eagle represented an exception with 'Cultural Significance/Symbolism' accounting for the fourth highest response received (Figure 2.4). However, this was primarily because of many respondents associating the bird with symbolic perceptions (e.g., strength and power) rather than a cultural value.

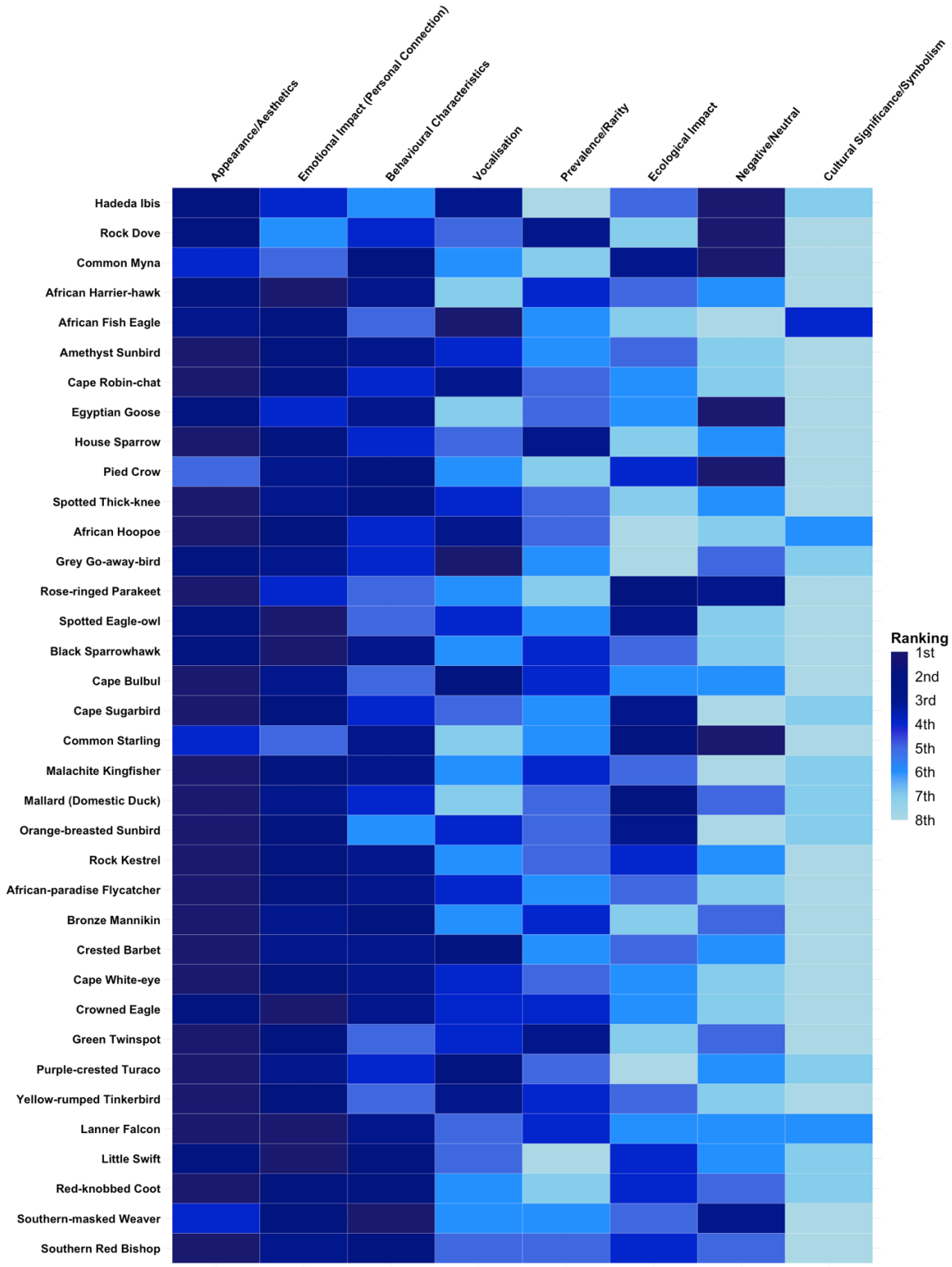


Figure 2.4: Heat map displaying the ranking of the 'likeability reasoning categories' of the 36 species that were assessed and included in the analysis. The colour scale represented the rank of each category (from 1st to 8th) of a species based on all responses received for the species in the questionnaire. A darker colour suggested the responses, for that particular species, was mostly associated with responses in that specific category. The first 11 species displayed were included in at least two of the research questionnaires.

2.4.4. Bundling Cultural Ecosystem Services

The exploratory factor analysis identified three bundles of cultural ecosystem services for species value, which cumulatively explained 75.7 % of variance in responses. Five of the themes loaded strongly (factor loading > 0.35) onto one of the three possible factors, while three themes (Behavioural Characteristics, Prevalence/Rarity, Emotional Impact (Personal Connection) loaded strongly onto two factors.

The first bundle accounted for species perception and environmental impact responses (Behavioural Characteristics, Ecological Impact, Prevalence/Rarity, and Negative/Neutral) and explained 32.8 % of variation in responses. The second bundle accounted for responses associated with cultural and emotional resonance (Cultural Significance/Symbolism, Vocalisation, and Emotional Impact (Personal Connection)) and explained 21.6 % of variation in responses. The third bundle accounted for responses associated with species behavioural and aesthetic appeal (Behavioural Characteristics, Prevalence/Rarity, Appearance/Aesthetics, and Emotional Impact (Personal Connection)), explaining 21.3 % of the total variation. When plotted, these bundles described the multidimensional nature of cultural ecosystem services from different bird species (Figure 2.5).

Correlation of factor loadings between bundles were all negative, however, there were no significant correlations between any of the bundle pairings for explaining the multidimensional nature of these services ($p > 0.05$; $S = 108$). The multidimensional nature of CES was described as a strong association, or synergy, between two bundles of CES (blue quadrant; Figure 2.5 a-c). This suggested that the perception of the birds was strongly influenced by both bundles of CES when considering both the positive and negative values of a specific species. Comparatively, if species values were found to be strongly influenced by only one bundle of CES (red quadrants; Figure 2.5 a-c), this suggested that an association

where one bundle of CES has a stronger influence on value as opposed to multiple bundles simultaneously .

For example, the Pied Crow (PC in Figure 2.5) showed a complex pattern in its provision of cultural ecosystem services. The Pied Crow showed strong synergies between correlations between each bundle of CES plotted together (Figure 2.5 a-c). In Figure 2.5a, for example, the Pied Crow exhibited the multidimensional nature of CES as its value was strongly influenced by both the bundle of 'Cultural and Emotional Resonance' and the bundle of 'Perception of Environmental Impact'. Hence, the Pied Crow experienced a synergy in how people perceive its provision of cultural ecosystem services as people value the bird simultaneously for the emotional response it elicits as well as its environmental impact. These synergies for the Pied Crow showed a generally negative perception as the emotional resonance and environmental impact responses for this species was largely negative in the questionnaires. Comparatively, the African Fish Eagle (AFE in Figure 2.5) showed that its value is not perceived through a multidimensional lens (Figure 2.5a). The African Fish Eagle was found to be more strongly valued for its 'Cultural and Emotional Resonance' but not for its environmental impact (Figure 2.5a). This showed that the associations of its values among respondents was influenced more strongly by one bundle of CES as opposed to multiple simultaneously.

The results from this Chapters analyses need to be considered with limitations of bias in the response to the questionnaires, including a demographic, urban, and socio-economic bias (further elaborated under *Limitations* below).

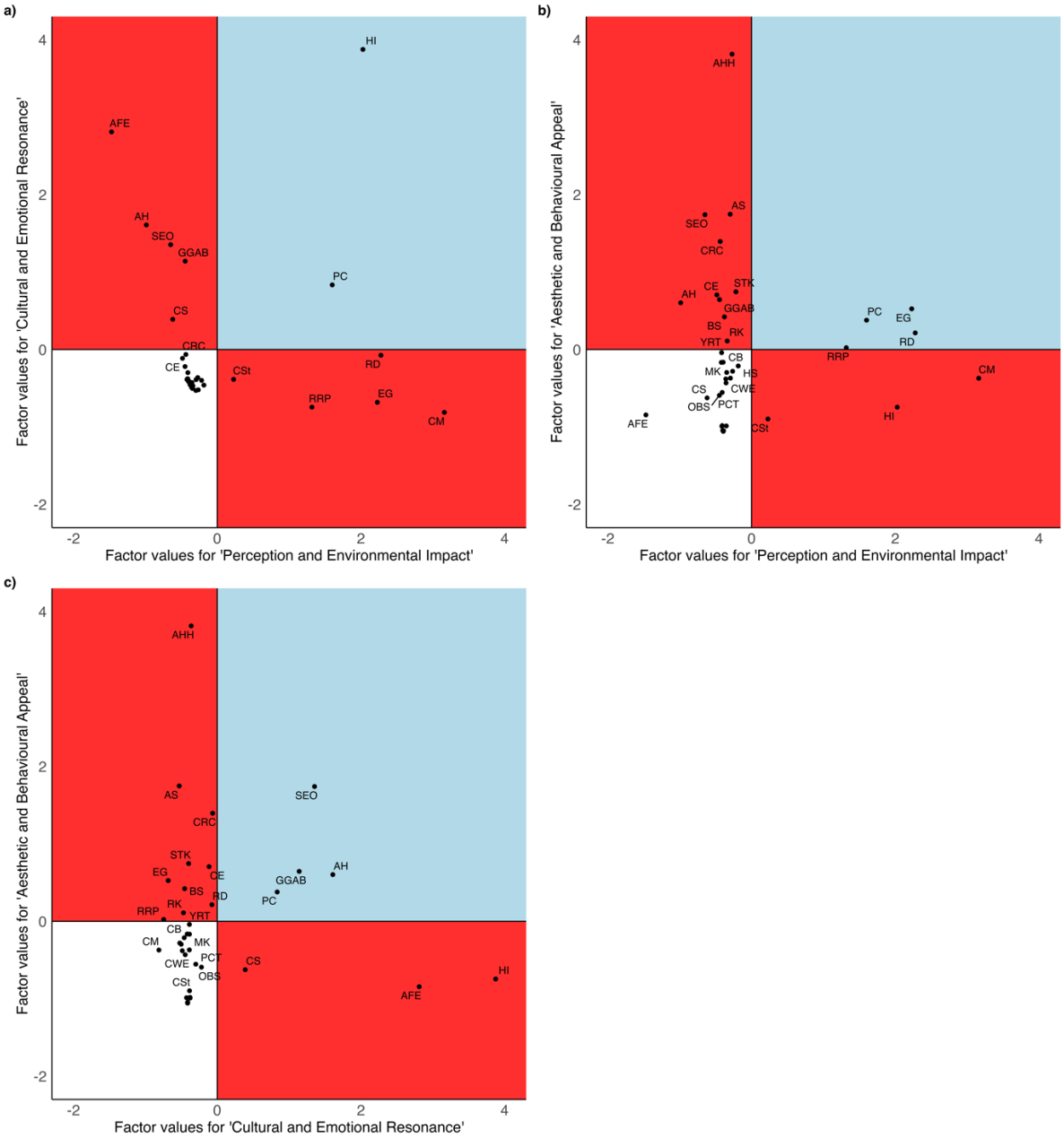


Figure 2.5: Multidimensional nature of cultural ecosystem service provision between the response bundle categories for the responses received to describe likeability of the different bird species based on opinions and perceptions of South African residents. Species in blue shadings represent synergies where both bundles are influencing value, whereas species in red shadings show an association where one bundle drives the value of the bird more strongly. Note: Species codes are presented on the figures for neatness. For full species names see Appendix A, Supplementary Table S1.

2.5. DISCUSSION

In this study, I produced a quantitative and qualitative assessment of cultural ecosystem services provided by birds. Quantitative results showed that the likeability of birds

in urban contexts, while generally positive, may have varied at the species level. When coupled with the open-ended responses from the questionnaires, the findings highlighted that cultural ecosystem services provided by birds tended to be strongly influenced by the aesthetic appeal of different species. Additionally, the large-language model (LLM) analysis showed that high likeability scores were also associated with emotional connectedness that some people have towards specific species. Contrastingly, species that notably influence the occurrence and prevalence of other species (i.e., have a non-native provenance or are strong urban competitors) tended to elicit a more negative response from respondents. Cultural significance and symbolism surprisingly did not have a large influence on value. These observations supported the notion that while birds are an overall well-liked taxon, reasons for likeability will vary based on individual preferences of trait-based characteristics, behaviours, and personal experiences with different birds.

Species-level Variation in Likeability

Overall, my findings aligned with those of Clergeau et al. (2001) and Belaire et al. (2015), which also found that birds are a well-liked and well-valued taxon in urban landscapes in the Global North, or Graviola et al. (2024) in the Global South. At species level, however, there was variability in likeability with some species being more well-liked than others. Variation in likeability was common among bird species (e.g., Lišková and Frynta 2013; Tisdell et al. 2015), with numerous factors, such as species visibility, recognisability, physical traits, and behaviours influencing species-level perceptions (Cox and Gaston 2015; Collins et al. 2021; Andrade et al. 2022; Champness et al. 2023; Graviola et al. 2024). Surprisingly, my study found almost all species to be generally positively perceived, contrasting patterns of variation in previous literature. Of the 36 species analysed, only three

were found to be predominantly disliked by respondents – namely the Common Myna, Common Starling, and Pied Crow.

Themes of Likeability across species

By assessing the reasons for likeability using open-ended responses, I was able to tease apart the factors that influenced these patterns of likeability. Overall, LLMs are still being tested for their ability to conduct sentiment analysis and have been observed to lag in certain complex sentiment-related tasks compared with domain-specific small language models (Zhang et al. 2023; Yang et al. 2024). However, here I found that LLMs may be a key tool for mining through large datasets (~71 000 responses) in sentiment analyses. ChatGPT recognised, and was generally able to categorise, sentiment responses for perception of likeability into eight major themes. Previous literature has generally used trait-based factors (e.g., Collins et al. 2021; Andrade et al. 2022) or behavioural characteristics (e.g., Perry et al. 2020; Champness et al. 2023) to describe why urban residents like different bird species. Here, I found that reasons for likeability, while conserved to eight major themes, were more complicated for different species.

The highest rated species from my study were the Malachite Kingfisher, Orange-breasted Sunbird, and African-paradise Flycatcher. Sentiment responses from the research questionnaires indicated that the main theme of likeability for these species was the aesthetic appeal of these birds. Specifically, responses highlighted favour for the bright colouration and small sizes of these species. Compared with previous trait-based analyses, these observations supported general patterns of positive species perception being influenced by trait-based factors (i.e., body size, wingspan, and number of colours) as opposed to species abundance and richness (Collins et al. 2021; Andrade et al. 2022). These patterns, however, cannot be applied to all the study species in my analysis.

From the quantitative results, I noted that some of the highest rated bird species in the questionnaires were notably birds of prey, which are characteristically larger in size and have simpler plumage colours (e.g., Crowned Eagle and Black Sparrowhawk). This suggested that aesthetic appeal is not the sole driver of high perceptive value. The sentiment analysis results recognises that the main theme of likeability that influences raptor species likeability was the theme of 'Emotional Impact (Personal Connection)'. There were two exceptions to this observation, namely the African Fish Eagle and the Rock Kestrel, where the top themes were 'Vocalisation' and 'Appearance/Aesthetics', respectively. In general, however, these sentiments suggest raptors to be well-liked because of an emotional connectedness derived from experience and enjoyment of seeing these typically rare birds. Previous research highlights that birds of prey are typically an uncommon study model (Donázar et al. 2016) but tend to be extremely well-liked (Perry et al. 2020; Champness et al. 2023). This is largely driven by the high recognisability (Donázar et al. 2016), as well as an elicitation of strong emotional responses such as joy and a natural sense of fear that are associated with birds of prey (Perry et al. 2020; Champness et al. 2023). Additionally, the desire to conserve these species following rapid raptor population declines, perhaps further boosts the likeability of birds in this category (Donázar et al. 2016; Perry et al. 2020; Champness et al. 2023). Surprisingly, raptor species maintain a high likeability rating despite the portrayal of aggressive behaviours (i.e., hunting; Perry et al. 2020; Champness et al. 2023), which contributed to lower scores of some of the least liked species from my questionnaires.

The strong negative value of the Common Myna, Common Starling, and Pied Crow was observed to be primarily associated with sentiments of negative behaviours towards other species. These species are typically regarded as pest-like, with Myna and Starling also notably being recognised for their non-native provenance in South Africa (Matin-Albarracin et al. 2015). Non-native species are notably stronger competitors in urban landscapes

enabling them to thrive, albeit at the cost of native or indigenous species (Matin-Albarracin et al. 2015; Naidoo et al. 2024). While the Pied Crow is an indigenous member of South Africa's avifauna, its pest-like habits (Fincham et al. 2015), and generalist nature has likely contributed to similar impacts on native species populations (Cunningham et al. 2016; Shivambu et al. 2020). Hence, negative perceptions of these species may be concurrent with their roles in decreasing overall species diversity. The challenge, however, was that these patterns of negative perception are not applicable to all the non-native, or pest-like, species assessed in my study. For example, the House Sparrow and the Rose-ringed Parakeet, two non-native South African species (NEMBA 2004) and the Hadeda Ibis, a typical pest species (Reynolds and Howes 2023), received moderately positive responses in the questionnaires. Rather than being strongly disliked for their nuisance-like behaviours, these species were found to have more positive scores. This was associated with open-ended responses linked to the species aesthetic appeal and an emotional connectedness towards the species.

Multidimensional nature of avian cultural ecosystem services

Overall, these patterns of likeability and perception highlighted the complexity that was associated with the quantification and qualification of cultural ecosystem services. While the results show that likeability is largely associated with aesthetic, environmental, and emotional values, it is important to recognise that these factors do not act in isolation. In our urban spaces, I observed that there are certain species that exhibit synergies and others that exhibit simple associations between the bundles of CES that influence the value of different bird species. For example, the African Fish Eagle's value was solely driven by its 'Cultural and Emotional Resonance' but was not influenced by its 'Ecological and Environmental Impact'. Contrastingly, the Pied Crow's value was strongly influenced by a synergy between these two bundles. This supported the value of the Pied Crow being influenced by negative

behaviours towards other species, which also elicited an emotional dislike of the species. Hence, cultural ecosystem services provided by birds can be seen as complex with different attributes of different species, as well as individual experiences, affecting how different birds are valued. While this complexity has not previously been assessed for birds, similar complexity in cultural ecosystem service values was shown by Ament et al. (2017). Ament et al. (2017) assessed similar synergies and trade-offs for cultural ecosystem services in South African protected areas. From their findings, Ament et al. (2017) showed that the complexity of cultural ecosystem services arises from landscape effects, as well as social preferences for the types of services being offered in the environment. Hence, cultural ecosystem services tend to be a largely complex and subjective ecosystem service type where individual experience and exposure may influence value.

2.5.1. LIMITATIONS

I have interpreted the value of birds across urban habitats in South Africa based on individual likeability ratings and the sentiment behind the ratings. Because of the distribution of the questionnaires across an electronic platform, I recognise that the responses may not be entirely representative of South Africa's true perception of urban birds. In particular, a general bias of the research questionnaires towards avid birders, limits the interpretation of the value of cultural ecosystem services provided by birds more generally. This is primarily associated with two key factors. Firstly, by having respondents mostly comprised of avid birds, the results do not adequately reflect perceptions of individuals who may not have an ingrained knowledge about different bird species and their ecosystem roles. Secondly, the birding community of South Africa tends to be dominated by the white demographic. Additionally, the majority of the responses received were from individuals living in generally higher urban landscapes with higher socio-economic status. As such, the results do not reflect

responses of individuals across the diverse socio-economic gradient of urban South Africa (Swilling 2010). These demographic biases may be strong contributors to the observed response patterns. In particular, by having a low diversity of responses culturally (i.e., few responses across the racial demographic of the country) may be a primary cause for the observation of low 'cultural significance/symbolism' responses. Since majority of the responses came from individuals that tend to be more akin to the aesthetic or emotional value of birds rather than from individuals that may rely on birds for other cultural purposes (e.g., traditional medicine or cultural practice) this study is unable to provide specific insights for the more direct cultural value of birds.

Overall, the results of this study can be recognised as being non-representative of the broad demographic populations of South Africa. This means that I have a limited ability to explain the true value of birds and their cultural ecosystem services across different cultural groups, which may explain limited associations with the cultural symbolism of birds. To mitigate these biases, further study is recommended to target the broader demographic of South Africa's population. This includes acquiring data on the perceptions of individuals representative of the diverse cultural groups in the country, as well as doing more fieldwork or focus groups, such as in-person interviews or distributing physical questionnaires to individuals in areas with limited internet access, to acquire data from the lower income demographic of the country.

Nevertheless, the response rate and inclusion of a multitude of species across different key urban habitats provides a suitable foundation to generally support patterns of how people may value the cultural ecosystem services provided by birds. The findings of this study provide a basis to understand how people value different birds and highlights which factors are most influential when explaining the value and roles of birds in urban ecosystems. Furthermore, this study provides information that may be useful for improving efforts to

nurture biodiversity in urban landscapes by improving the knowledge we have surrounding what types of bird's people to like to experience in their environments. This is particularly important with the rapid rates of development and change associated with urbanisation in South Africa – and subsequently how this has, and continues to, affect the urban biodiversity that can provide these services.

2.5.2. CONCLUSION

This study demonstrates that while birds are a well-liked taxon there is variability in how urban bird species are perceived and valued across the urban landscapes of South Africa. While the general appreciation of birds in urban ecosystems stems from their aesthetic appeal, individual experiences and connectedness with different species is also a strong driver of the perception of cultural ecosystem services provided by birds. This suggests that, in part, people may have higher value for experiencing a diverse selection of birds in their environments over an abundance of a specific urban birds. Hence, greater attention and efforts should be focused on creating spaces that generate increased species diversity in urban environments to improve both individuals' emotional connection to nature, but also to improve access to ecosystem services from birds. Doing so will create a stronger and more diverse biological environment, whilst also contributing towards enhancement of a human-nature connection, which may bring greater awareness to the value of birds and nature in general.

CHAPTER III:

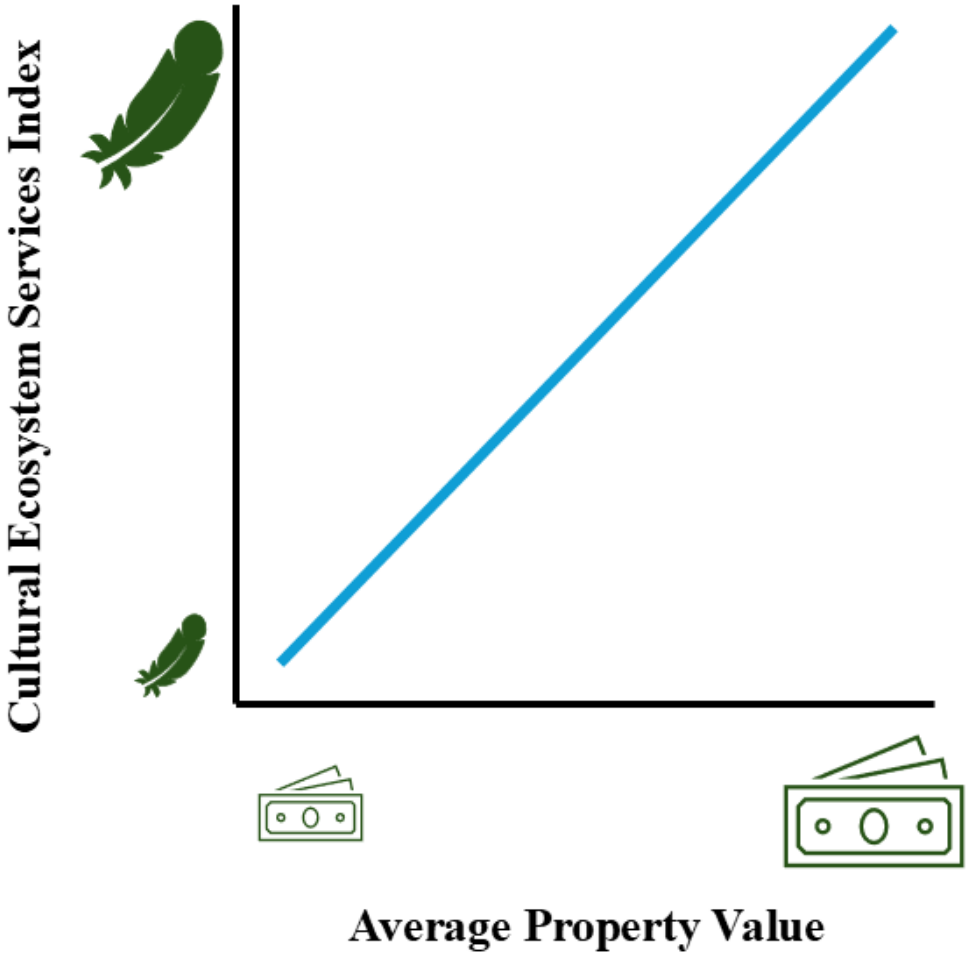
A Test of The Luxury Effect in Urban South Africa: Assessing Access to Avian Cultural Ecosystem Services Along an Urban and Socio-economic Gradient

ABSTRACT

The Luxury Effect posits a strong positive effect of socio-economic status on biodiversity, showing wealthier communities to have greater access to biodiversity. Luxury Effect studies have typically focused on biodiversity indices such as richness and diversity, however, these provide little insight to the effects on human well-being. Studies of the Luxury Effect can therefore be expanded to assess other biodiversity indices, such as ecosystem services, which may show a direct correlation between biodiversity access and well-being. To test the Luxury Effect on access to avian cultural ecosystem services across urban and socio-economic landscapes of four South African provinces, I created a novel and spatially explicit index. My novel cultural ecosystem services index (CES Index) combined quantitative likeability scores of avian CES, extracted from online research questionnaires conducted between September 2023 and January 2024, with a measure of the probability of species occurrence derived from the Southern African Bird Atlas Project 2 (SABAP2). I mapped this index across urban landscapes and observed that highly urbanised landscapes have a higher index score. I then used a linear mixed effects model to test for a Luxury Effect on access to cultural ecosystem services (CES) across the urban and socio-economic gradients in South Africa. I observed a strong positive correlation between socio-economic status and access to avian CES, showing high socio-economic landscapes to have greater access to these services. Interestingly, in lower socio-economic landscapes, urban cover had little effect on the CES Index, which remained consistently low. These findings may suggest that communities in lower socio-economic landscapes may experience a stronger extinction of experience correlated to the inequitable distributions of bird species, and subsequently their ecosystem services. To mitigate these environmental injustices, sustainable urban planning should focus on nurturing biodiversity in lower socio-economic landscapes to promote equitable access to ecosystem services.

Keywords: environmental injustice, occurrence probability, spatially explicit index, South Africa, urban development

GRAPHICAL ABSTRACT



3.1. INTRODUCTION

Urban ecosystems and their associated biodiversity provide many benefits towards the quality of life and are therefore the focus many urban studies (Belaire et al. 2015; Aronson et al. 2017; Soga and Gaston 2020). Urban biodiversity is responsible for providing ecosystem services that benefit urban residents (Hostetler et al. 2011; Irvine 2013; Tanner et al. 2014; McPhearson et al. 2015). This includes benefits that are both tangible (e.g., buffers against urban heat island effects, pollination, or flood mitigation) and intangible (e.g., improved mental and physical health) in nature (Irvine 2013; Tanner et al. 2014; Belaire et al. 2015; McPhearson et al. 2015). However, research indicates that these benefits and services may not be equitably distributed across urban landscapes as wealthier communities (i.e., areas characterised by high income and well-maintained/developed landscapes) tend to have greater access to biodiversity (e.g., Luck et al. 2009; Leong et al. 2016; Leong et al. 2018; Chamberlain et al. 2019; Chamberlain et al. 2020). This is a phenomenon that has been termed the "Luxury Effect" (Hope et al. 2003).

The Luxury Effect posits a positive correlation between socio-economic status (i.e., a measure of social and economic position in society) and levels of biodiversity in urban landscapes (Hope et al. 2003). It has been hypothesised that this phenomenon is influenced by the availability and allocation of resources, and landscape management practices in different communities (Leong et al. 2018). In general, wealthier communities can develop biodiverse green spaces that enhance access to ecosystem services, while limited resources and land management in low-income areas hinder such opportunities (Leong et al. 2018; Chamberlain et al. 2020; Tooke et al. 2010; Apparicio et al. 2012). The Luxury Effect therefore highlights clear environmental injustices in our cities that are associated with access to biodiversity across urban and socio-economic landscapes (Kinzig et al. 2005; Chamberlain et al. 2020).

It has been shown that the Luxury Effect exists across different taxonomic groups including plants (e.g., Hope et al. 2003; Martin et al. 2004; Baldock et al. 2019), birds (Chamberlain et al. 2019; Chamberlain et al. 2020), and insects (Reynolds et al. 2025). While studies of the Luxury Effect show a generally positive correlation between socio-economic status and biodiversity, however, there are also some studies that observed no, or an inverse, correlation between these variables (e.g., Davis et al. 2012; Figueroa et al. 2018; Howes and Reynolds 2021). Variability in urban structure, socio-economic factors, and environmental conditions may therefore influence how the Luxury Effect manifests across different landscapes (Leong et al. 2018).

Tests of the Luxury Effect suggest that wealthier communities are also experiencing greater benefits from biodiversity (i.e., have greater access to ecosystem services) driven by enhanced biodiversity levels (Chamberlain et al. 2020). This has been assessed across numerous landscapes, largely in Global North (Europe and America), with very few studies in the Global South (Chamberlain et al. 2020). Despite extensive studies on the Luxury Effect, most have focused on alpha-biodiversity indices (see Leong et al. 2018; Chamberlain et al. 2020). This gap hinders our understanding of how ecological functions, such as the provision of ecosystem services, vary across socio-economic gradients (Reynolds and Howes 2023). Irrespective, some studies have assessed how urban green infrastructure influences the provision of ecosystem services along socio-economic gradients. For example, regulating ecosystem services have been observed to decrease with an increase in urban population density (Larondelle and Haase 2013; Shen et al. 2021).

Conversely, the provision of cultural ecosystem services has been observed to either decrease with increased urban density (Larondelle and Haase 2013; Shen et al. 2021) or increase with socio-economic status (Liu et al. 2018; Dade et al. 2020). Reynolds and Howes (2023) produced a study to understand these rapid urban effects at a more localised scale by

examining access to avian ecosystem services in public urban green spaces (PUGS) in the City of Johannesburg. In this study, they observed variation in the provision of ecosystem services along a socio-economic gradient (Reynolds and Howes 2023). For example, the study showed that landscapes of lower socio-economic status have greater access to cultural ecosystem services but lower access to supporting ecosystem services (Reynolds and Howes 2023). These variations highlight the need for focused studies on how urban and socio-economic development may shape access to ecosystem services.

While these studies show that urban and socio-economic development do influence the delivery of ecosystem services, Reynolds and Howes (2023) emphasise that such research remains limited across Africa. Existing Luxury Effect studies in Africa have largely focused on biodiversity and species richness indices in South Africa (e.g., Chamberlain et al. 2019; Venter et al. 2020; Howes and Reynolds 2021). Given Africa's rapid urbanisation, however, understanding how access to biodiversity and ecosystem services vary across socio-economic gradients is critical (Awoyemi and Ibanez-Alamo 2023; Reynolds and Howes 2023). Studying the relationship between urban and socio-economic status on access to cultural ecosystem services may provide useful insights for developing this knowledge.

Cultural ecosystem services are the most challenging type of ecosystem service to quantify (Plieninger et al. 2013). Irrespective, its basis in personal experience and individual subjectivity suggests that cultural ecosystem services offer an opportunity to understand the varied access to biodiversity and their benefits through a more personalised lens (Plieninger et al. 2013; Methorst et al. 2021). By focusing on specific taxa, such as birds, studies have used methods such as surveys to gage individual perception (e.g., Clergeau et al. 2001; Belaire et al. 2015), as well as scores of public interests (Reynolds and Howes 2023) to quantify urban perceptions of cultural ecosystem services. In general, birds are found to be a well-liked and well-valued taxon for their cultural ecosystem services (Belaire et al. 2015).

Additionally, Reynolds and Howes (2023) show that urban and socio-economic developments do influence access to cultural ecosystem services. The challenge, however, is that the scale of these studies, being localised to singular urban neighbourhoods or cities, limits our understanding as to how access to these services could vary across communities of different urban and socio-economic status at larger, country-wide scales. Furthermore, inconsistencies in the methodology used among these studies suggests that there is a need for a standardised approach that can be used to evaluate access to these services in different landscapes.

Given this scarcity in studies assessing urban and socio-economic effects on access to cultural ecosystem services, as well as the lack of a standardised CES metric, I set out to test the Luxury Effect using a novel CES index. Using birds as a study model, I produced an index that combined a measure of how likeable species are and their distribution across the urban landscape. I predicted that access to avian cultural ecosystem services would positively correlate with socio-economic status, mirroring patterns observed for bird alpha-biodiversity (Chamberlain et al. 2019). This study examined how urban and socio-economic gradients shape access to avian cultural ecosystem services, providing novel insights into environmental injustices in South Africa. The findings of this study may be used to inform equitable urban planning and biodiversity conservation strategies by uncovering patterns of access to avian cultural ecosystem service across socio-economic gradients in South Africa. Ultimately, I aimed for the results of this study to inform the development of urban landscapes that mitigate the inequitable distribution of biodiversity and ecosystem services.

3.2. AIM, OBJECTIVES, AND HYPOTHESES

The aim of this chapter was to test whether there is a Luxury Effect on access to avian cultural ecosystem services across urban and socio-economic landscapes of South Africa. To achieve this, I addressed the following objectives:

1. Create a novel index of avian cultural ecosystem services using species likeability scores derived from research questionnaires in combination with the records of species occurrence in urban spaces in South Africa.
2. Map the novel index of avian cultural ecosystem services across urban landscapes (>1% urban cover) for four South African provinces.
3. Assess the influence of urban development and socio-economic status on the access to avian cultural ecosystem services in urban South Africa.

It is hypothesised that access to avian cultural ecosystem services may show similar patterns to the biodiversity indices that have been assessed by the Luxury Effect. Specifically, I anticipate access to these services to be greater within higher income landscapes with greater bird diversity compared to lower income landscapes with poorer diversity (Chamberlain et al. 2019).

3.3. METHODS

3.3.1. Methods Overview

I created a spatially explicit index of avian cultural ecosystem services (CES) to assess how access to cultural ecosystem services varies along urban and socio-economic gradients in South Africa. This CES index was derived by merging species occurrence data from the Southern African Bird Atlas Project 2 (SABAP2) with individual scores of bird species likability from a questionnaire (Chapter II) (Figure 3.1 a-c, Phase One). I mapped this novel CES index across the urban habitats (>1% urban cover) to visualise the spatial

distribution of avian CES across four South African provinces. I then tested the Luxury Effect on my novel index using a metric of urban cover, derived from the South African National Land Cover (SANLC) dataset for 2020, and a metric of socio-economic status, derived from Property24 (Figure 3.1 d-f, Phase Two).

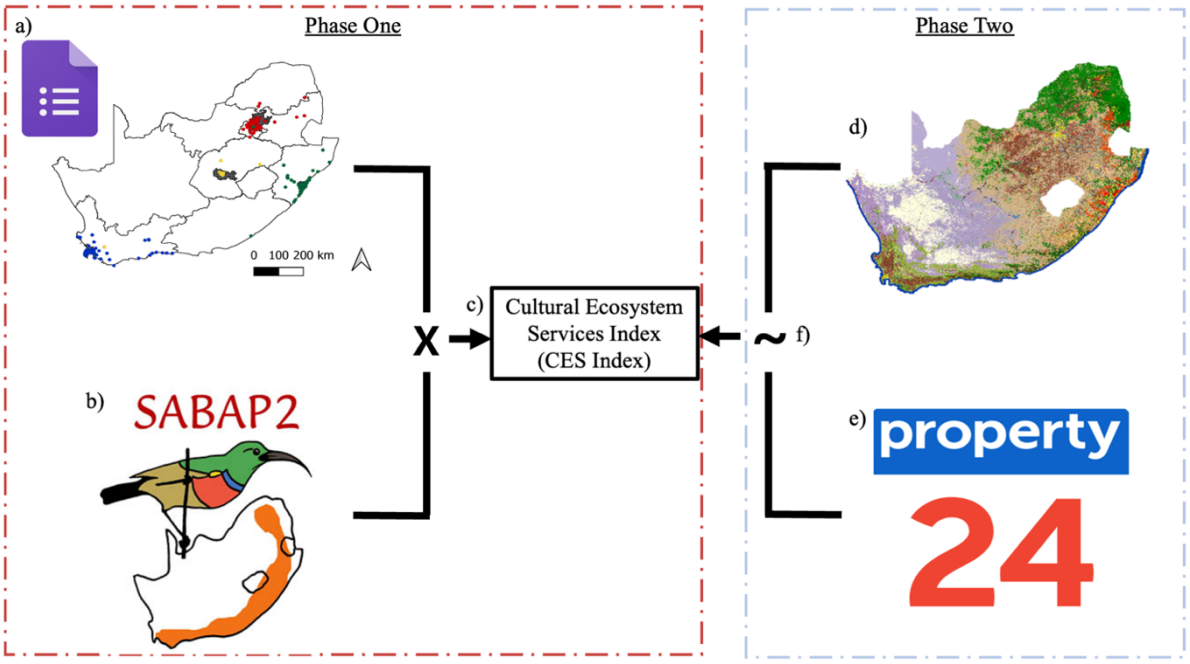


Figure 3.1. Schematic diagram depicting a summary of the methodology used to create the novel Cultural Ecosystem Services Index (Phase 1) and test for a Luxury Effect on this indicator/index (Phase 2). Using the (a) likeability scores from the research questionnaires, and (b) a measure of the probability of species occurrence derived from the Southern African Bird Atlas Project 2 (SABAP2) reporting rates. The novel index was calculated by (c) multiplying these (a and b) values together. To test the Luxury Effect, I used a metric of urban cover (selecting all pentads with >1% urban land cover) derived from the (d) 2020 South African National Land Cover Dataset and a socio-economic index derived from (e) property values from Property24. Using these two measures, I conducted a linear model analysis (f) to test the Luxury Effect on access to avian cultural ecosystem services.

3.3.2. Creation of a Novel Cultural Index

Pentad Species Occurrence. Landscape structure is found to affect the distribution and occurrence of bird species (Chamberlain et al. 2019). Hence, to create a spatially explicit index to evaluate access to avian cultural ecosystem services, it was important to incorporate a measure of the probability of species occurrence across urban landscapes in South Africa.

Determining species occurrence was achieved through two main steps: (1) Data screening and processing and (2) Occupancy modelling and extraction of probability estimates.

Data screening and processing

SABAP2 is a major citizen science bird atlassing project in South Africa. This project collects data on the occurrence of birds across the country within 5 min x 5 min latitudinal and longitudinal grid cells ('pentads') using atlas protocol cards (Brooks et al. 2022). I used the SABAP2 database (2007-ongoing) to download all observation records, in the form of full protocol atlas cards, for the study species in all pentads across South Africa. I filtered the atlas records to include only cards between January 2019 and February 2024, to ensure that the species occurrence records would match the records of my other metrics (i.e., 2020 urban land cover, 2024 property values, and the 2023-24 bird species likeability scores – *described below*). Because of citizen scientist contributions, there may be biases in the sampling efforts across different urban landscapes (Hugo and Altwegg 2017; White et al. 2024). I therefore screened the datasets prior to modelling to remove any atlas cards that were sampled for 10+ hours and below 2 hours within each pentad. Removal of these cards ensured the effects of 'oversampling' or 'undersampling' on occurrence probability were minimised.

Occupancy modelling

I used single-species occupancy modelling to assess species occurrence in urban environments, while accounting for imperfect detection (Tyre et al. 2003; Kéry and Schmidt 2008). With these models I was able to include covariates that influence species occurrence and detectability. This includes the detection parameters, which are factors that affect probability of detection (such as sampling effort in number of hours sampled) and survey

covariates, which are variables that can change between surveys at the same site (such as climate variables, including temperature and precipitation).

I extracted climate data for each study pentad from the TerraClimate package in Google Earth Engine (Gorelick et al. 2017). This included measures of the average annual (minimum and maximum) temperature, precipitation, and solar radiation from the TerraClimate package for the years 2019-2024. I used measures of the average minimum temperature and precipitation in the study pentad as the survey-level covariates as these are the strongest predictors of African bird distributions (Huntley et al. 2006; White et al. 2024). Additionally, I removed other climate variables that were observed to be highly correlated ($r > 0.5$) with each other (e.g., temperature and solar radiation). Occupancy was therefore modelled as a function of the species occurrence (presence/absence) within pentads and measures of temperature and precipitation. Because of imperfect detections in citizen science collected data (White et al. 2024), I incorporated Julian day and sampling effort as the detection parameters in the models. These variables were associated with each card. Julian day was derived from observation dates where I converted it first to degrees and radians to account for circularity. Sampling effort was represented by the log of total survey hours of each card.

I modelled the occupancy of the 36 study species of interest across the full extent of South Africa, and then clipped the predictions to the regions of interest (i.e., urban study pentads). For species with limited distributions (i.e., 9/36 species; Appendix A, Supplementary Table S6), additional processing of the atlas cards was employed. For seven of these nine species, I clipped the atlas card data to the study pentads across the four study provinces (Appendix A, Supplementary Table S6). For the two remaining species (i.e., the Mallard (*Anas platyrhynchos*) and the Rose-ringed Parakeet (*Psittacula krameri*)) additional processing was required. For these two species, I clipped the SABAP2 atlas card data to the

study pentads of the province associated with the questionnaire the species was included in. Hence, atlas card data for the Mallard was clipped to study pentads in the Western Cape and atlas card data for the Rose-ringed Parakeet was clipped to study pentads in Gauteng (Appendix A, Supplementary Table S6). Furthermore, for these two species I had to implement a cut-off (minimum 30 cards per pentad) for the number of atlas cards used for occupancy modelling to account for potential oversampling or undersampling within different pentads. Hence, I hypersampled the SABAP2 datasets for these two species to remove a random selection of atlas cards within each pentad across the province (Appendix A, Supplementary Table S6).

To ensure that I used the best representative model for the occurrence prediction of each individual species per pentad, I developed multiple models to test drivers of species occupancy. Four models were developed for each species (Appendix A, Supplementary Table S7). These models included a null model (incorporating occurrence data only), a temperature only model (incorporating occurrence data and minimum temperature), a precipitation only model (incorporating occurrence data and precipitation), and a full model (incorporating occurrence data, minimum temperature, and precipitation). The detection covariates were kept consistent across all models. Model selection was used to select the model best (i.e., with the lowest ΔAIC score) from the four to use for the prediction of the species occurrence per pentad (see Appendix A, Supplementary Table S7 for a list of models per species ranked by ΔAIC).

Generating Species Likeability Scores. The second component required for my novel cultural ecosystem services index was a measure of how likeable birds are in different landscapes. To achieve this, I asked South African residents to rate different bird species to get a score of how likeable different bird species are using research questionnaires.

Questionnaires were designed to collect quantitative data on how the likeability of different bird species varied across urban landscapes in Johannesburg, Cape Town, Durban, and Bloemfontein. In the questionnaires, respondents were asked to rate the appeal of different birds on a 5-point Likert scale (1 = no appeal and 5 = very high appeal). To ensure a diverse representation of bird species were assessed, I used SABAP2 to select a stratified sample of diverse species that occur in these urban landscapes (for a full description of selection of study species, see *Species Likeability – Study Species Selection* in Chapter II). To focus my results to an urban context, I used this quantitative likeability data to calculate an average likeability score across pentads with >1% urban cover in the provinces of Gauteng, Western Cape, KwaZulu-Natal, and Free State as a representation of my study region.

Selection of Study Regions. I generated a metric of urban cover using the South African National Land Cover (SANLC) dataset for 2020. The SANLC dataset depicts the country in its dominant land cover classes, derived from Landsat 8 imagery at a resolution of 30 m by 30 m. I used the 2020 land cover dataset as it provided the best representation of current urban development. I defined urban land cover by the dominant urban classes of formal, informal, settlement, commercial, and industrial surfaces. Urban cover was therefore calculated as a percentage derived from the 'total urban cover' (summing pixel counts of aforementioned land cover classes) divided by 'total land cover' (summing pixel counts of all land cover classes in the SANLC dataset). I limited the study region to pentads with >1% urban cover (838/5520 pentads). This was later reduced to 455/838 pentads (97 = Gauteng, 91 = Western Cape, 215 = KwaZulu-Natal, and 52 = Free State; hereafter referred to as 'study pentads') after I processed the SABAP2 occurrence data for occupancy modelling to include only records between January 2019 to February 2024.

Species Pentad Likeability. I calculated the average likeability scores for each species within the study pentads (hereafter referred to as 'average pentad likeability score'). I used the suburb names provided in the questionnaires by respondents to derive coordinates for near-exact locations of where the questionnaires were received using Google Earth Pro (2024). I used these coordinates to then identify the study pentads that had a questionnaire response that was directly associated with it (130/455 pentads; hereafter 'questionnaire pentads'; Figure 3.2). I then calculated the average species likeability within these pentads using the likeability scores from the responses associated with the pentad.

For study pentads that did not have a questionnaire response directly associated with it (and therefore did not have any species likeability scores), I used either a nearest-neighbour approach (142/455 pentads, hereafter 'neighbour pentads'; Figure 3.2), or the overall provincial average species average (183/455 pentads; hereafter 'provincial pentads'; Figure 3.2) to calculate the average pentad likeability score. Neighbour pentads refer to the study pentads that occur within a three pentad (or ~27 km) buffer range of at least one of the questionnaire pentads. For these neighbour pentads, I calculated the likeability score by averaging the calculated 'average pentad likeability scores' of questionnaire pentad(s) that were within the three-pentad buffer range. Provincial pentads are those that did not have an associated questionnaire response and fell beyond the three-pentad range for a nearest-neighbour assessment. I assigned these provincial pentads the overall average provincial likeability scores (Appendix A Supplementary Table S2; Chapter II Figure 2.3) for the specific species from all questionnaires received in the respective province. A schematic map of the designation of pentads to these different 'categories' is provided in Figure 3.2.

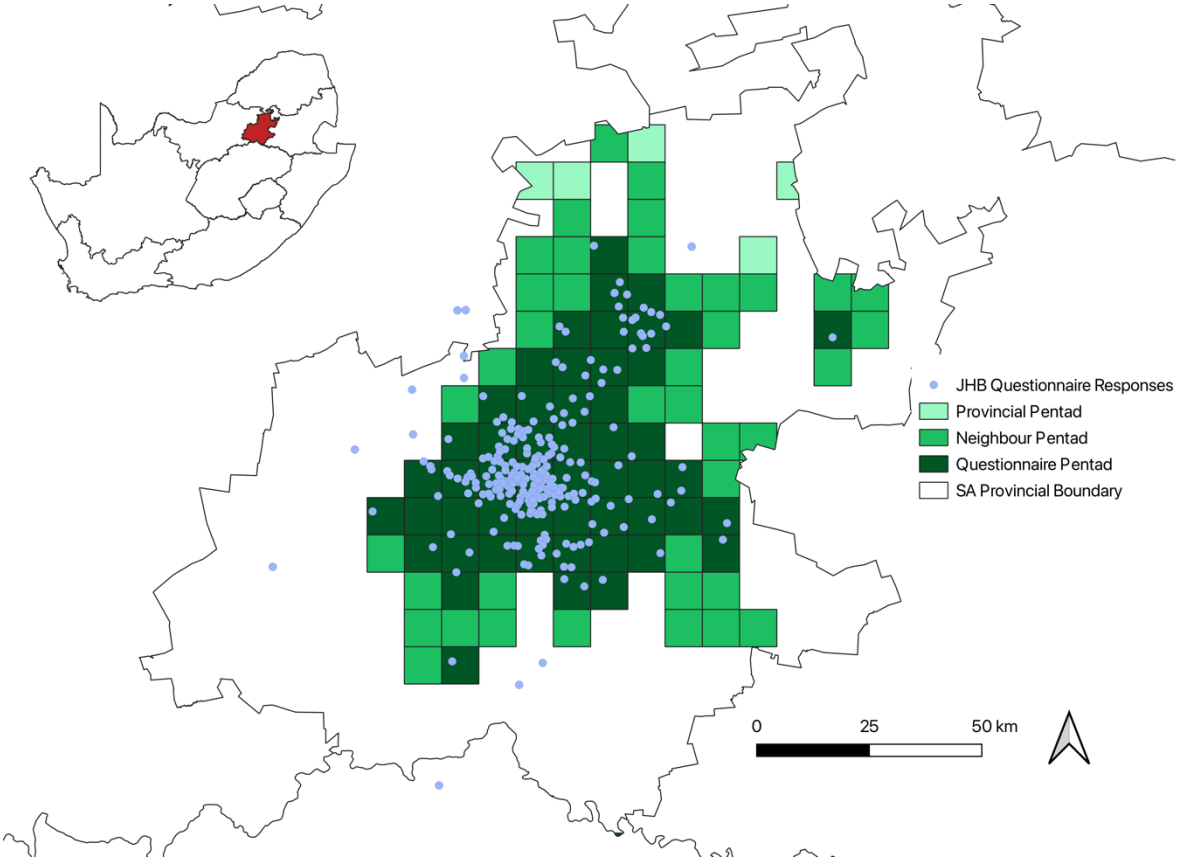


Figure 3.2: Schematic map depicting the designation of pentads as a questionnaire, neighbour, or provincial pentad for calculating the average pentad likeability score, as explained under the "Species Pentad Likeability" section, for the province of Gauteng in South Africa.

South African perceptions of bird values. I generated a novel Cultural Ecosystem Services Index (CES Index), which is a spatially explicit representation of cultural ecosystem services provided by birds in South Africa. I calculated the CES Index by multiplying the average pentad likeability score by the species pentad occupancy prediction (Figure 3.1.c). Hence, the index represents a spatially explicit measure based on how likeable different birds are, and where they occur across the urban landscapes. I first calculated the CES Index for each species individually. This meant focusing only on the average pentad likeability scores and pentad occupancy predictions per individual species – providing a CES Index value for each study pentad that the species was assessed in relative to the provincial questionnaire it was included in. I then computed an overall CES Index value across all the study pentads by summing the individual species CES Index measures.

Spatial Assessment. I plotted a heat map of the overall CES Index to visualise the spatial distribution and identify potential hotspots of avian cultural ecosystem services using the ggplot2 package (v3.4.2; Wickham 2016) in R Studio (R Core Team 2024). Maps were also produced to visualise the spatial distribution of the CES Index calculated for each individual species for the province(s) they were assessed in (see Appendix B, Supplementary Figures S1-S36 for all individual species maps).

3.3.3. Quantifying Socio-economic Development

Socio-economic development. Acquiring socio-economic data from global/national products are challenging, hence I generated a representative metric of socio-economic status across the four provinces. I used the Property24 average cost of a two-bedroom house to represent changes to socio-economic status across the study pentads. Property value serves as a suitable measure for socio-economic status as residential property is typically regarded as a high-value asset for many people (Coffee et al. 2013; Muvengwi et al. 2024). Hence, the use of Property24 can be regarded as a viable index of socio-economic status, particularly relative to wealth or income. I used Google Earth Pro (2024) to identify urban locations (including settlements, communities, and suburbs) within the study pentads. It is important to note that there were large variations in the urban sectors that existed within the 9 x 9 km range of each pentad. Because of the resolution of Property24 data, some pentads were comprised of multiple smaller urban suburbs/cities, whereas other pentads were predominantly represented by larger urban cities. Hence, where possible, I recorded up to six urban locations per pentad to use towards extracting the socio-economic records.

I used these locations to search for the housing values under Property24's property trends and statistics records. The average cost for a two-bedroom house for each location was

recorded, and the overall averages for pentads with more than one urban location was computed. Because of certain limitations in the Property24 database, 122 pentads had no suitable urban property values. For these pentads I extracted the average two-bedroom cost from either a larger urban area associated with a pentad (14.1%), a nearest neighbour approach – where the average of the closest two-to-three nearest urban or municipal regions was calculated (7.9%), or using the average cost associated with the broader district region the pentad occupied (4.8%).

3.3.4. Statistical Analyses

Statistical Analyses. An ANOVA was used to test for a difference between provinces on the CES Index. A Tukey HSD post-hoc test was used to determine which provinces were significantly different to each other.

A general linear mixed effects model (model 1 in Appendix A, Supplementary Table S8; Bates et al. 2014) was used to explore the effects of urban development and socio-economic status on the CES Index for South Africa. The CES Index score was fitted as the response variable in the model and was tested against an interaction between urban cover and socio-economic status (model 1 in Appendix A, Supplementary Table S8). I incorporated province as a random effect to account for potential influences of individual responses by location on likeability and on the occurrence probability of the species, additionally to account for the imbalance of responses received between provinces (model 1 in Appendix A, Supplementary Table S8). To determine the best model for this analysis, I tested different model iterations. This included three general linear mixed effects models where (1) both urban cover and socio-economic status were untransformed, (2) only socio-economic status was logged, and (3) both urban cover and socio-economic status were logged. Logging was used to ‘normalise’ the two predictor variables to account for the broad scales of data. Using a

model Likelihood Ratio Test, I determined the best model was model (3), which had both predictor variables logged (model 1 in Appendix A, Supplementary Table S8). Predictor variables were backtransformed prior to plotting the interaction (Figure 3.4) to aid interpretability but were kept logged for the simplified interaction plot (Figure 3.5) to display the interaction effect. I additionally used general linear models to assess the effects of urban development and socio-economic status on the CES Index of each bird species individually (model 2-37 in Appendix A, Supplementary Table S8). Similar to the overall model, I logged both predictor variables in these models. For all models, model residuals were used to ensure data were a good fit.

All analysis were conducted in R Version 4.3.1 – "Beagle Scouts" (R Core Team 2024). The linear mixed effects model was run using the lmer package (Bates et al. 2014), while general linear models were run using base R.

3.4. RESULTS

3.4.1. Spatial Distribution of Access to Cultural Ecosystem Services

A visual display of the CES Index across urban South Africa showed variation in the spatial distribution of cultural ecosystem services provided by birds (Figure 3.3). In Gauteng, there was a slight north-to-south gradient, with a higher CES Index in the northern regions (Figure 3.3). KwaZulu-Natal showed a west-to-east gradient with higher index values along the coastline (Figure 3.3). Similarly, the Western Cape also showed a higher index level along its coastline compared with inland urban regions (Figure 3.3). In the Free State, index values were generally consistent along its urban regions with little visual variation shown by the CES Index per pentad (Figure 3.3). There was visual 'hotspots' of avian cultural ecosystem services that can be recognised (Figure 3.3). Generally, these hotspots occurred in the more urbanised city centres in the provinces.

The CES Index for birds was found to differ significantly by province ($F = 8.27$, $df = 3$, $p < 0.001$). I found that the Western Cape yielded the lowest CES Index with an average score of 31.29/65, while the Free State had the highest index value, averaging 36.48/65. The Tukey post-hoc test showed significant differences between Western Cape with both the Free State (mean difference = -5.19; $p = 0.001$) and KwaZulu-Natal (mean difference = -4.70; $p < 0.001$), but not Gauteng. Meanwhile, Gauteng, KwaZulu-Natal, and Free State showed no difference in the CES Index value.

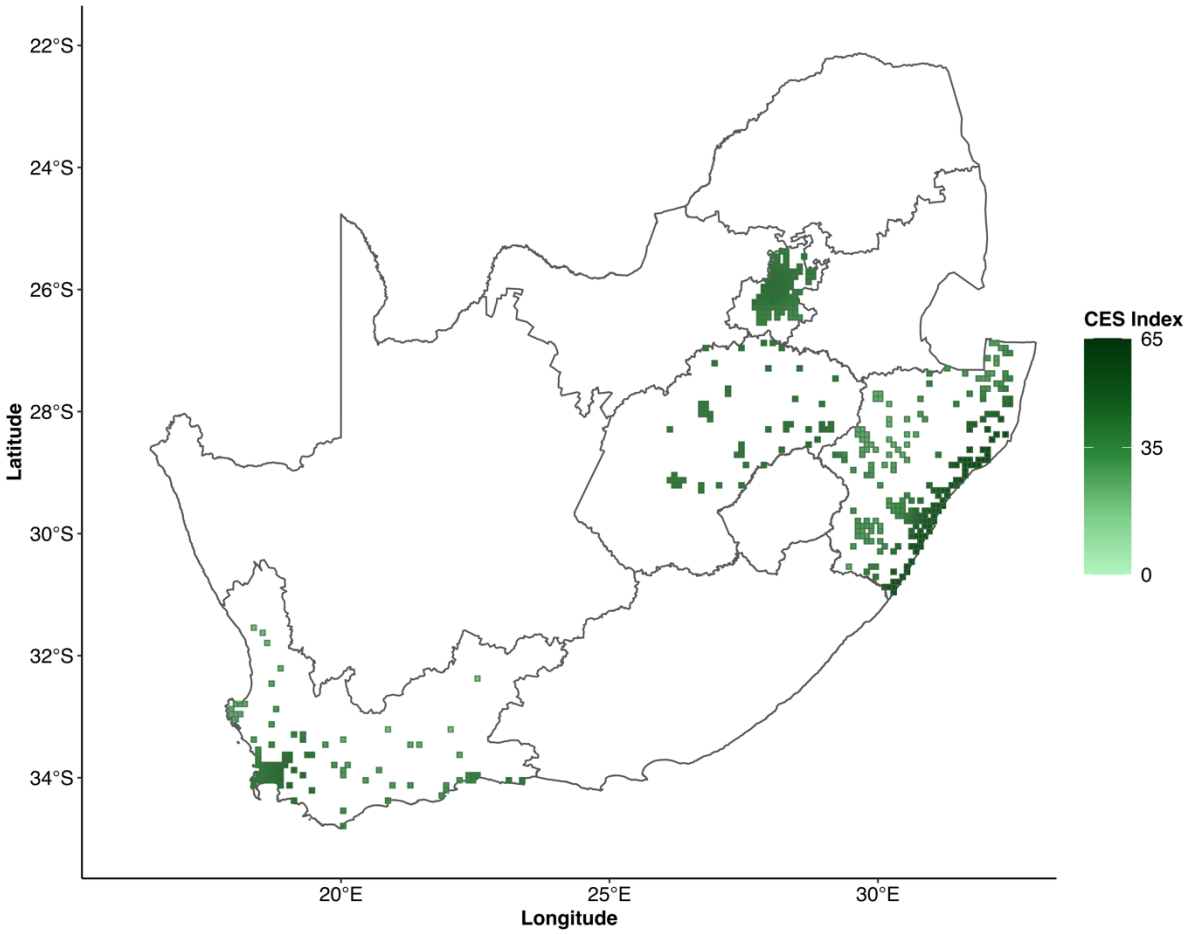


Figure 3.3: Spatial distribution of the cultural ecosystem services index (CES Index) derived from the average likeability and occurrence probabilities of species within each pentad representing regions with urban cover >1 %. The CES Index are displayed for the provinces of Gauteng, Western Cape, KwaZulu-Natal, and Free State where questionnaires were distributed and are based on the cumulative CES Index values for the 13 species analysed per province. The colour legend displays the range of the CES Index (0-65) where a darker shade of green suggests a region with higher access to avian cultural ecosystem services.

3.4.2. Urban and Socio-economic Influence on Access to Cultural Ecosystem Services

There was a significant interaction between urban cover and socio-economic status on the CES Index ($X^2 = 5.84$, $p = 0.016$; Appendix A, Supplementary Table S9; Supplementary Table S10 for individual species models), indicating that access to avian cultural ecosystem services varied with levels of both urban and socio-economic development. This pattern is visualised in Figure 3.4, which presents the full interaction effect, and in the simplified representation in Figure 3.5, which illustrates the linear trend in CES Index values across five levels of urban development.

In general, areas of higher socio-economic status (Figure 3.4 a & b) experienced greater access to avian cultural ecosystem services, indicated by a higher CES Index. This pattern was observed across an increasing urban gradient for high socio-economic landscapes (Figure 3.5). Contrastingly, areas of lower socio-economic status (Figure 3.4 c & d) experienced poorer access to avian cultural ecosystem services, indicated by a lower CES Index. For areas of lower socio-economic status, the pattern of low access persisted across the urban gradient (Figure 3.5) suggesting urban cover does not typically influence access to avian cultural ecosystem services in these landscapes.

The results from this Chapters analyses need to be considered with limitations of bias in the response to the questionnaires, including a demographic, urban, and socio-economic bias (further elaborated under *Limitations* below).

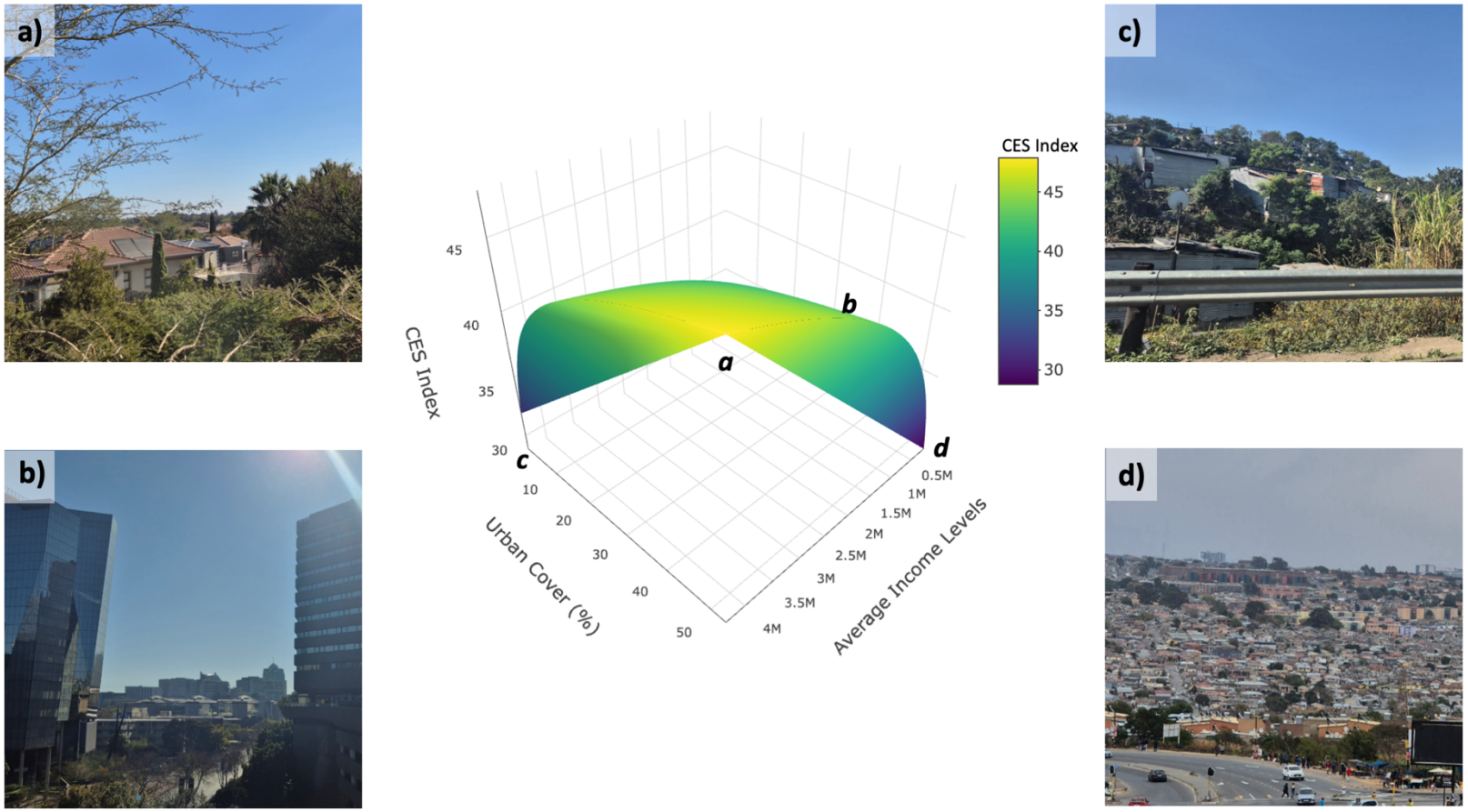


Figure 3.4: Interactive effects of urban cover and socio-economic status on the access to cultural ecosystem services provided by birds (centre panel), represented by my cultural ecosystem services index (CES Index), with representative landscapes (outer panels). The CES Index was derived from the average likeability of species from questionnaires multiplied by the occurrence probability of species in urban areas of >1 % cover as depicted in Figure 3.3. Urban cover was derived as a percentage of land cover represented by urban landcover classes within each pentad. Socio-economic status is the average costs, in Rands, associated with a two-bedroom house within the urban spaces of each pentad. Note that analysis was performed on logged predictor variables, but they are presented here as the back-transformed values to represent the interaction clearly and aid interpretation more accurately. Illustrated landscapes were (a) high socio-economic, low urban cover, (b) high socio-economic,

high urban cover, (c) low socio-economic, low urban cover, and (d) low socio-economic, high urban cover. Bold italic letters on the graph indicate approximate socio-economic and urban cover values that correspond to the images in the outer panels. Images supplied by Sage K. Naidoo (a, b, and d) and Nicolette J. Naidoo (c).

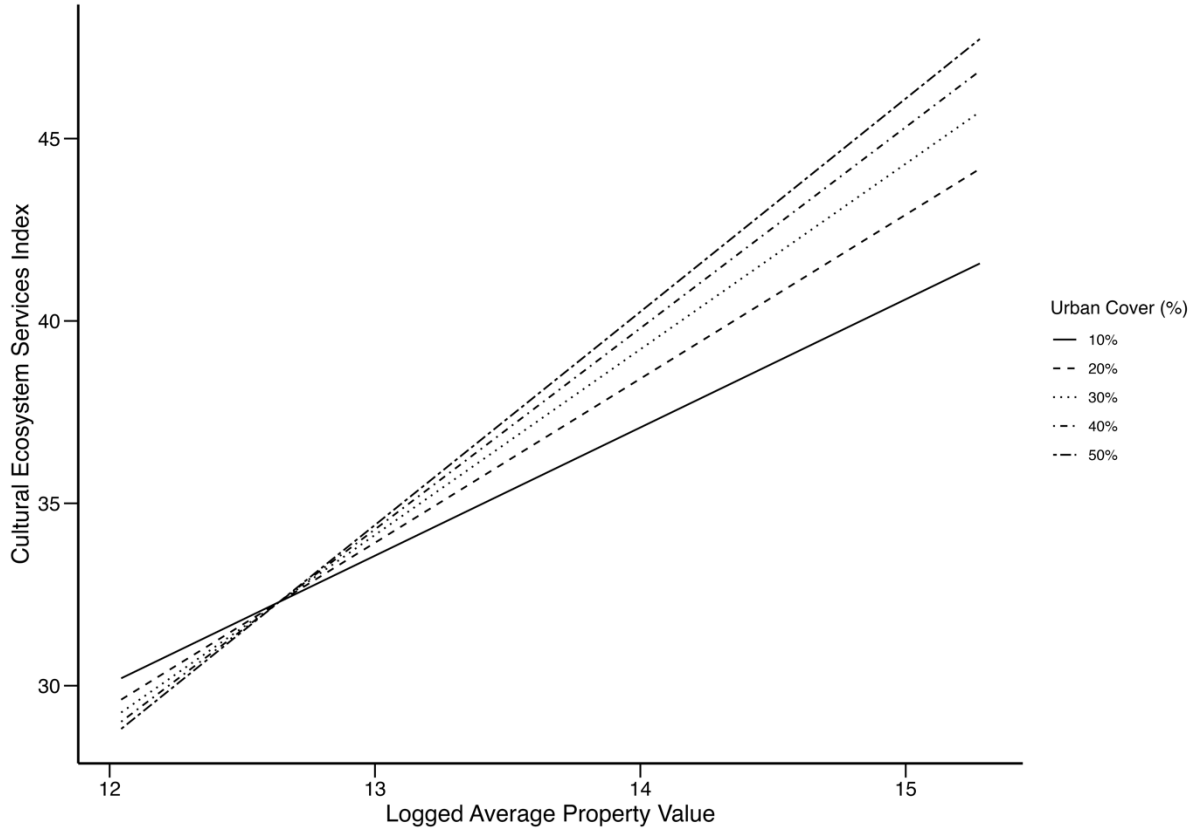


Figure 3.5: Alternative representation of the interaction effect of urban cover and socio-economic status (represented by average cost of a two-bedroom house) on the cultural ecosystem services index (CES Index) score for birds. Logged Average Property Value represents the logged socio-economic status metric, in Rands, at pentad level.

3.5. DISCUSSION

I found that there was strong support for a Luxury Effect on access to avian cultural ecosystem services across socio-economic landscapes, which was mediated by urban cover. My results also showed a consistent increase in the CES Index with increased urbanisation. This suggested that people in more a highly urbanised ecosystem tended to have greater access to avian cultural ecosystem services compared with people in less urbanised ecosystems. Interestingly, in areas of lower socio-economic status, the CES Index tended to remain constant with increased urban cover. These patterns highlighted the ongoing environmental injustices that exist along the urban and socio-economic gradients of South Africa.

Previous assessments of the Luxury Effect have primarily used biodiversity indicators (e.g., species richness) to evaluate how access to biodiversity varies along urban and socio-economic landscapes (e.g., Hope et al. 2003; Leong et al. 2018; Chamberlain et al. 2020). Here, I provided a novel approach to understanding the Luxury Effect by evaluating how access to avian cultural ecosystem services varies along these gradients. Chamberlain et al. (2019) produced an assessment of the effects of urban and socio-economic status on the distribution of bird species richness in South Africa. In the country, they observed contrasting patterns of socio-economic status on bird richness with different levels of urban cover (Chamberlain et al. 2019). Specifically, with low urban cover there was a positive correlation between bird species richness and socio-economic status, but the inverse was observed under high urban cover (Chamberlain et al. 2019). In my study, I observed a generally similar pattern in access to avian cultural ecosystem services with the socio-economic gradient, which increased with socio-economic status. Along the urbanisation gradient, however, I observed a contrasting pattern for access to avian cultural ecosystem services compared to species richness patterns observed by Chamberlain et al. 2019. Specifically, while Chamberlain et al. (2019) found bird species richness to be greater in areas of lower urban cover, compared to areas of higher urban cover, within high income landscapes, my study shows that access to avian cultural ecosystem services increases consistently with urban cover. These patterns were generally consistent irrespective of socio-economic status, except for low socio-economic landscapes where access to avian cultural ecosystem services remained consistently low. These patterns therefore may suggest that access to avian cultural ecosystem services is correlated to patterns of the diversity of birds and how they are distributed across urban and socio-economic landscapes.

For this study, I suggest that the broad scope of the urban and socio-economic landscape influences the types of biodiversity, and subsequently the types of cultural

ecosystem services that may be accessed in different landscapes. Urbanisation is generally associated with a homogenisation of species (Campbell et al. 2022). But this homogenisation is generally mitigated by incorporation of both public and private urban green spaces (Hostetler et al. 2011; Irvine 2013; Tanner et al. 2014; McPhearson et al. 2015). The challenge, however, is that these urban green spaces tend to be inequitably distributed along urban and socio-economic gradients (Wolch et al. 2014).

Observations of greater avian species diversity and richness in wealthier urban communities in South Africa may be correlated to the landscape management in these communities (Chamberlain et al. 2019). Two key mechanisms that support the greater access of wealthier communities to higher biodiversity are (1) resource availability that enable the development and maintenance of biodiverse urban green spaces (UGS) and (2) community establishment in greener and more biodiverse landscapes (Leong et al. 2018). The creation of, and access to, diverse public and private UGS (Goddard et al. 2010; Schwarz et al. 2015; Brooks et al. 2016; Davoren et al. 2016; Leong et al. 2018) contributes towards habitat and resource availability that encourages more avian diversity (Lerman and Warren 2011; Luck et al. 2013; Lowenstein and Minor 2016). Wealthier communities therefore benefit from the UGS that enables them to experience a greater diversity of bird species in their environments (Wolch et al. 2014; Chamberlain et al. 2019). For poorer communities, increased urbanisation and limitations on the implementation of UGS may further homogenise the available avian diversity. Consequently, with greater access to bird species, it can be expected that access to [cultural] ecosystem services from the greater diversity of bird species would be greater in wealthier urban regions. My study demonstrated this potential pattern as the novel CES Index indicated that access to avian cultural ecosystem services was higher in wealthier urban landscapes. The challenge, however, lies in the uneven distribution of biodiversity and its

associated ecosystem services across urban and socio-economic gradients, which can lead to inequitable access at varying scales.

Reynolds and Howes (2023), for example, conducted a study across public urban green spaces (PUGS) in the City of Johannesburg and observed that there is indeed a relationship between socio-economic status and the ecosystem services provided by birds. Using a score of 'public interest' of different bird species, as well as functional traits, they were able to assess the key types of ecosystem services provided in urban PUGS across a socio-economic gradient (Reynolds and Howes 2023). Interestingly, the study found landscapes of lower socio-economic status to support species that are associated with providing more cultural ecosystem services (Reynolds and Howes 2023). This provides a direct contrast to my results, which was that access to avian cultural ecosystem services was lower in lower socio-economic landscapes compared with higher socio-economic landscapes. Hence, there is evidence that studies conducted at different scales, Reynolds and Howes (2023) across PUGS in a city and my study across urban pentads at a country-level, can show different levels of variation in access to ecosystem services. Cities, for example, are recognised as patchy landscapes where small UGS patches can contribute towards a more nuanced overview of the types of birds and services available to different socio-economic groups (Schwarz et al. 2015). Comparatively, by focusing on a country-level across all urban landscape types (i.e., including built infrastructure, and public and private UGS), I provided a broader perspective of access to avian cultural ecosystem services influenced by general urban landscape effects that may not be solely influenced by the occurrence and patchiness of UGS.

These patterns of the distribution of biodiversity and access to cultural ecosystem services provides additional clarity to understanding how different communities can benefit or use the nature surrounding them. In particular, the findings can be used to tackle ongoing

environmental injustices that exist across the South African urban and socio-economic landscapes. This in turn provides a basis to understand how the "extinction of experience" (Pyle 1978; Miller 2005), a phenomenon describing the loss of human-nature interactions as a result of increased urbanisation, may vary across different landscape gradients (e.g., Cox and Gaston 2016; Soga et al. 2016; Hedblom et al. 2017; Awoyemi et al. 2024b). If landscapes of higher socio-economic status support more biodiverse habitats that enable greater access to cultural ecosystem services, it is possible to suggest that these communities have greater experiences with nature. Contrastingly, communities of lower socio-economic status may be experiencing a greater decline in their access to nature overall. These patterns may suggest the extinction of experience to be more prevalent for our communities with lower socio-economic status. This suggests a critical problem that needs to be addressed in our urban and socio-economic landscapes as we are recognising a further exacerbation of environmental injustices across the country.

3.5.1. LIMITATIONS

Here I have interpreted and analysed how access to avian cultural ecosystem services may vary across urban and socio-economic gradients in South Africa, however, there are certain limitations to be considered when interpreting the results. The novel CES Index was calculated using likeability scores derived from online research questionnaires distributed to four city hubs in South Africa. This suggests that access to the questionnaires was somewhat limited as not every individual (e.g., residents in lower income regions outside city limits or individuals without easy internet access) could respond to the questionnaire. Additionally, responses to the questionnaires were demographically biased with a greater proportion of 'white' respondents (Chapter II). Hence, there is a bias in the likeability score data that was

used to calculate the CES Index as it does not reflect the full extent of the possible diverse responses that could be received from South African residents.

Despite this, I incorporated a metric of bird species occurrence into the CES index to aid in mitigating some of these biases. Using a metric of species occurrence in the index accounts for the inherent variability in the distributions of birds across South Africa (Chamberlain et al. 2019). Additionally, accounting for the species occurrence across the country also helped reduce the bias incurred by having limited likeability data in regions of lower socio-economic status. Hence, by multiplying the likeability score by a metric of species occurrence, the index represents how likeable birds are relative to their occurrence and distribution across urban and socio-economic landscapes. Collectively, these limitations of urban and socio-economic biases suggest the extrapolated findings may not be truly reflective of the urban resident's access to avian cultural ecosystem services across the country. Rather, to provide a truly holistic representation of the access of all South African residents to avian cultural ecosystem services, additional work would need to be done to get representative questionnaire responses from individuals across the entire urban and socio-economic landscape.

Despite the limitations based on questionnaire accessibility, the extrapolated findings do still provide valuable insights as to how access to the cultural ecosystem services provided by birds may vary along developing landscapes. This is crucial in developing urban systems as it highlights the need to target communities of lower socio-economic status for biodiversity initiatives if we are to mitigate the influences of environmental injustices that exist as a result of inequitable distributions of biodiversity.

3.5.2. CONCLUSION

Patterns of access to avian cultural ecosystem services can largely be attributed to environmental and socio-economic injustices. The Luxury Effect shows that communities of lower socio-economic status are experiencing lower access to avian cultural ecosystem services. Consequently, this may suggest these communities are experiencing stronger effects of the extinction of experience compared with wealthier communities. In general, these patterns may be associated with inequitable distributions of biodiversity across urban and socio-economic landscapes. The ability of wealthier communities to increase access to biodiversity by creating diverse private and public green spaces suggests that we need to focus efforts for nurturing and enhancing biodiversity in areas of lower socio-economic status. Doing so will aid in improving the access that these communities may have to biodiversity, which can subsequently improve access to cultural ecosystem services. This will aid in ensuring all residents, irrespective of urban and socio-economic status, may benefit from the services of nature and help to reduce the environmental and socio-economic injustices prevalent across these gradients.

CHAPTER IV:

The Synthesis

Urban landscapes, shaped by the rapid pace of urbanisation, present unique challenges and opportunities for biodiversity conservation and human well-being and human-nature interactions (Seto et al. 2011; Soga and Gaston 2016; de Lima Filho et al. 2021). While urban green infrastructure (UGI) can help restore these connections and support biodiversity, the uneven distribution of biodiversity reinforces socio-economic inequalities and environmental injustices, through patterns of the "Luxury Effect" and "extinction of experience" (Pyle 1978; Hope et al. 2003; Miller 2005; Chamberlain et al. 2020). Birds, as a widespread and culturally significant taxon, offer a valuable lens for understanding how urban and socio-economic gradients influence access to, perception of, and benefits from biodiversity — especially in underrepresented regions like sub-Saharan Africa, where such research remains limited (Belaire et al. 2015; Lapointe et al. 2019; Donázar et al. 2016; Chamberlain et al. 2019; Chamberlain et al. 2020; Reynolds and Howes 2023).

This dissertation investigated the intersection of urban ecology and biodiversity through the lens of avian cultural ecosystem services (CES) in South Africa. By quantifying the value of birds in urban settings and exploring socio-economic disparities in CES access, this research provided a novel insight into the intricate relationships between people, biodiversity, and urban environments.

4.1. SUMMARY OF THE RESULTS AND MAJOR FINDINGS

In this study, I used research questionnaires to collect data from residents across four South African provinces to produce a quantitative and qualitative assessment of the cultural ecosystem services offered by birds in urban landscapes. I found that while birds are an overall well-liked taxon, likeability varies at the species level. To understand why there was this variability, I used the open-ended responses that were categorised using ChatGPT. With this novel approach, I found that ChatGPT was a very useful tool for dealing with large

sentiment datasets. ChatGPT identified eight major themes of likeability, including Aesthetics, Emotional Connectedness, Behavioural Characteristics, and overall Negative values. While sentiment for all species could generally be confined to these themes, I found that different species are valued for different cultural ecosystem services. For example, smaller and colourful birds like the Malachite Kingfisher (*Corythornis cristatus*) and Orange-breasted Sunbird (*Anthobaphes violacea*) were well-liked for their aesthetic value whereas raptor species such as the Spotted Eagle-owl (*Bubo africanus*) were well-liked for the emotion it elicits from people. Despite some species value being more strongly associated with a single type of cultural ecosystem services, other species highlight the complexity that is associated with cultural ecosystem services. By bundling themes of likeability, I observed that there are some species that offer cultural ecosystem services across a multidimensional plane (i.e., perception is influenced by more than one service group).

I then used the quantification data from the questionnaires, in collaboration with a measure of bird species occurrence from the SABAP2 project, to create a novel index to test the Luxury Effect on access to avian cultural ecosystem services along urban and socio-economic landscapes. This novel approach to the Luxury Effect, using an index of cultural ecosystem services rather than a biodiversity indicator, provided key insights to the distribution and access to avian cultural ecosystem services. I found that there was a positive correlation between socio-economic status and urban cover on access to cultural ecosystem services. Here, I highlighted that lower income communities have lower access to avian cultural ecosystem services. Interestingly, I also found that changes to urban cover in low-income landscapes had little to no effect on access to these services. The findings of this study therefore support ongoing environmental injustices in South Africa and highlights a need to focus on mitigating these effects by targeting lower income communities in efforts to reduce inequitable access to biodiversity and the ecosystem services it provides.

4.2. THE COMPLEXITY OF CULTURAL ECOSYSTEM SERVICE DYNAMICS

The findings of my dissertation highlighted the inherent complexity that has been associated with cultural ecosystem services. In general, birds were a well-valued taxon in urban landscapes for the cultural ecosystem services they provide, but across a range of varied benefits that includes their aesthetic, emotional, and ecological values. These patterns showed the nuanced ways in which cultural ecosystem services can be perceived and valued in diverse contexts when considering that there are strong influences of individual subjectivity driven by experience, knowledge, and exposure to different bird species. This study integrated ecological and socio-economic dimensions in an urban context and highlighted the interconnections between these fields. Chapter II provided the understanding of how complex values of cultural ecosystem services can be through assessing how different individuals perceive the services offered by different species. In Chapter III, I provided a more nuanced evaluation of access to avian biodiversity, and subsequently the [cultural] ecosystem services it provides.

I developed a novel index that could possibly aid in addressing this complexity, but also contribute towards understanding the environmental injustices that are associated with access to biodiversity. The CES Index I created contributes towards furthering the development of urban ecological research by providing a framework for examining interactions between humans and nature. This index aided in providing a more nuanced perspective of the Luxury Effect by providing a more specific evaluation as to how humans may be directly impacted by the varied distributions of biodiversity in cities. While a key purpose of the index was to encourage the development of a quantitative measure of CES, it also contributed towards understanding how human well-being may be intersecting with biodiversity in different contexts. In particular, I have shown that environmental injustices

that were previously correlated solely to indices of biodiversity richness can be directly correlated to an index that can be reflective of human well-being. This index highlighted that our lower income urban environments should be a point of focus when aiming to mitigate the environmental injustices associated with access to biodiversity and their services. Hence, I suggest from these findings efforts to nurture biodiversity should focused on implementing green infrastructure to increase available biodiversity in our lower income communities first, before targeting efforts in the wealthier biodiverse communities.

4.3. FUTURE RECOMMENDATIONS AND CONSERVATION IMPLICATIONS

This study provided valuable insights into understanding the value of cultural ecosystem services provided by birds but also highlighted that not all communities experience biodiversity and its benefits equitably. Because of these patterns additional research is required to move towards developing sustainable urban landscapes that offer equitable access to biodiversity.

The data of this study was limited by the methods used to distribute research questionnaires, preventing a full view of avian cultural ecosystem services in South Africa. It is recommended that further studies be conducted with the implementation of more fieldwork in lower income landscapes to understand the varied perceptions of birds, from an individual and perhaps cultural, background. Fieldwork may involve conducting the questionnaires in person within communities where access to the internet may be limited. Hence, it would be recommended that future studies either set up interview stations to either disseminate physical copies of the questionnaires or conducting verbal interviews with prospective respondents. By conducting more fieldwork and in-person questionnaires, we may be able to better understand how cultural backgrounds and broader demographic perspectives in different locations may influence perceptions of different bird species. Addressing these

limitations in future studies may provide better grounds to understand how to develop urban landscapes in a more sustainable way, while targeting the urban and socio-economic biases that drive environmental injustices. One key solution would be the development of better maintained public urban green spaces that can encourage an increase in biodiversity and bring about a shift away from distinctive injustices linked to access to biodiversity and its services (Lerman and Warren 2011; Luck et al. 2013; Leong et al. 2018; Chamberlain et al. 2019).

Another recommendation for future studies would be building upon the CES Index I have created to make it more nuanced, adaptable, and applicable to other forms of biodiversity. Overall, urban biodiversity comprises of a diverse array of plant, vertebrate, and invertebrate taxa. All of these taxa offer their own types of ecosystem services that assist in improving human well-being. Hence, I recommend that future studies be conducted that use the methods to create the CES Index to evaluate the role and access of the ecosystem services provided by other forms of urban biodiversity. This will provide a broader perspective of the important roles that different forms of urban biodiversity may play in the improving human well-being. By broadening the scope of this study to assess more urban taxa, research may be able to better understand the steps that need to be taken preserve urban ecosystems. Additionally, these forms of studies may contribute towards further pinpointing the types of biodiversity, and the different areas, where we need to nurture biodiversity to ensure that urban landscapes across the socio-economic gradient are ensuring equitable access to all forms of biodiversity.

4.4. CONCLUDING REMARKS

The complexity associated with cultural ecosystem services has resulted in limited attempts to quantify and understand its values across different landscapes. Nevertheless, the

results of this study have contributed towards a growth in knowledge focused on avian cultural ecosystem services. This study highlights the key importance of birds to urban residents as ecosystem services providers but also illuminates the prevalent environmental injustices across urban and socio-economic landscapes. Based on this study findings, lower income communities are facing an exacerbated loss of biodiversity and access to ecosystem services, and thus may be experiencing an increased extinction of experience. A primary solution to mitigate these issues would therefore be to implement strategies that target lower income communities in a way that reduces the observable biodiversity crisis and aids in bringing about a more equitable distribution of ecosystem services.

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With all my heart, I wish you all eternal sunshine ☼

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WITWATERSRAND,
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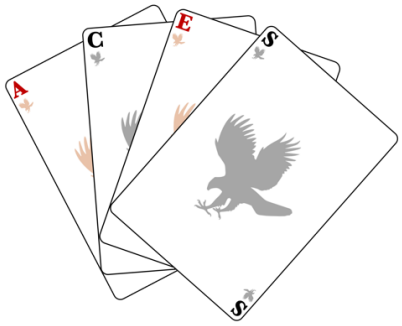
The Avian Cultural Ecosystem Services Project:

Quantifying the cultural ecosystem services provided by birds across South Africa's urban ecosystems

Sage K. Naidoo and Associate Professor Chevonne Reynolds

Appendix



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Appendix A: Supplementary Tables

Supplementary Table S1: Selected bird species for survey review from the SABAP2 database reporting rates. The family, order, and IUCN status (Least Concerned = LC, Near Threatened = NT, Endangered = EN), and provenance to South Africa (i.e., native, invasive, or endemic) are also provided.

Common name	Scientific name	Species Code	Family	Order	Status	Provenance
African Fish Eagle	*Haliaeetus vocifer*	AFE	Accipitridae	Accipitriformes	LC	Native
African-Harrier Hawk	*Polyboroides typus*	AHH	Accipitridae	Accipitriformes	LC	Native
African Hoopoe	*Upupa africana*	AH	Upupidae	Bucerotiformes	LC	Native
African Oystercatcher	*Haematopus moquini*	AO	Haematopodidae	Charadriiformes	LC	Near-endemic
African-paradise Flycatcher	*Terpsiphone viridis*	APF	Monarchidae	Passeriformes	LC	Native
Amethyst Sunbird	*Chalcomitra amethystina*	AS	Nectariniidae	Passeriformes	LC	Native
Blacksmith Lapwing	*Vanellus armatus*	BL	Charadriidae	Charadriiformes	LC	Native
Bronze Mannikin	*Lonchura cucullata*	BM	Estrrildidae	Passeriformes	LC	Native
Black Sparrowhawk	*Accipiter melanoleucus*	BS	Accipitridae	Accipitriformes	LC	Native
Cape Bulbul	*Pycnonotus capensis*	CB	Pycnonotidae	Passeriformes	LC	Endemic
Cape Cormorant	*Phalacrocorax capensis*	CC	Phalacrocoracidae	Suliformes	EN	Near-endemic
Crested Barbet	*Trachyphonus vaillantii*	CBa	Lybiidae	Piciformes	LC	Native
Crowned Eagle	*Stephanoaetus coronatus*	CE	Accipitridae	Accipitriformes	NT	Native
Common Myna	*Acridotheres tristis*	CM	Sturnidae	Passeriformes	LC	Invasive
Cape Robin-chat	*Cossypha caffra*	CRC	Muscicapidae	Passeriformes	LC	Native
Cape Sugarbird	*Promerops cafer*	CS	Promeropidae	Passeriformes	LC	Endemic
Common Starling	*Sturnus vulgaris*	CSt	Sturnidae	Passeriformes	LC	Invasive
Cape White-eye	*Zostereps virens*	CWE	Zosteropidae	Passeriformes	LC	Endemic
Mallard (Domestic Duck)	*Anas platyrhynchos*	DD	Anatidae	Anseriformes	LC	Invasive

Egyptian Goose	*Alopochen aegyptiaca*	EG	Anatidae	Anseriformes	LC	Native
Grey Go-away bird	*Corythoixoides concolor*	GGAB	Musophagidae	Musophagiformes	LC	Native
Green Twinspot	*Mandingoa nitidula*	GT	Estrildidae	Passeriformes	LC	Native
Hadada Ibis	*Bostrychia hagadash*	HI	Threskiornithidae	Pelecaniformes	LC	Native
House sparrow	*Passer domesticus*	HS	Passeridae	Passeriformes	LC	Invasive
Lanner Falcon	*Falco biarmicus*	LF	Falconidae	Falconiformes	LC	Native
Little Swift	*Apus affinis*	LS	Apodidae	Caprimulgiformes	LC	Native
Long-Crested Eagle	*Lophaetus occipitalis*	LCE	Accipitridae	Accipitriformes	LC	Native
Malachite Kingfisher	*Corythornis cristatus*	MK	Alcedinidae	Coraciiformes	LC	Native
Orange-breasted Sunbird	*Anthobaphes violacea*	OBS	Nectariniidae	Passeriformes	LC	Endemic
Peregrine Falcon	*Falco peregrinus*	PF	Falconidae	Falconiformes	LC	Native
Pied Crow	*Corvus albus*	PC	Corvidae	Passeriformes	LC	Native
Purple-crested Turaco	*Tauraco porphyreolophus*	PCT	Musophagidae	Musophagiformes	LC	Native
Rock Dove	*Columba livia*	RD	Columbidae	Columbiformes	LC	Invasive
Rock Kestrel	*Falco rupicolus*	RK	Falconidae	Falconiformes	LC	Native
Red-knobbed Coot	*Fulica cristata*	RKC	Rallidae	Gruiformes	LC	Native
Rose-ringed (Ring-necked) Parakeet	*Psittacula krameri*	RRP	Psittaculidae	Psittaciformes	LC	Invasive
Spotted Eagle-owl	*Bubo africanus*	SEO	Strigidae	Strigiformes	LC	Native
Southern-masked Weaver	*Ploceus velatus*	SMW	Ploceidae	Passeriformes	LC	Native
Southern Red Bishop	*Euplectes orix*	SRB	Ploceidae	Passeriformes	LC	Native
Spotted Thick-knee	*Burhinus capensis*	STK	Burhinidae	Charadriiformes	LC	Native
White-eared Barbet	*Stactolaema leucotis*	WEB	Lybiidae	Piciformes	LC	Native
Yellow-rumped Tinkerbird	*Pogoniulus bilineatus*	YRT	Lybiidae	Piciformes	LC	Native

Supplementary Table S2: List of study species from research surveys that were selected for analysis – showing the survey species were included in, the mean response, and the standard error. For species with an (*) next to the 'Y' for survey(s) included in, indicates that the species was excluded from any analysis in the study.

Species Code	JHB	CPT	DBN	BLM	Mean Response	Standard Error
AFE		Y		Y	4.88	0.20
AHH	Y		Y		4.57	0.67
AH	Y				4.80	0.32
AO		Y*			4.63	-
APF			Y		4.89	0.13
AS	Y		Y		4.75	0.41
BM			Y		4.40	0.79
BS		Y			4.71	0.39
BL				Y*	4.23	-
CB		Y			4.33	0.80
CC		Y*			4.28	-
CBa	Y*			Y	4.65 (4.74 in BLM)	0.72
CE			Y		4.82	0.32
CM	Y		Y	Y	2.50	1.77
CRC	Y			Y	4.41	0.88
CS		Y			4.79	0.36
CSt		Y			2.95	1.49
CWE			Y		4.55	0.54
DD		Y			3.50	1.76
EG	Y	Y			3.38	1.60
GGAB	Y				4.22	0.99
GT			Y		4.77	0.35
HI	Y	Y	Y	Y	3.48	1.72
HS			Y	Y	3.91	1.13
LF				Y	4.56	0.96
LS				Y	4.50	1.04
LCE				Y*	4.66	-
MK		Y			4.91	0.15
OBS		Y			4.91	0.19
PF	Y*		Y*		4.70	-
PC	Y	Y			3.00	1.79
PCT			Y		4.83	0.25
RD	Y	Y	Y	Y	3.12	1.57
RK		Y			4.66	0.43
RKC				Y	3.87	1.55
RRP	Y				3.65	1.89
SEO	Y				4.60	1.03
SMW				Y	4.33	0.99
SRB				Y	4.59	0.65
STK	Y			Y	4.35	0.88
WEB			Y*		4.35	-
YRT			Y		4.62	0.53

Supplementary Table S3: Description of the categories for the thematic categorisation of open-ended survey responses for ChatGPT

Category	Description/Definition
Appearance/Aesthetics	Responses that mention any references to the appearance and aesthetics of the bird, including physical characteristics (such as body traits), colour, and descriptive adjectives associated with the 'look' of the bird.
Behavioural Characteristics	Responses that relate to any behaviours or habits of the bird, or behaviours that the bird may perform. This includes any responses mentioning movement, flight, hunting, feeding, breeding, etc.
Ecological Impact	Responses that relate to the ecological role of a bird in its ecosystem, as well as its impact on other species. This may be based on services provided, being an indicator of something in the environment (e.g., seasonal shift), or the provenance of the bird in the area.
Cultural Significance/Symbolism	Responses that relate to a cultural or spiritual connection of the bird to ones religious or cultural background, as well as responses that suggest the bird is seen as a symbol of something in the environment (e.g., strength, power, or is a symbol of the land).
Emotional Impact (Personal Connection)	Responses that relate to the personal experience, enjoyment, or emotional/personal attachment that someone has to a particular bird that are not associated with a cultural/spiritual belief.
Vocalisation	Responses that relate to the call or sounds of the bird, including mentions of vocal patterns and any synonymous words with 'call' (e.g., cry, chirp, song).
Prevalence/Rarity	Responses that relate to how often a bird is seen in the environment, or how likely a bird is to be found in ones environment – hence referring to the level of commonness of the bird.
Negative/Neutral	Responses that are of distinct negative perspective, or clear neutral response to a bird that suggests there is no 'likeability' or appeal of the species.

Supplementary Table S4: Number of responses received from surveys distributed to the cities of Johannesburg, Cape Town, Durban, and Bloemfontein, with responses extending to the respective provinces of Gauteng, Western Cape, KwaZulu-Natal, and Free State

Survey	Responses
Gauteng	1 149
Western Cape	376
KwaZulu-Natal	428
Free State	41
TOTAL	**1 994**

Supplementary Table S5: Breakdown of the demographic responses of individuals who responded to one of the four ACES research surveys, based on respondent gender, age class, race (in a South African context), and dwelling type.

Gender

	Male	**Female**	**Agender/Non-Binary**	**Prefer Not to Say**
Gauteng	358	775	11	5
Western Cape	122	254	0	0
KwaZulu-Natal	284	141	2	1
Free State	16	25	0	0

Age

	<18	**18-30**	**31-40**	**41-50**	**51-60**	**61-70**	**70+**	**Prefer Not to Say**
Gauteng	8	293	171	186	202	174	114	1
Western Cape	7	29	61	44	71	92	71	1
KwaZulu-Natal	2	22	56	56	100	137	54	1
Free State	0	6	8	8	8	7	4	0

Race

	White	**Black**	**Indian**	**Coloured**	**Asian**	**Other**	**PNS**
Gauteng	867	120	100	26	6	5	25
Western Cape	322	4	16	17	1	2	14
KwaZulu-Natal	364	9	41	5	1	1	7
Free State	37	1	1	1	0	1	0

Dwelling

	Flat/ apartment	**Informal**	**Other**	**Plot**	**PNS**	**Stand-alone**	**Stand-alone (within Gated community/Estate)**
Gauteng	241	5	22	54	11	594	222
Western Cape	69	1	12	5	0	240	49
KwaZulu-Natal	54	0	16	13	0	278	67
Free State	9	0	1	2	0	23	6

Supplementary Table S6: Description of additional data processing steps used to organise and prepare data prior to conducting occupancy modelling and model selection for species. Where there is no information provided in the notes section for a species, it suggests occupancy modelling was consistent with determining occurrence across all of South Africa and then clipping predictions to urban pentads within study provinces.

Species	Notes
African Fish Eagle	
African Harrier-hawk	
African Hoopoe	
African-paradise Flycatcher	
Amethyst Sunbird	
Black Sparrowhawk	
Bronze Mannikin	
Cape Bulbul	Species map is based on clipping SABAP2 data to all study provinces (GT, WC, KZN, FS) for occupancy modelling.
Cape Robin-chat	
Cape Sugarbird	Species map is based on clipping SABAP2 data to all study provinces (GT, WC, KZN, FS) for occupancy modelling.
Cape White-eye	
Common Myna	
Common Starling	Species map is based on clipping SABAP2 data to all study provinces (GT, WC, KZN, FS) for occupancy modelling.
Crested Barbet	
Crowned Eagle	
Egyptian Goose	
Green Twinspot	
Grey Go-away-bird	Species map is based on clipping SABAP2 data to all study provinces (GT, WC, KZN, FS) for occupancy modelling.
Hadeda Ibis	
House Sparrow	
Lanner Falcon	
Little Swift	
Malachite Kingfisher	
Mallard (Domestic Duck)	Species map is based on clipping SABAP2 data to Western Cape and hyper-sampling to max. 60 cards for occupancy modelling.
Orange-breasted Sunbird	Species map is based on clipping SABAP2 data to all study provinces (GT, WC, KZN, FS) for occupancy modelling.
Pied Crow	
Purple-crested Turaco	
Red-knobbed Coot	
Rock Dove	Species map is based on clipping SABAP2 data to all study provinces (GT, WC, KZN, FS) for occupancy modelling.
Rock Kestrel	
Rose-ringed Parakeet	Species map is based on clipping SABAP2 data to Gauteng and hyper-sampling to max. 60 cards for occupancy modelling.
Southern Red Bishop	
Southern-masked Weaver	
Spotted Eagle-owl	
Spotted Thick-knee	

Yellow-rumped Tinkerbird	Species map is based on clipping SABAP2 data to all study provinces (GT, WC, KZN, FS) for occupancy modelling.

***no notes = maps are produced based on occupancy outputs acquired using all SABAP2 data across South Africa, with predictions then being clipped/masked to pentads with >0.99% urban cover in Gauteng, Free State, Kwa-Zulu Natal, and Western Cape provinces.**

Supplementary Table S7: Results of the model selection procedure used for each species to determine the best of four model types (including a null model) to use to conduct the occupancy models for species occurrence within our study ranges. Models are ranked using AIC. The best model set was considered as those where ΔAIC < 2, with the top model listed first. Model weights (AICcWt), cumulative model weights (Cum.Wt) and the number of estimable parameters (K) are also given. Relative to the models used, we compared influences of minimum temperature and average precipitation together and individually on species occurrence.

Species Code	Model	K	ΔAIC	AICcWt	Cum.Wt
AFE	Temp + Rain	5	0.00	1.00	1.00
	Temp	4	233.44	0.00	1.00
	Rain	4	245.42	0.00	1.00
	Null	3	568.68	0.00	1.00
AHH	Rain	4	0.00	0.69	0.69
	Temp + Rain	5	1.58	0.31	1.00
	Temp	4	264.85	0.00	1.00
	Null	3	288.09	0.00	1.00
AH	Temp + Rain	5	0.00	1.00	1.00
	Temp	4	115.86	0.00	1.00
	Rain	4	185.74	0.00	1.00
	Null	3	384.33	0.00	1.00
APF	Temp + Rain	5	0.00	1.00	1.00
	Rain	4	177.27	0.00	1.00
	Temp	4	855.25	0.00	1.00
	Null	3	1217.29	0.00	1.00
AS	Temp + Rain	5	0.00	1.00	1.00
	Rain	4	60.29	0.00	1.00
	Temp	4	1125.13	0.00	1.00
	Null	3	1368.59	0.00	1.00
BS	Temp + Rain	5	0.00	1.00	1.00
	Rain	4	98.72	0.00	1.00
	Temp	4	438.09	0.00	1.00
	Null	3	454.90	0.00	1.00
BM	Temp + Rain	5	0.00	1.00	1.00
	Rain	4	462.48	0.00	1.00
	Temp	4	1120.85	0.00	1.00
	Null	3	2092.13	0.00	1.00
CB	Temp + Rain	5	0.00	1.00	1.00
	Rain	4	11.58	0.00	1.00

	Null	3	167.25	0.00	1.00
	Temp	4	169.26	0.00	1.00
CRC	Temp + Rain	5	0.00	1.00	1.00
	Temp	4	249.11	0.00	1.00
	Rain	4	1231.44	0.00	1.00
	Null	3	1266.15	0.00	1.00
CS	Temp + Rain	5	0.00	0.85	0.85
	Rain	4	3.46	0.15	1.00
	Null	3	32.95	0.00	1.00
	Temp	4	34.80	0.00	1.00
CWE	Temp + Rain	5	0.00	1.00	1.00
	Rain	4	133.97	0.00	1.00
	Temp	4	773.58	0.00	1.00
	Null	3	788.83	0.00	1.00
CM	Temp + Rain	5	0.00	1.00	1.00
	Rain	4	31.43	0.00	1.00
	Temp	4	1331.33	0.00	1.00
	Null	3	1570.77	0.00	1.00
CSt	Temp + Rain	5	0.00	1.00	1.00
	Rain	4	22.24	0.00	1.00
	Null	3	60.49	0.00	1.00
	Temp	4	60.69	0.00	1.00
CBa	Temp + Rain	5	0.00	1.00	1.00
	Rain	4	87.05	0.00	1.00
	Temp	4	1151.76	0.00	1.00
	Null	3	1454.61	0.00	1.00
CE	Temp + Rain	5	0.00	1.00	1.00
	Rain	4	106.57	0.00	1.00
	Temp	4	257.06	0.00	1.00
	Null	3	552.20	0.00	1.00
EG	Temp + Rain	5	0.00	1.00	1.00
	Rain	4	173.96	0.00	1.00
	Temp	4	252.37	0.00	1.00
	Null	3	331.77	0.00	1.00
GGAB	Temp + Rain	5	0.00	1.00	1.00
	Temp	4	12.62	0.00	1.00
	Null	3	47.06	0.00	1.00
	Rain	4	49.01	0.00	1.00
GT	Temp + Rain	5	0.00	1.00	1.00
	Rain	4	33.81	0.00	1.00
	Temp	4	274.82	0.00	1.00
	Null	3	422.10	0.00	1.00
HI	Temp + Rain	5	0.00	1.00	1.00
	Rain	4	158.64	0.00	1.00
	Temp	4	1232.88	0.00	1.00
	Null	3	1273.55	0.00	1.00
HS	Temp + Rain	5	0.00	0.91	0.91
	Rain	4	4.54	0.09	1.00
	Null	3	20.43	0.00	1.00

	Temp	4	21.09	0.00	1.00
LF	Temp + Rain	5	0.00	0.55	0.55
	Temp	4	0.41	0.45	1.00
	Null	3	42.70	0.00	1.00
	Rain	4	44.69	0.00	1.00
LS	Temp + Rain	5	0.00	1.00	1.00
	Temp	4	27.87	0.00	1.00
	Rain	4	35.79	0.00	1.00
	Null	3	113.17	0.00	1.00
MK	Temp + Rain	5	0.00	0.91	0.91
	Rain	4	4.69	0.09	1.00
	Temp	4	253.00	0.00	1.00
	Null	3	292.78	0.00	1.00
DD	Rain	4	0.00	0.47	0.47
	Temp + Rain	5	0.98	0.29	0.75
	Null	3	2.30	0.15	0.90
	Temp	4	3.09	0.10	1.00
OBS	Temp + Rain	5	0.00	0.51	0.51
	Rain	4	0.04	0.49	1.00
	Null	3	12.84	0.00	1.00
	Temp	4	14.86	0.00	1.00
PC	Temp + Rain	5	0.00	1.00	1.00
	Rain	4	15.89	0.00	1.00
	Temp	4	94.64	0.00	1.00
	Null	3	189.20	0.00	1.00
PCT	Temp + Rain	5	0.00	1.00	1.00
	Rain	4	608.05	0.00	1.00
	Temp	4	835.06	0.00	1.00
	Null	3	2114.96	0.00	1.00
RKC	Temp + Rain	5	0.00	1.00	1.00
	Temp	4	459.67	0.00	1.00
	Rain	4	1124.69	0.00	1.00
	Null	3	1308.04	0.00	1.00
RD	Temp + Rain	5	0.00	0.73	0.73
	Temp	4	2.04	0.27	1.00
	Rain	4	21.45	0.00	1.00
	Null	3	54.68	0.00	1.00
RK	Temp + Rain	5	0.00	1.00	1.00
	Rain	4	240.44	0.00	1.00
	Temp	4	568.85	0.00	1.00
	Null	3	1089.86	0.00	1.00
RRP	Temp + Rain	5	0.00	0.97	0.97
	Rain	4	7.09	0.03	1.00
	Temp	4	42.36	0.00	1.00
	Null	3	49.82	0.00	1.00
SMW	Temp + Rain	5	0.00	0.94	0.94
	Temp	4	5.64	0.06	1.00
	Rain	4	84.91	0.00	1.00
	Null	3	130.47	0.00	1.00

SRB	Temp + Rain	5	0.00	1.00	1.00
	Temp	4	512.09	0.00	1.00
	Rain	4	578.90	0.00	1.00
	Null	3	864.09	0.00	1.00
SEO	Rain	4	0.00	0.67	0.67
	Temp + Rain	5	1.42	0.33	1.00
	Null	3	46.79	0.00	1.00
	Temp	4	47.08	0.00	1.00
STK	Temp + Rain	5	0.00	0.99	0.99
	Temp	4	9.01	0.01	1.00
	Rain	4	12.95	0.00	1.00
	Null	3	16.74	0.00	1.00
YRT	Temp + Rain	5	0.00	1.00	1.00
	Temp	4	12.67	0.00	1.00
	Rain	4	152.37	0.00	1.00
	Null	3	307.88	0.00	1.00

Supplementary Table S8: Details of the statistical models used in the analysis, where the dependent variable represents the associated cultural ecosystem estimate (CEE) for each analysis.

Model	Type	Dependent variable	Independent variable	Random effects	Sample size (n)
1	lmer	CEE	log_urban*log_socio	Province	457
2	lm	AFE_CEE	log_urban*log_socio	-	139
3	lm	AHH_CEE	log_urban*log_socio	-	316
4	lm	AH_CEE	log_urban*log_socio	-	97
5	lm	APF_CEE	log_urban*log_socio	-	219
6	lm	AS_CEE	log_urban*log_socio	-	316
7	lm	BM_CEE	log_urban*log_socio	-	219
8	lm	BS_CEE	log_urban*log_socio	-	93
9	lm	CB_CEE	log_urban*log_socio	-	93
10	lm	CBa_CEE	log_urban*log_socio	-	52
11	lm	CE_CEE	log_urban*log_socio	-	219
12	lm	CM_CEE	log_urban*log_socio	-	368
13	lm	CRC_CEE	log_urban*log_socio	-	149
14	lm	CS_CEE	log_urban*log_socio	-	93
15	lm	CSt_CEE	log_urban*log_socio	-	93
16	lm	CWE_CEE	log_urban*log_socio	-	219
17	lm	DD_CEE	log_urban*log_socio	-	93
18	lm	EG_CEE	log_urban*log_socio	-	190
19	lm	GGAB_CEE	log_urban*log_socio	-	97
20	lm	GT_CEE	log_urban*log_socio	-	219
21	lm	HI_CEE	log_urban*log_socio	-	461
22	lm	HS_CEE	log_urban*log_socio	-	271
23	lm	LF_CEE	log_urban*log_socio	-	52
24	lm	LS_CEE	log_urban*log_socio	-	52
25	lm	MK_CEE	log_urban*log_socio	-	93
26	lm	OBS_CEE	log_urban*log_socio	-	93

27	lm	PC_CEE	log_urban*log_socio	-	190
28	lm	PCT_CEE	log_urban*log_socio	-	219
29	lm	RD_CEE	log_urban*log_socio	-	461
30	lm	RK_CEE	log_urban*log_socio	-	93
31	lm	RKC_CEE	log_urban*log_socio	-	52
32	lm	RRP_CEE	log_urban*log_socio	-	97
33	lm	SEO_CEE	log_urban*log_socio	-	97
34	lm	SMW_CEE	log_urban*log_socio	-	52
35	lm	SRB_CEE	log_urban*log_socio	-	52
36	lm	STK_CEE	log_urban*log_socio	-	149
37	lm	YRT_CEE	log_urban*log_socio	-	219

Supplementary Table S9: Model statistical outputs showing the estimates, standard error, the lower and upper limits of the 95 % confidence interval, and p-values of all model variables of each predictor variable relative to the cultural ecosystem estimate (CEE) of the all birds combined. Significant variables for each model are presented in bold text.

Model	Predictor	Estimate	Standard Error	Upper Limit	Lower Limit	P-value
1	Urban	1.584	0.407	0.772	2.369	0.0001
	Socioeconomic	1.195	0.422	0.330	2.005	0.0049
	Urban*socioeconomic	0.950	0.393	0.184	1.724	0.0161

Supplementary Table S10: Model statistical outputs showing the estimates, standard error, the lower and upper limits of the 95 % confidence interval, and p-values of all model variables of each predictor variable relative to the cultural ecosystem estimate (CEE) of each individual study species assessed. Significant variables for each model are presented in bold text.

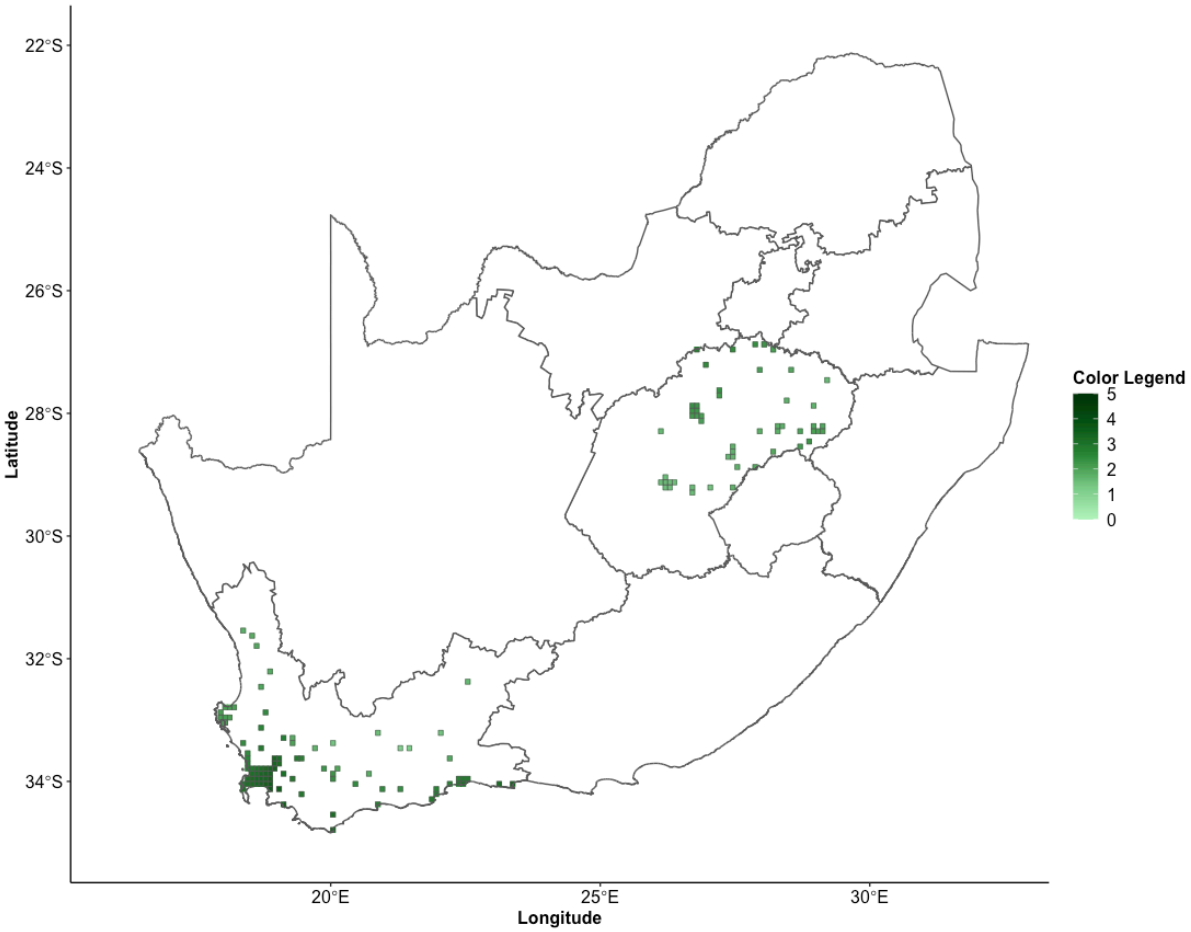
Model	Species	Predictor	Estimate	Standard Error	Upper Limit	Lower Limit	P-value
2	African Fish Eagle	**Urban**	**0.209**	**0.049**	**0.112**	**0.306**	**<2e-16**
		Socioeconomic	**0.185**	**0.049**	**0.086**	**0.285**	**0.0003**
		Urban*socioeconomic	-0.014	0.054	-0.120	0.093	0.8014
3	African Harrier-hawk	**Urban**	**-0.106**	**0.031**	**-0.167**	**-0.045**	**0.0007**
		Socioeconomic	**0.095**	**0.031**	**0.033**	**0.156**	**0.0027**
		Urban*socioeconomic	**0.082**	**0.030**	**0.023**	**0.140**	**0.0065**
4	African Hoopoe	Urban	0.074	0.051	-0.027	0.176	0.1500
		Socioeconomic	**0.126**	**0.056**	**0.015**	**0.237**	**0.0263**
		Urban*socioeconomic	0.075	0.075	-0.019	0.169	0.1146
5	African Paradise-flycatcher	Urban	0.041	0.038	-0.034	0.116	0.2818
		Socioeconomic	0.019	0.037	-0.053	0.091	0.6060
		Urban*socioeconomic	0.050	0.30	-0.009	0.109	0.0975
6	Amethyst Sunbird	**Urban**	**-0.174**	**0.045**	**-0.261**	**-0.086**	**0.0002**
		Socioeconomic	**0.132**	**0.045**	**0.043**	**0.220**	**0.0037**
		Urban*socioeconomic	**0.173**	**0.043**	**0.089**	**0.257**	**6.45e-05**
7	Bronze Mannikin	**Urban**	**0.193**	**0.090**	**0.016**	**0.370**	**0.0332**
		Socioeconomic	0.108	0.086	-0.062	0.278	0.2118
		Urban*socioeconomic	0.138	0.071	-0.001	0.277	0.0515

8	Black Sparrowhawk	Urban	0.148	0.083	-0.016	0.312	0.007
		Socioeconomic	0.033	0.081	-0.128	0.194	0.683
		Urban*socioeconomic	-0.125	0.083	-0.290	0.040	0.135
9	Cape Bulbul	Urban	0.075	0.069	-0.063	0.212	0.2849
		Socioeconomic	**0.213**	**0.068**	**0.077**	**0.348**	**0.0024**
		Urban*socioeconomic	**0.192**	**0.069**	**0.054**	**0.329**	**0.0070**
10	Crested Barbet	Urban	-0.040	0.053	-0.145	0.066	0.454
		Socioeconomic	-0.028	0.054	-0.136	0.081	0.610
		Urban*socioeconomic	-0.002	0.057	-0.117	0.113	0.973
11	Crowned Eagle	**Urban**	**0.319**	**0.096**	**0.129**	**0.508**	**0.0011**
		Socioeconomic	0.122	0.092	-0.060	0.304	0.1892
		Urban*socioeconomic	0.126	0.076	-0.022	0.275	0.0956
12	Common Myna	Urban	0.015	0.037	-0.057	0.088	0.6737
		Socioeconomic	**0.084**	**0.037**	**0.011**	**0.157**	**0.0239**
		Urban*socioeconomic	0.025	0.035	-0.044	0.095	0.4739
13	Cape Robin-chat	Urban	**-0.190**	**0.049**	**-0.287**	**-0.092**	**0.0002**
		Socioeconomic	0.035	0.056	-0.076	0.145	0.5360
		Urban*socioeconomic	**0.108**	**0.053**	**0.003**	**0.214**	**0.0448**
14	Cape Sugarbird	**Urban**	**0.512**	**0.174**	**0.167**	**0.857**	**0.0041**
		Socioeconomic	0.138	0.171	-0.202	0.477	0.4229
		Urban*socioeconomic	-0.155	0.174	-0.501	0.191	0.3753
15	Common Starling	Urban	0.134	0.091	-0.046	0.314	0.143
		Socioeconomic	0.146	0.089	-0.030	0.324	0.101
		Urban*socioeconomic	-0.023	0.091	-0.203	0.157	0.801
16	Cape White-eye	Urban	-0.045	0.047	-0.137	0.048	0.3401
		Socioeconomic	**0.116**	**0.045**	**0.027**	**0.204**	**0.0109**
		Urban*socioeconomic	-0.010	0.037	-0.083	0.063	0.7855
17	Mallard (Domestic Duck)	**Urban**	**0.132**	**0.043**	**0.047**	**0.218**	**0.0028**
		Socioeconomic	-0.005	0.042	-0.089	0.079	0.9080
		Urban*socioeconomic	-0.078	0.043	-0.163	0.007	0.0733
18	Egyptian Goose	Urban	0.0739	0.052	-0.028	0.176	0.154
		Socioeconomic	-0.045	0.053	-0.149	0.060	0.402
		Urban*socioeconomic	0.056	0.054	-0.051	0.162	0.306
19	Grey Go-away-bird	Urban	0.105	0.119	-0.131	0.340	0.3800
		Socioeconomic	**0.293**	**0.129**	**0.036**	**0.549**	**0.0256**
		Urban*socioeconomic	0.204	0.109	-0.013	0.420	0.0646
20	Green Twinspot	**Urban**	**0.405**	**0.116**	**0.176**	**0.633**	**0.0006**
		Socioeconomic	0.176	0.111	-0.043	0.396	0.1142
		Urban*socioeconomic	0.134	0.091	-0.045	0.314	0.1405
21	Hadeda Ibis	Urban	-0.012	0.031	-0.072	0.049	0.7040
		Socioeconomic	**-0.129**	**0.032**	**-0.191**	**-0.067**	**5.18e-05**
		Urban*socioeconomic	0.060	0.033	-0.004	0.124	0.0662
22	House Sparrow	Urban	0.006	0.023	-0.039	0.051	0.802
		Socioeconomic	-0.006	0.022	-0.049	0.038	0.793
		Urban*socioeconomic	-0.016	0.018	-0.052	0.020	0.373
23	Lanner Falcon	Urban	-0.000	0.020	-0.040	0.039	0.980
		Socioeconomic	0.003	0.020	-0.038	0.044	0.870
		Urban*socioeconomic	0.013	0.022	-0.031	0.056	0.561
24	Little Swift	Urban	-0.017	0.019	-0.055	0.021	0.373

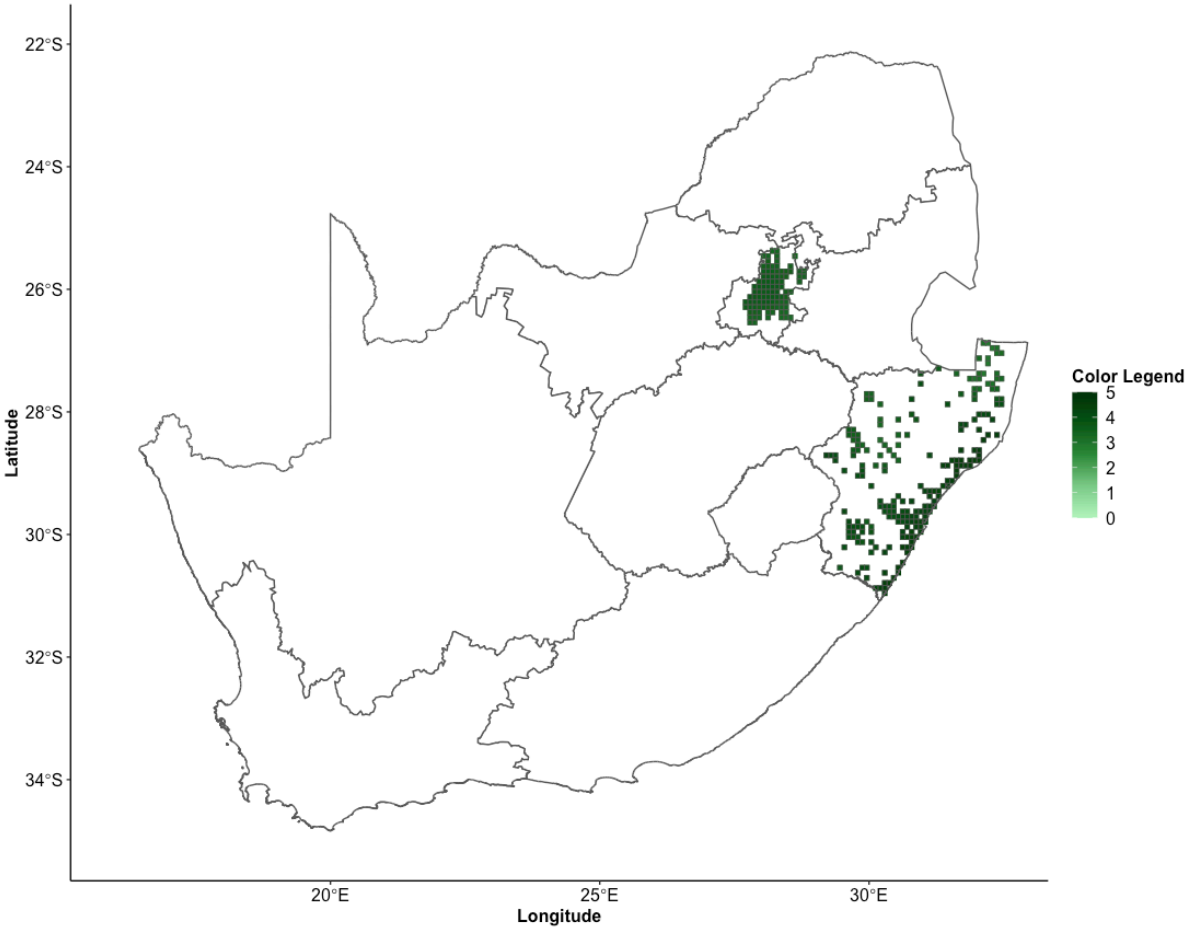
		Socioeconomic	-0.009	0.020	-0.049	0.030	0.632
		Urban*socioeconomic	-0.018	0.021	-0.059	0.024	0.394
25	Malachite Kingfisher	Urban	**0.193**	**0.070**	**0.054**	**0.333**	**0.0072**
		Socioeconomic	0.086	0.069	-0.051	0.224	0.2138
		Urban*socioeconomic	-0.032	0.070	-0.172	0.107	0.6472
26	Orange-breasted Sunbird	**Urban**	**0.408**	**0.160**	**0.091**	**0.725**	**0.0123**
		Socioeconomic	0.091	0.157	-0.221	0.403	0.5625
		Urban*socioeconomic	-0.181	0.160	-0.498	0.137	0.2617
27	Pied Crow	**Urban**	**-0.113**	**0.040**	**-0.193**	**-0.034**	**0.0054**
		Socioeconomic	0.067	0.041	-0.015	0.149	0.1080
		Urban*socioeconomic	-0.040	0.042	-0.123	0.043	0.3429
28	Purple-crested Turaco	**Urban**	**0.373**	**0.131**	**0.116**	**0.631**	**0.0047**
		Socioeconomic	0.139	0.125	-0.108	0.386	0.2690
		Urban*socioeconomic	**0.232**	**0.103**	**0.030**	**0.434**	**0.0244**
29	Rock Dove	Urban	0.008	0.015	-0.021	0.037	0.5915
		Socioeconomic	-0.029	0.015	-0.059	0.001	0.0554
		Urban*socioeconomic	0.007	0.016	-0.024	0.037	0.6683
30	Rock Kestrel	**Urban**	**-0.336**	**0.090**	**-0.515**	**-0.157**	**0.0003**
		Socioeconomic	-0.004	0.089	-0.180	0.173	0.9668
		Urban*socioeconomic	0.167	0.090	-0.012	0.347	0.0673
31	Red-knobbed Coot	Urban	0.002	0.057	-0.112	0.116	0.975
		Socioeconomic	0.002	0.058	-0.115	0.120	0.968
		Urban*socioeconomic	0.049	0.062	-0.075	0.173	0.428
32	Rose-ringed (Ring-necked) Parakeet	**Urban**	**0.508**	**0.124**	**0.263**	**0.753**	**8.41e-05**
		Socioeconomic	**0.564**	**0.134**	**0.297**	**0.831**	**6.28e-05**
		Urban*socioeconomic	**0.258**	**0.114**	**0.032**	**0.483**	**0.0257**
33	Spotted Eagle-owl	Urban	-0.029	0.049	-0.126	0.069	0.5588
		Socioeconomic	**0.110**	**0.053**	**0.004**	**0.216**	**0.0429**
		Urban*socioeconomic	0.083	0.045	-0.007	0.172	0.0695
34	Southern-masked Weaver	Urban	0.042	0.031	-0.021	0.104	0.189
		Socioeconomic	-0.011	0.032	-0.076	0.053	0.727
		Urban*socioeconomic	0.023	0.034	-0.045	0.091	0.498
35	Southern Red Bishop	Urban	0.002	0.032	-0.062	0.066	0.957
		Socioeconomic	0.003	0.033	-0.063	0.069	0.929
		Urban*socioeconomic	0.034	0.035	-0.036	0.104	0.332
36	Spotted Thick-knee	Urban	-0.054	0.029	-0.110	0.003	0.0633
		Socioeconomic	0.037	0.032	-0.027	0.101	0.2550
		Urban*socioeconomic	**0.062**	**0.031**	**0.000**	**0.123**	**0.0487**
37	Yellow-rumped Tinkerbird	Urban	0.479	0.122	0.240	0.719	0.0001
		Socioeconomic	0.081	0.117	-0.149	0.311	0.4869
		Urban*socioeconomic	0.157	0.100	-0.031	0.345	0.1007

Appendix B: Supplementary Figures

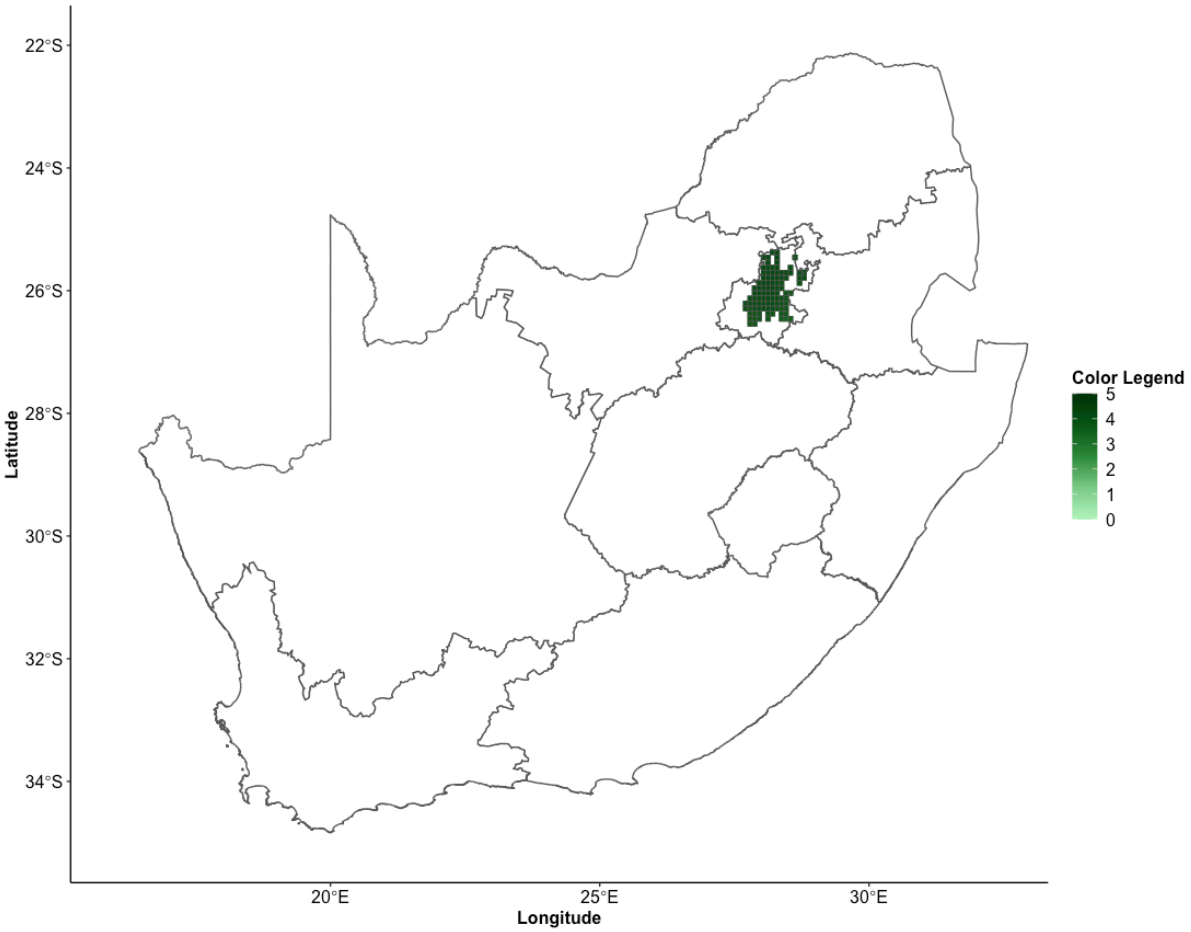
The following 36 figures display the Cultural Ecosystem Services Index (CES Index) for the species that were included in the final analysis. The CES Index, as described in the methods for Chapter II, were derived from the likeability scores of a species within a particular pentad multiplied by the species occurrence/occupancy of the pentad. These figures display the spatial distribution of the cultural values for each bird species across urban areas with >1 % urban cover within the provinces that each species was surveyed in.



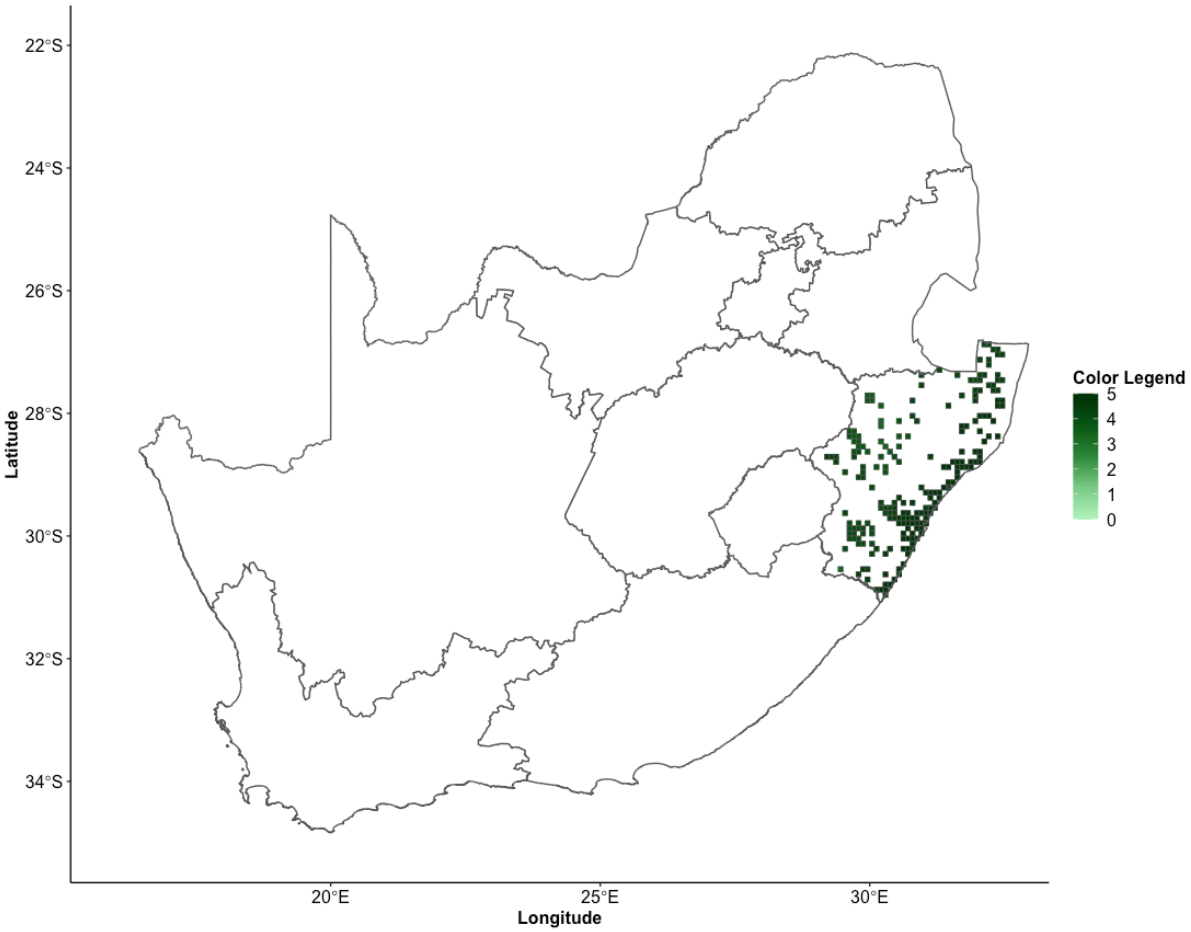
Supplementary Figure S1: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the African Fish Eagle (*Haliaeetus vocifer*) across pentads with greater than 1 % urban cover in the provinces of the Western Cape and Free State where the species was surveyed.



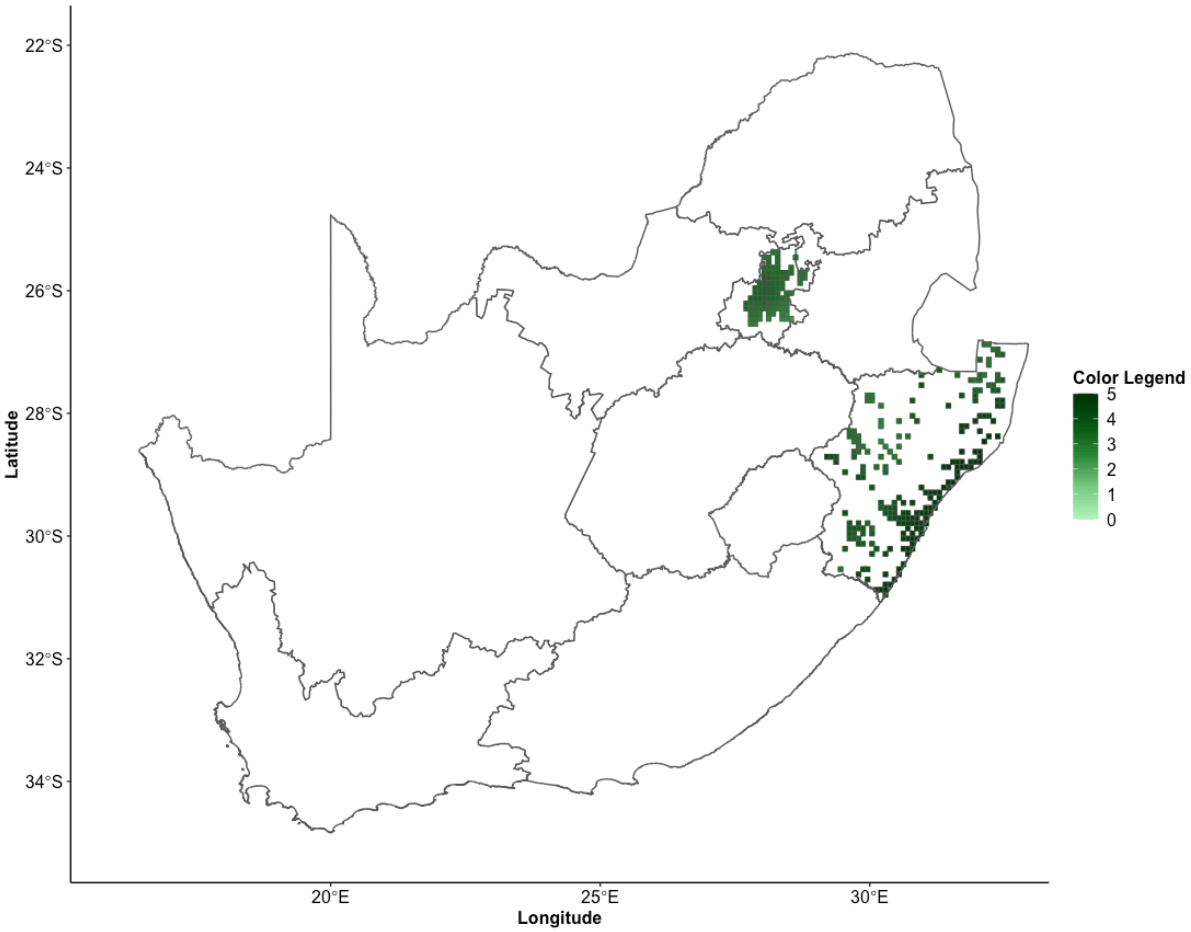
Supplementary Figure S2: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the African Harrier-hawk (*Polyboroides typus*) across pentads with greater than 1 % urban cover in the provinces of the Gauteng and KwaZulu-Natal where the species was surveyed.



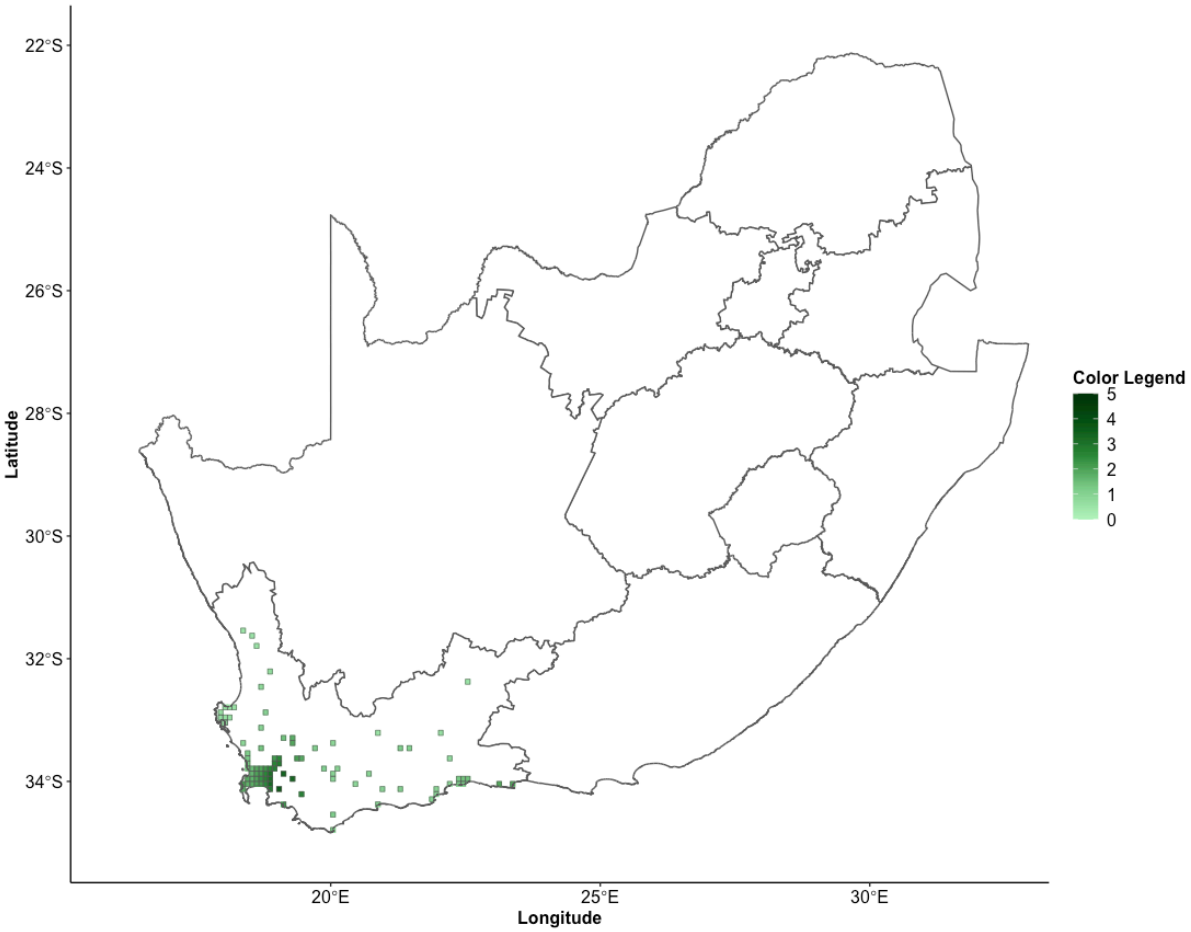
Supplementary Figure S3: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the African Hoopoe (*Upupa africana*) across pentads with greater than 1 % urban cover in the province of Gauteng where the species was surveyed.



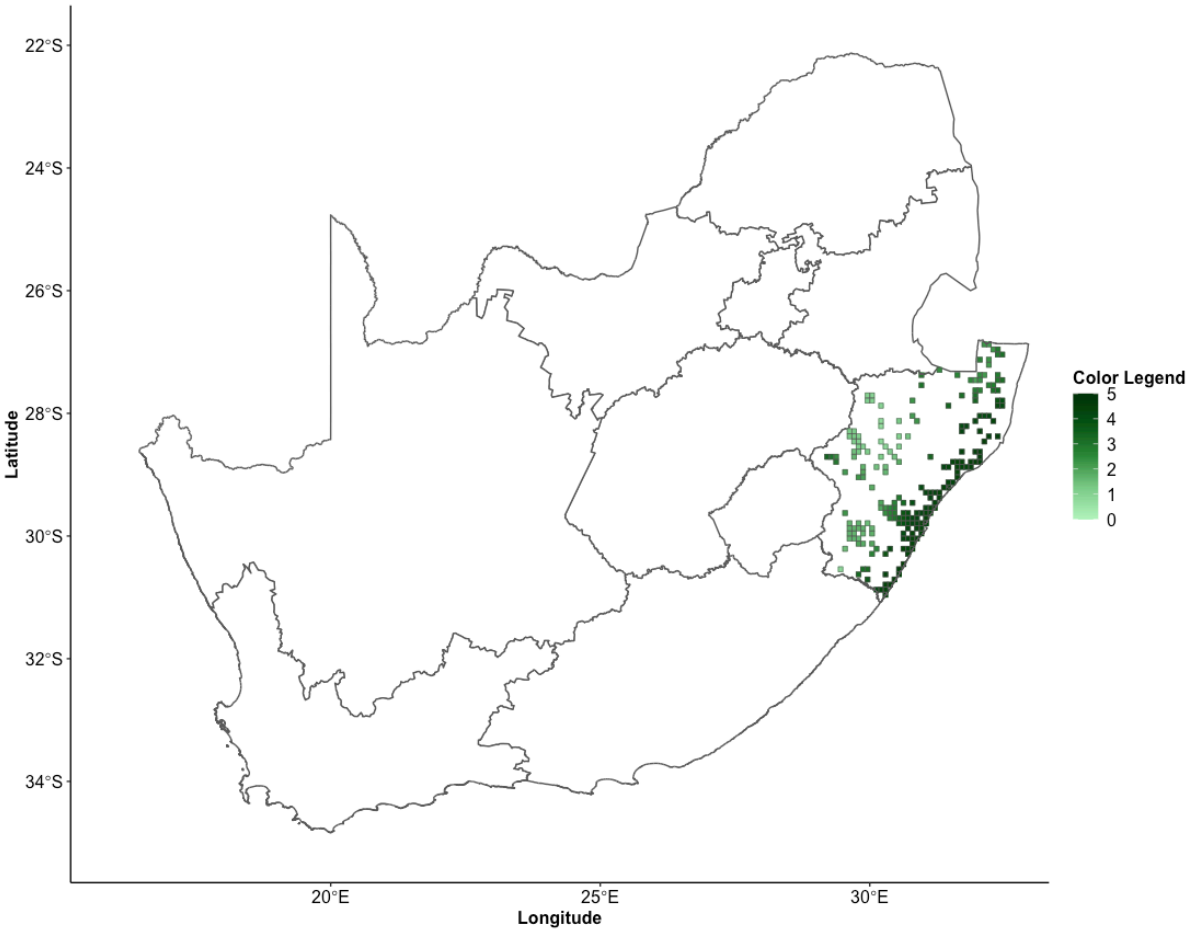
Supplementary Figure S4: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the African Paradise-flycatcher (*Terpsiphone viridis*) across pentads with greater than 1 % urban cover in the province of KwaZulu-Natal where the species was surveyed.



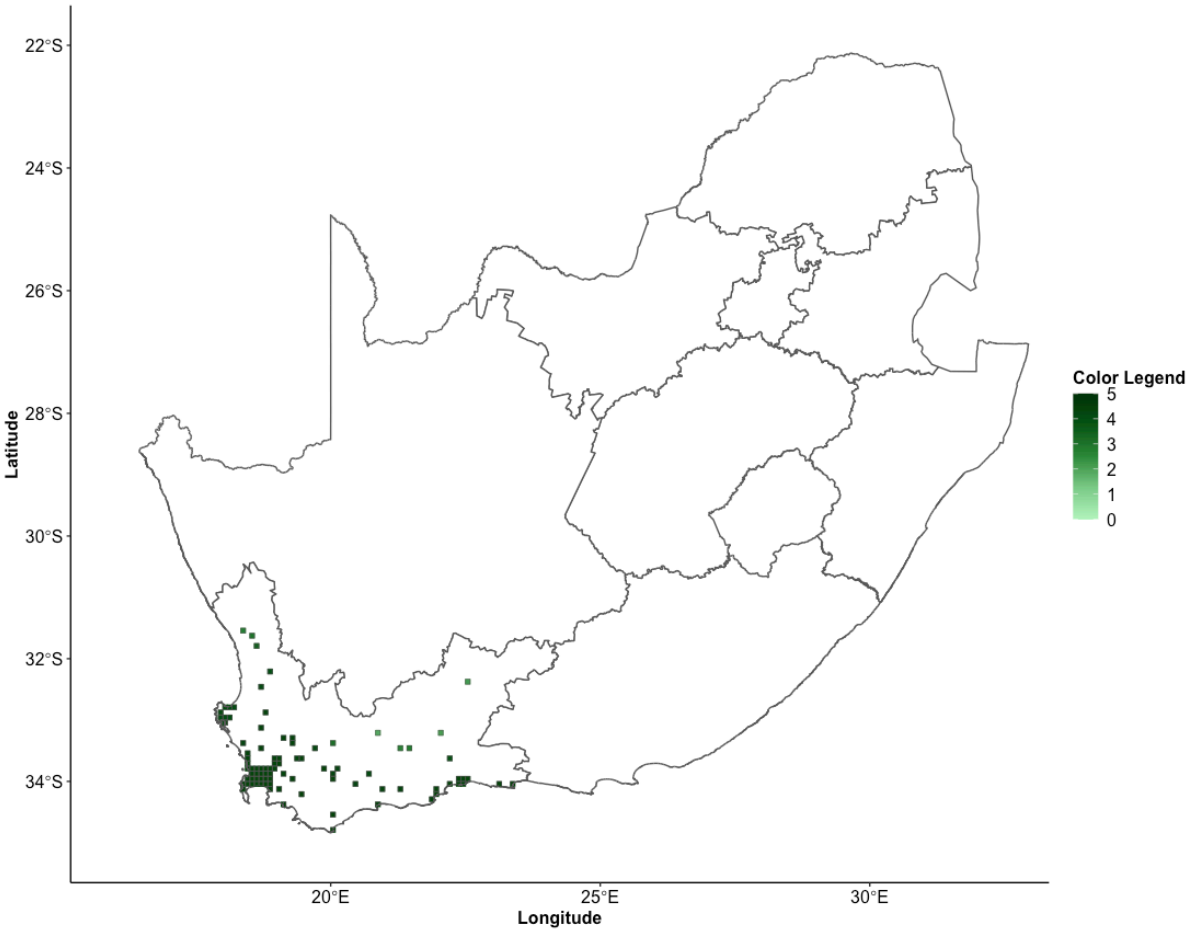
Supplementary Figure S5: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Amethyst Sunbird (*Chalcomitra amethystina*) across pentads with greater than 1 % urban cover in the provinces of the Western Cape and Free State where the species was surveyed.



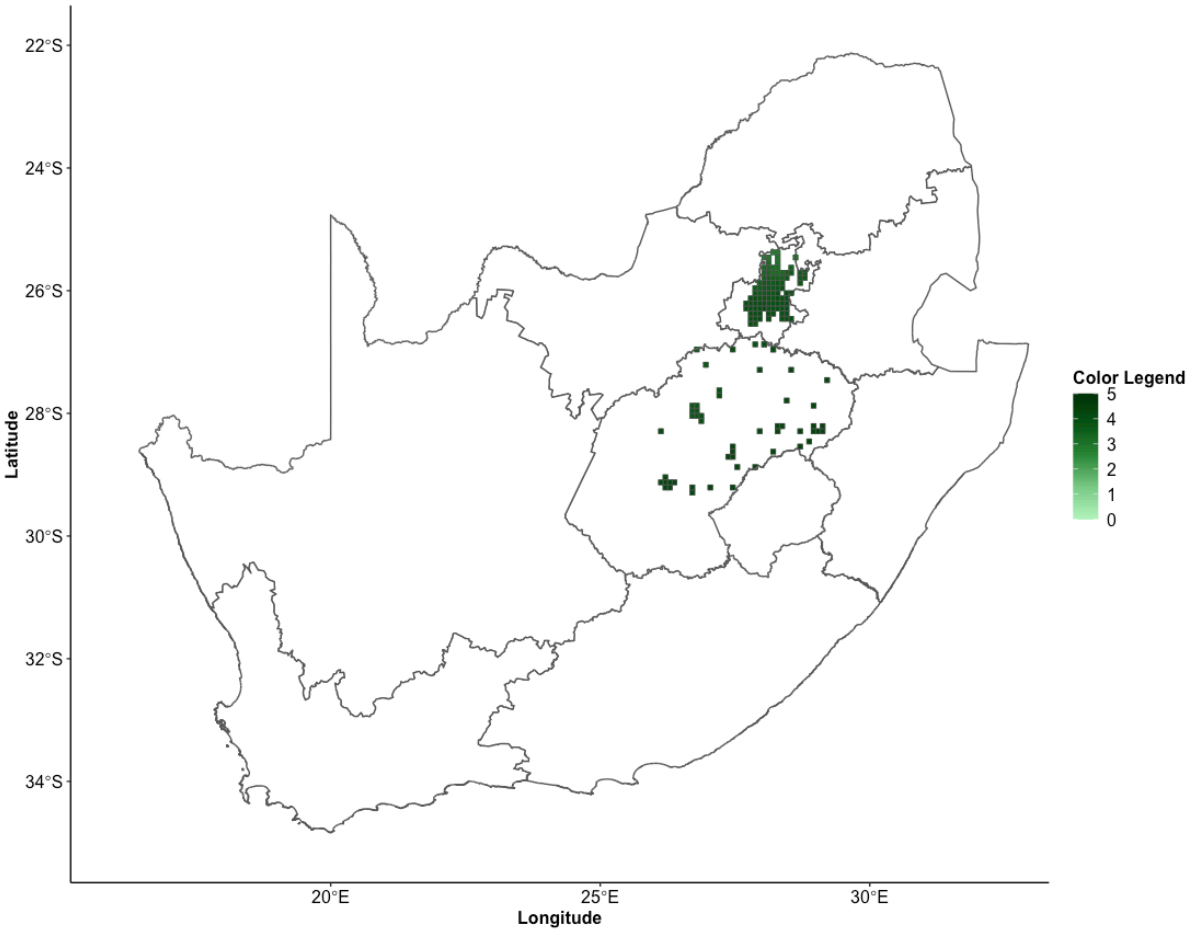
Supplementary Figure S6: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Black Sparrowhawk (*Accipiter melanoleucus*) across pentads with greater than 1 % urban cover in the province of the Western Cape where the species was surveyed.



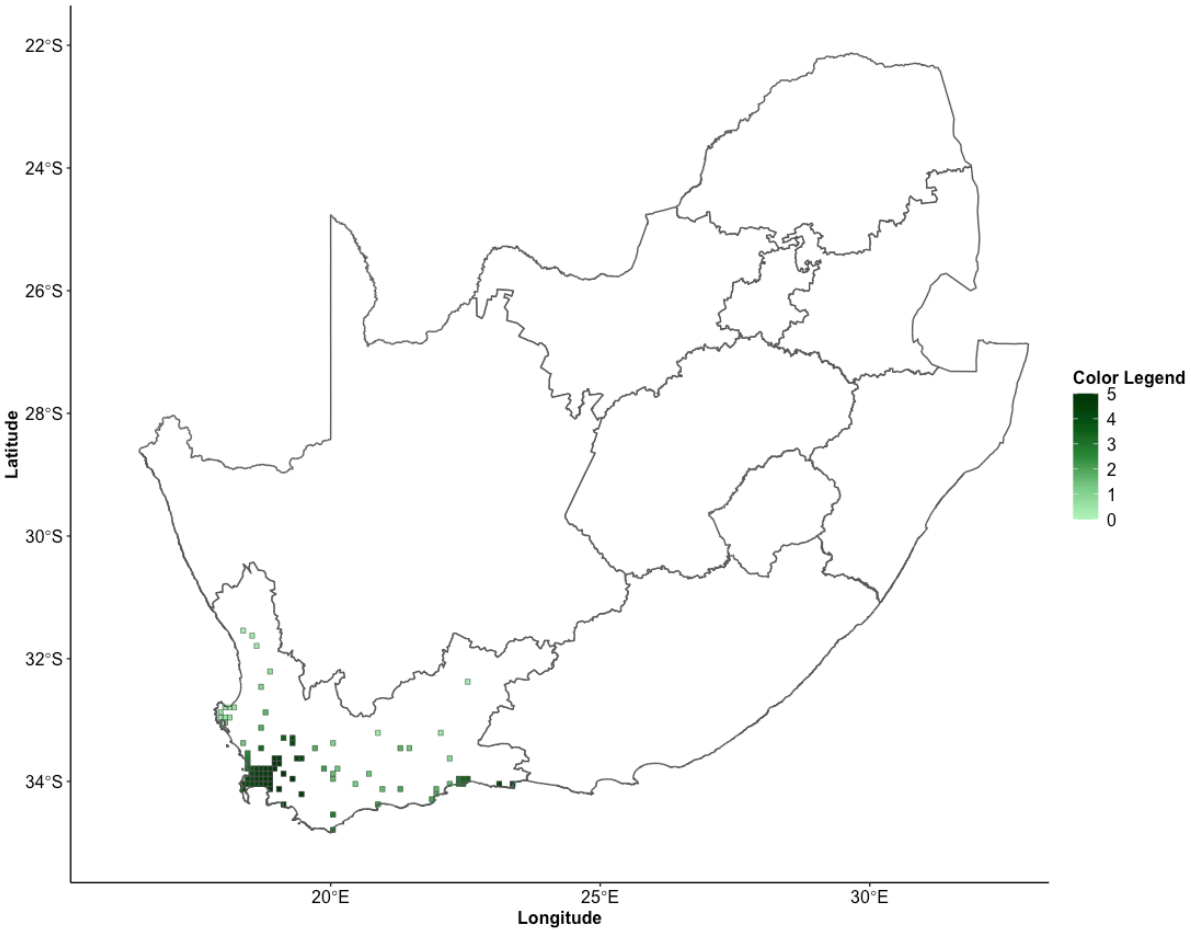
Supplementary Figure S7: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Bronze Mannikin (*Spermestes cucullatus*) across pentads with greater than 1 % urban cover in the provinces of KwaZulu-Natal where the species was surveyed.



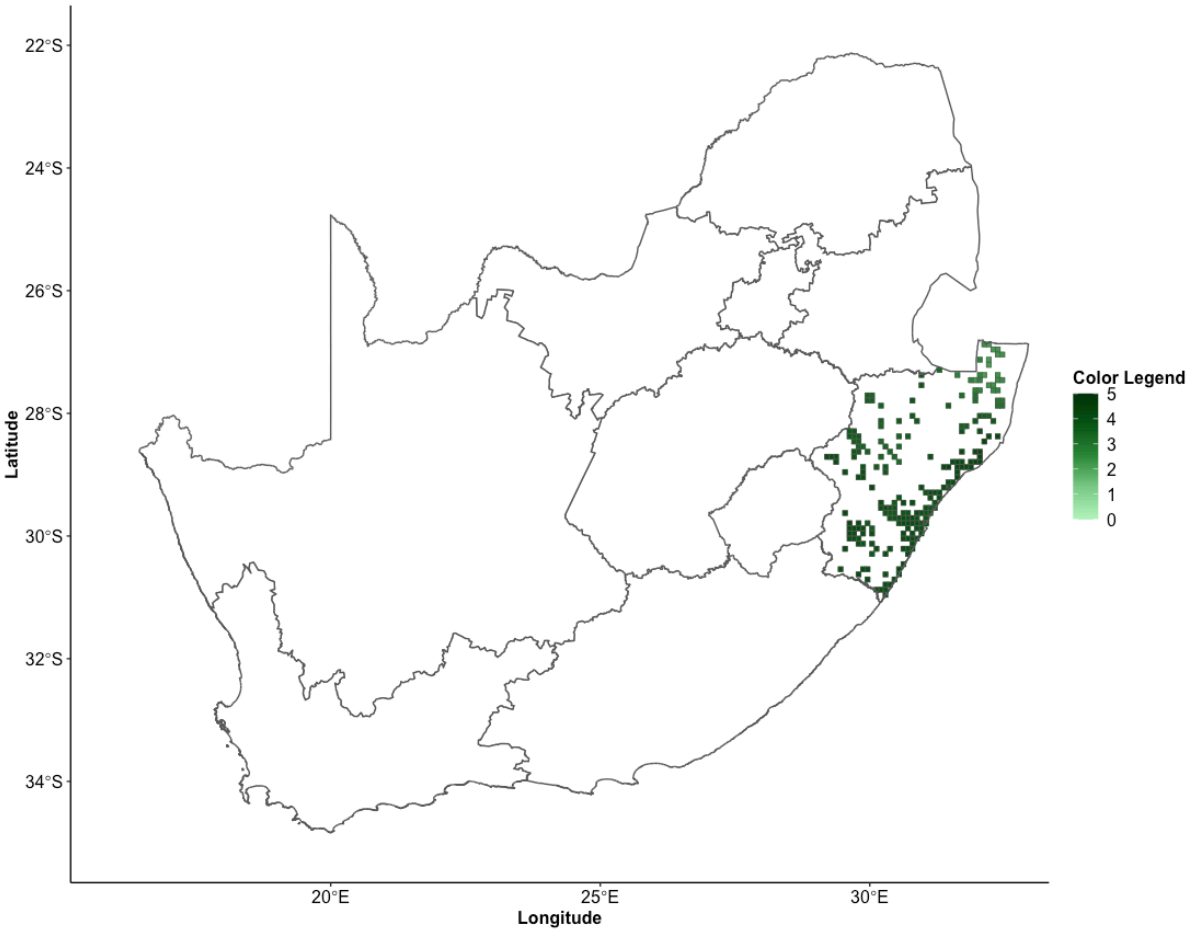
Supplementary Figure S8: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Cape Bulbul (*Pycnonotus capensis*) across pentads with greater than 1 % urban cover in the province of the Western Cape where the species was surveyed.



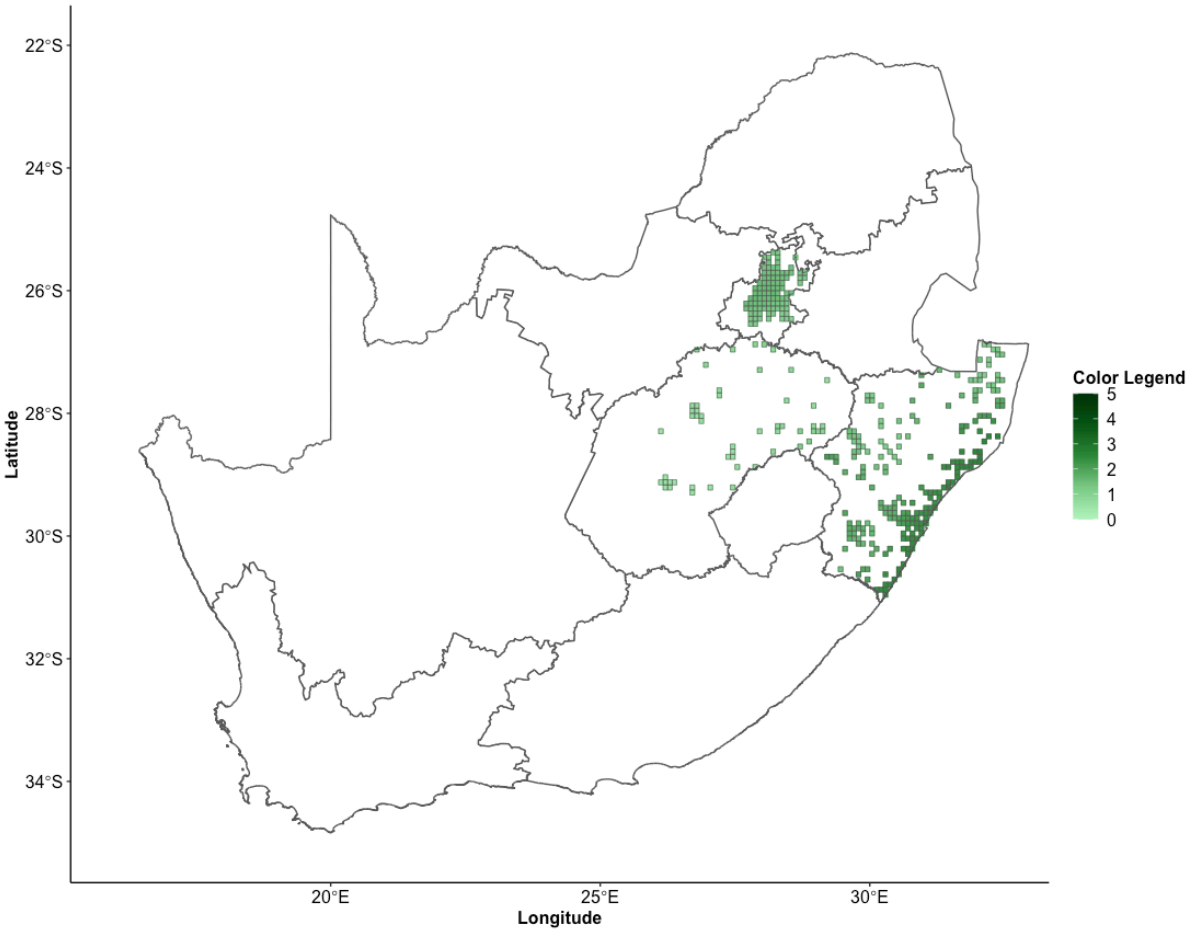
Supplementary Figure S9: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Cape Robin-chat (*Cossypha caffra*) across pentads with greater than 1 % urban cover in the provinces of Gauteng and Free State where the species was surveyed.



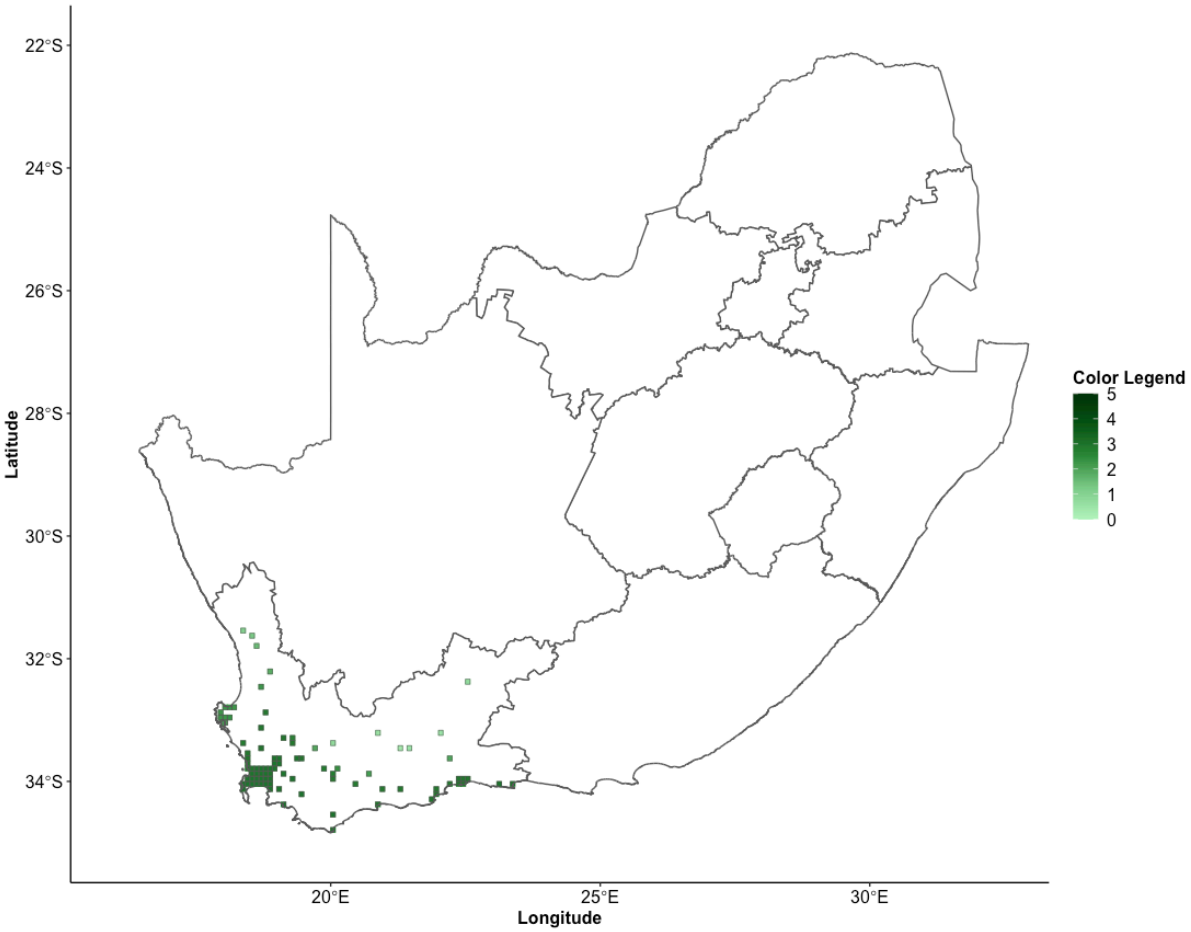
Supplementary Figure S10: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Cape Sugarbird (*Promerops cafer*) across pentads with greater than 1 % urban cover in the province of the Western Cape where the species was surveyed.



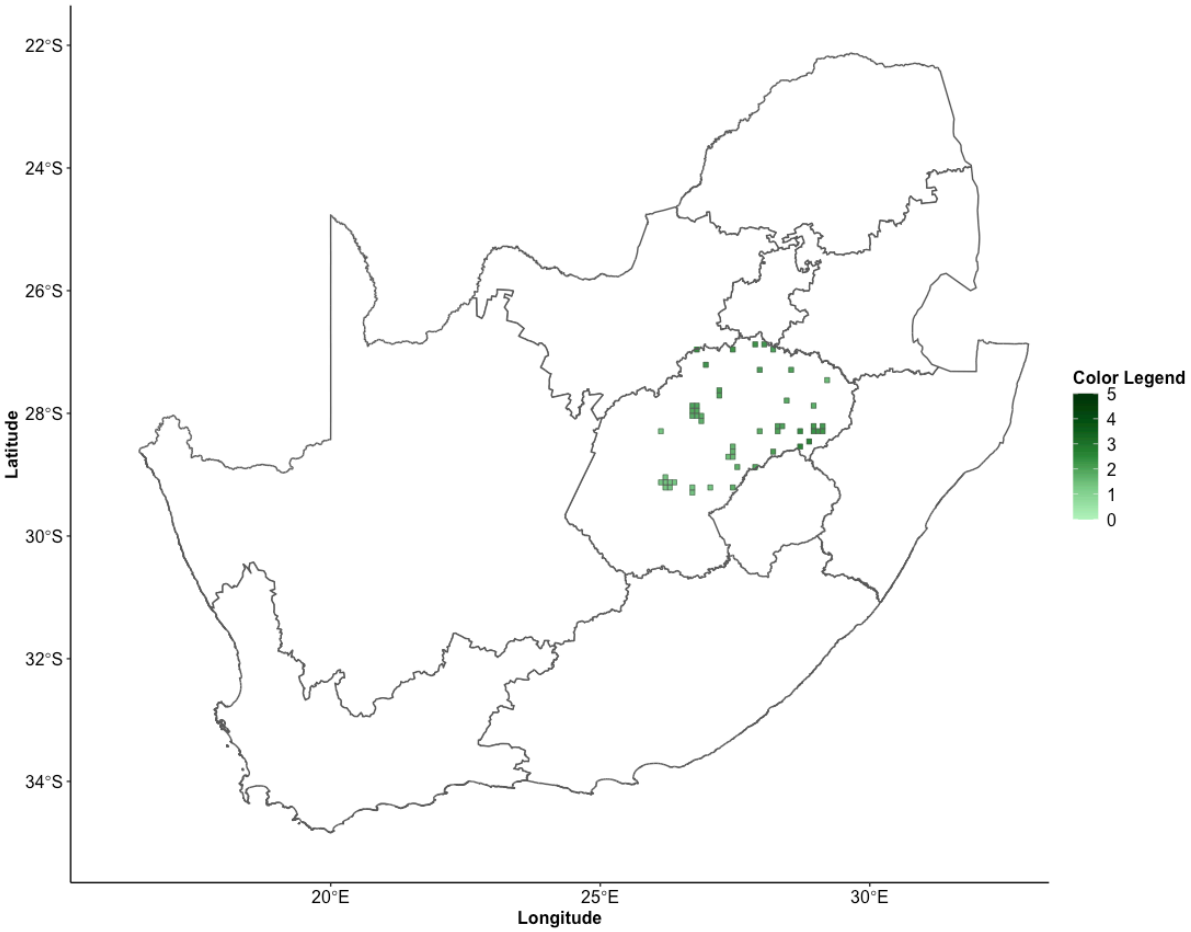
Supplementary Figure S11: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Cape White-eye (*Zosterops capensis*) across pentads with greater than 1 % urban cover in the province of KwaZulu-Natal where the species was surveyed.



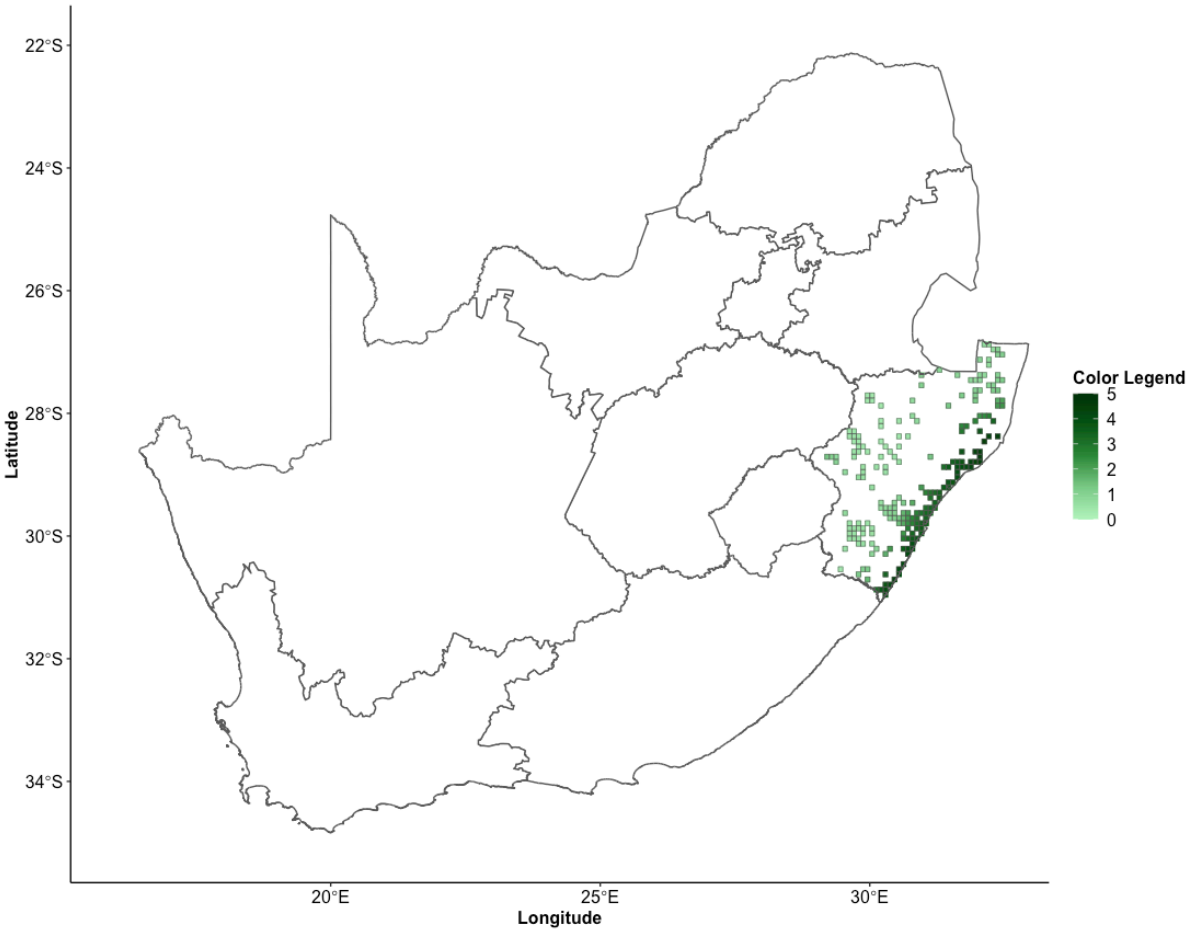
Supplementary Figure S12: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Common Myna (*Acridotheres tristis*) across pentads with greater than 1 % urban cover in the provinces of Gauteng, KwaZulu-Natal, and Free State where the species was surveyed.



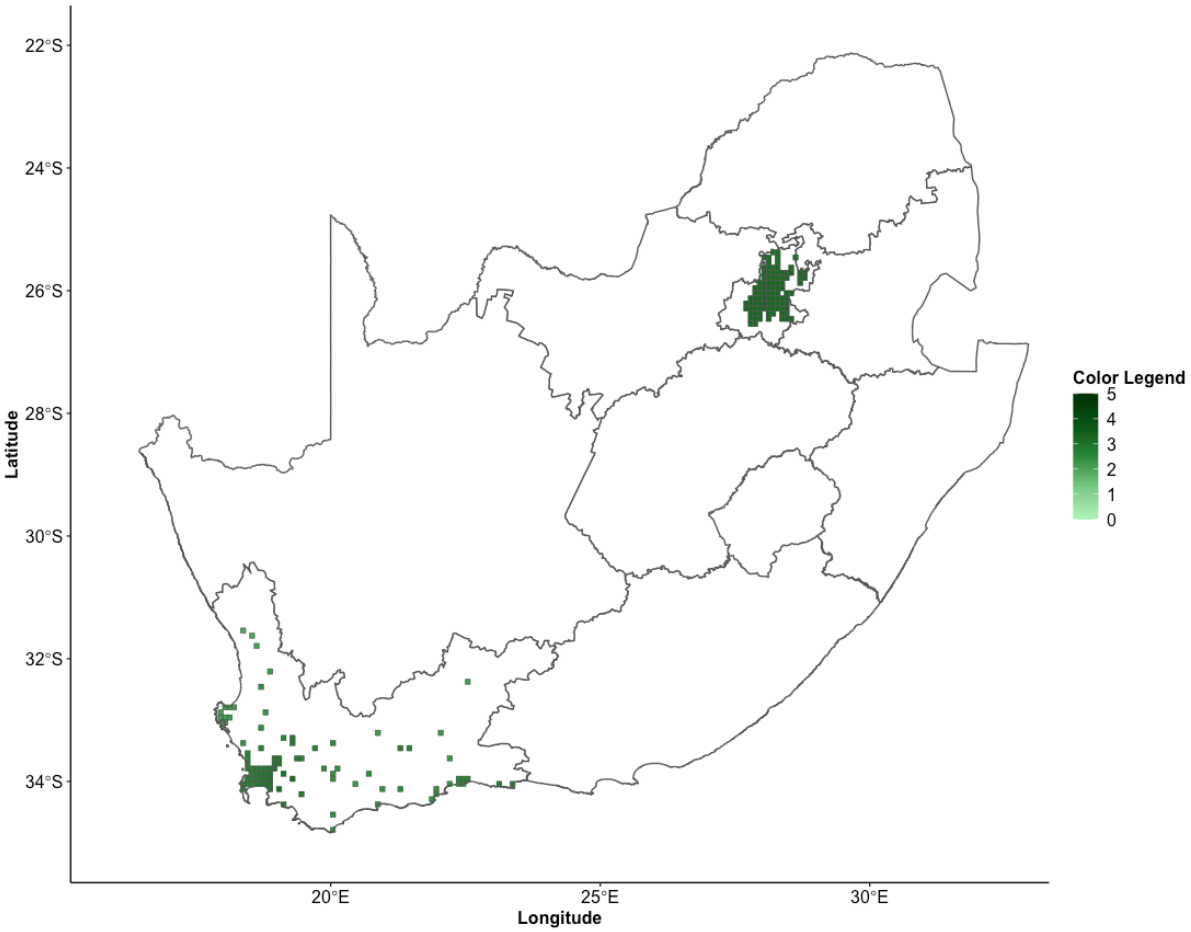
Supplementary Figure S13: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Common Starling (*Sturnus vulgaris*) across pentads with greater than 1 % urban cover in the province of the Western Cape where the species was surveyed.



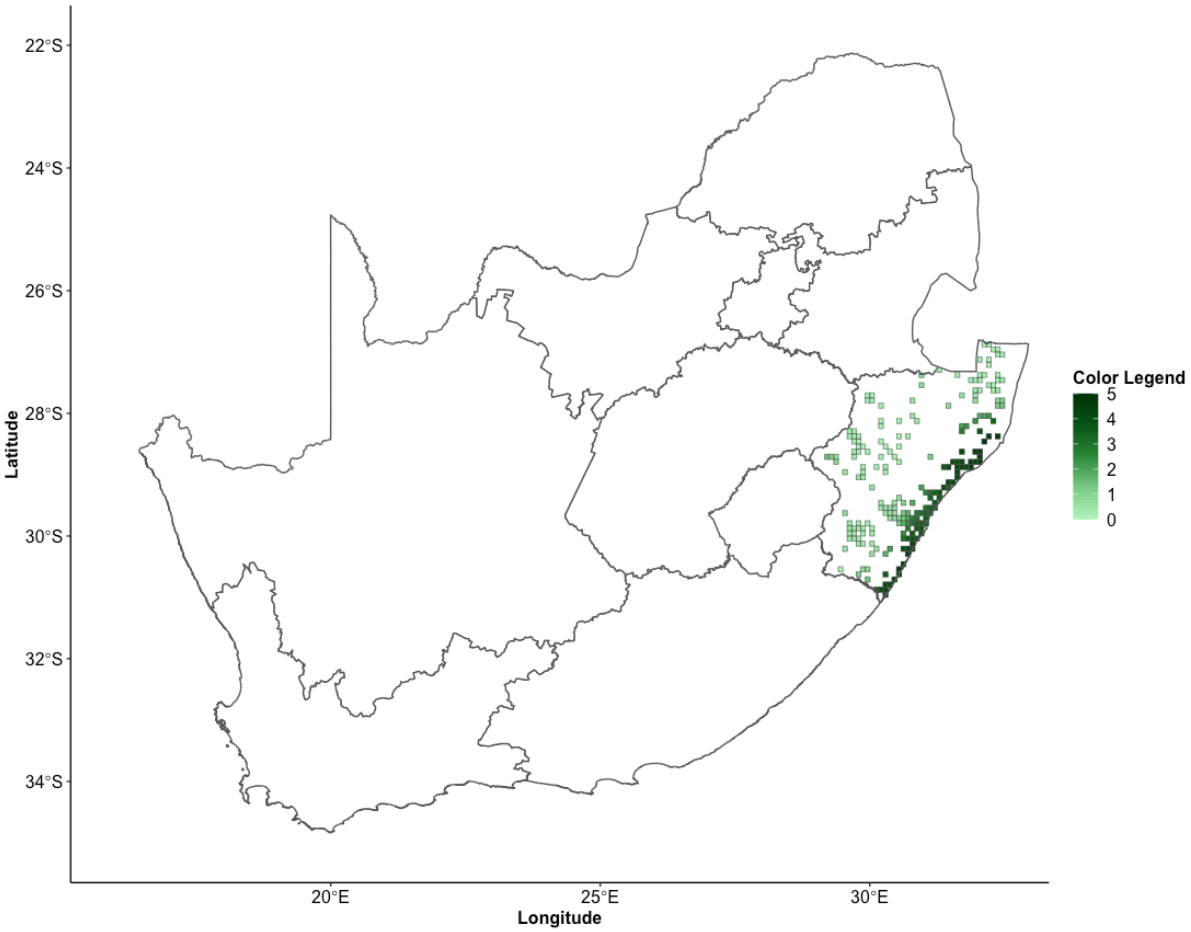
Supplementary Figure S14: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Crested Barbet (*Trachyphonus vaillantii*) across pentads with greater than 1 % urban cover in the province of the Free State where the species was surveyed.



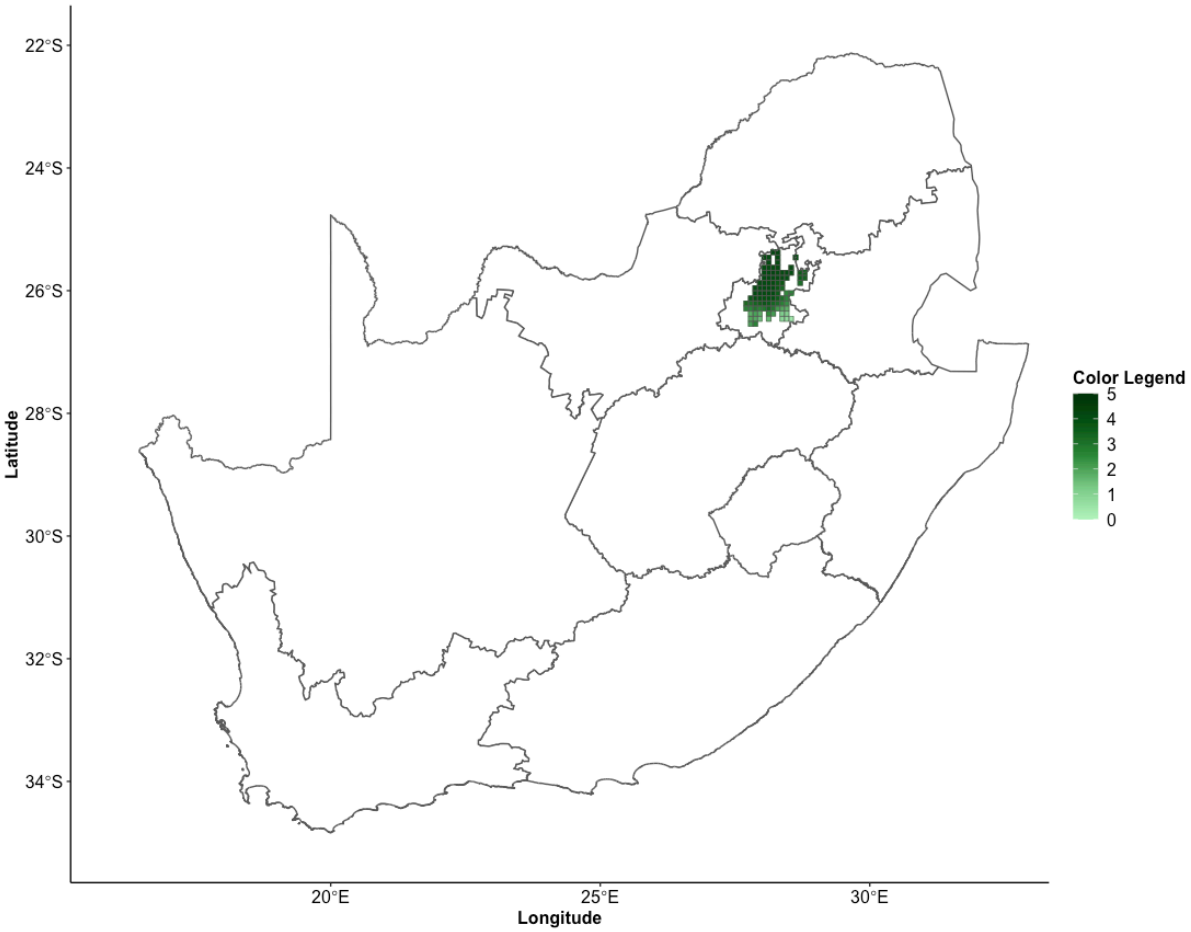
Supplementary Figure S15: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Crowned Eagle (*Stephanoaetus coronatus*) across pentads with greater than 1 % urban cover in the province of KwaZulu-Natal where the species was surveyed.



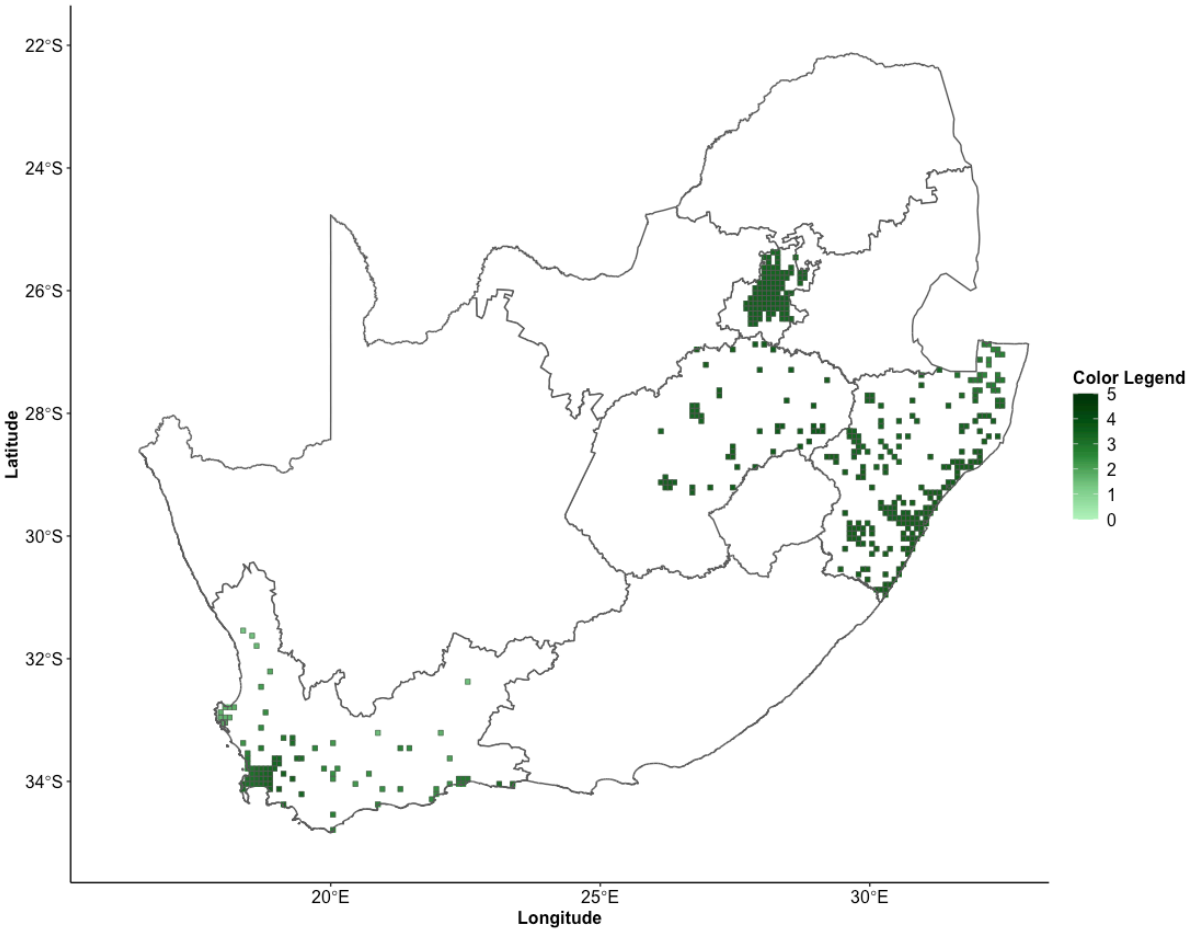
Supplementary Figure S16: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Egyptian Goose (*Alopochen aegyptiaca*) across pentads with greater than 1 % urban cover in the provinces of Gauteng and the Western Cape where the species was surveyed.



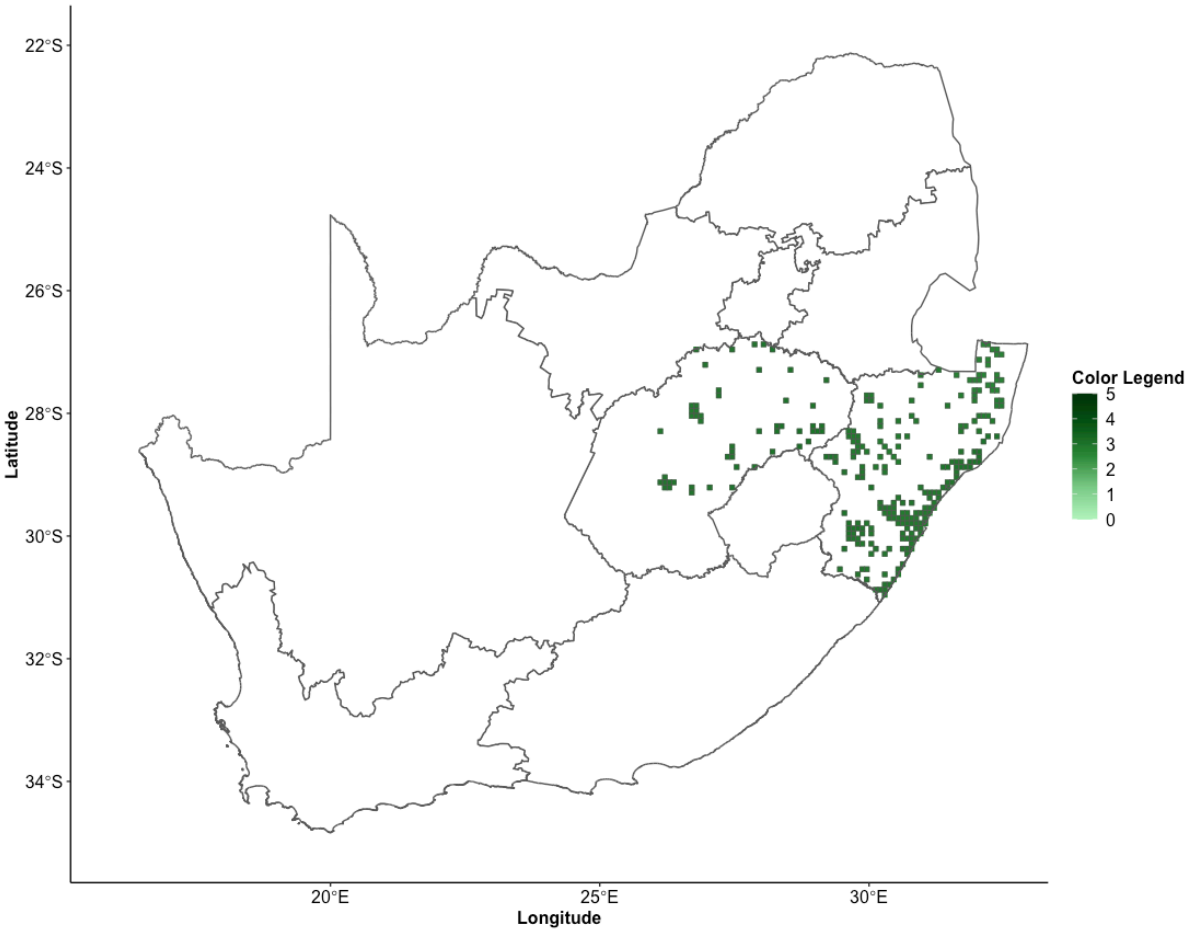
Supplementary Figure S17: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Green Twinspot (*Mandingoa nitidula*) across pentads with greater than 1 % urban cover in the province of KwaZulu-Natal where the species was surveyed.



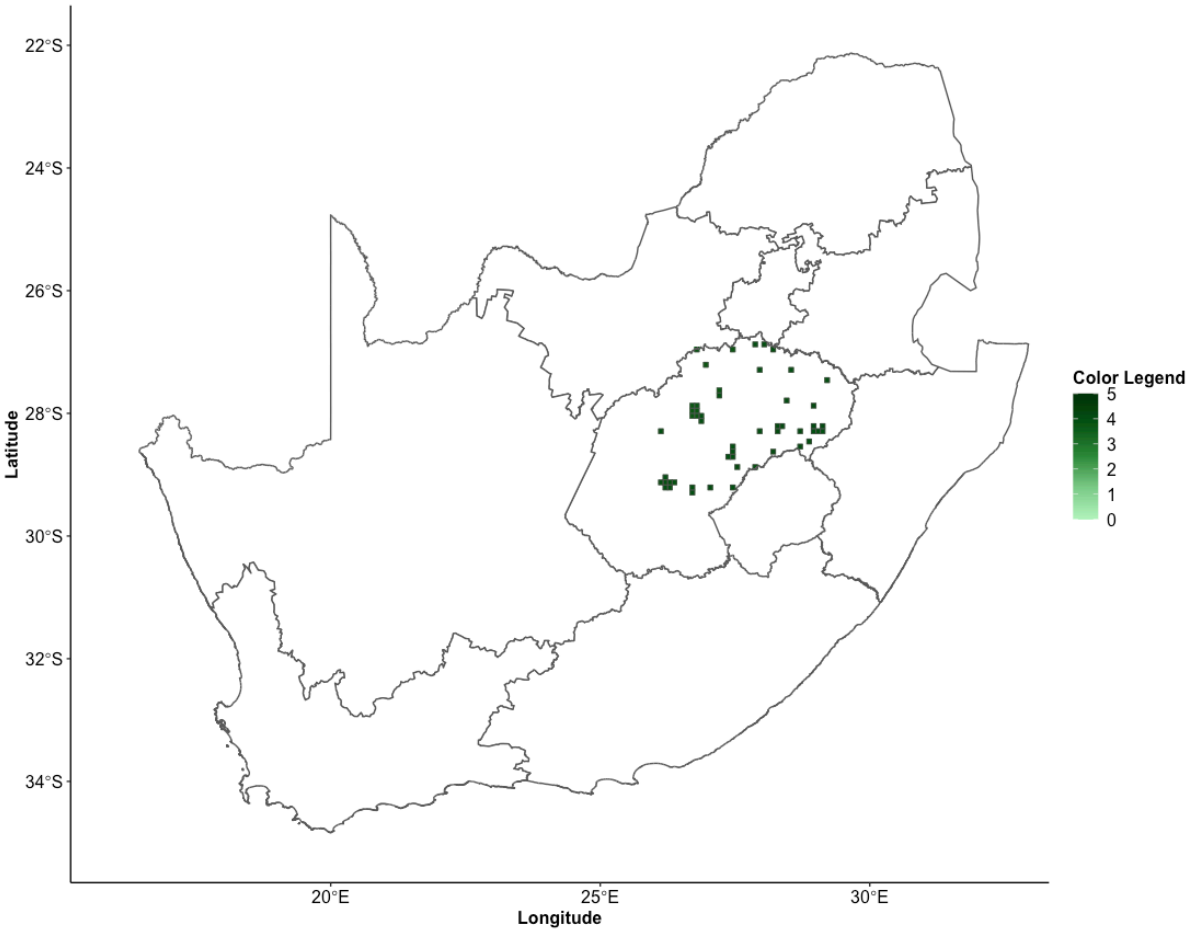
Supplementary Figure S18: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Grey Go-away-bird (*Corythaxoides concolor*) across pentads with greater than 1 % urban cover in the province of Gauteng where the species was surveyed.



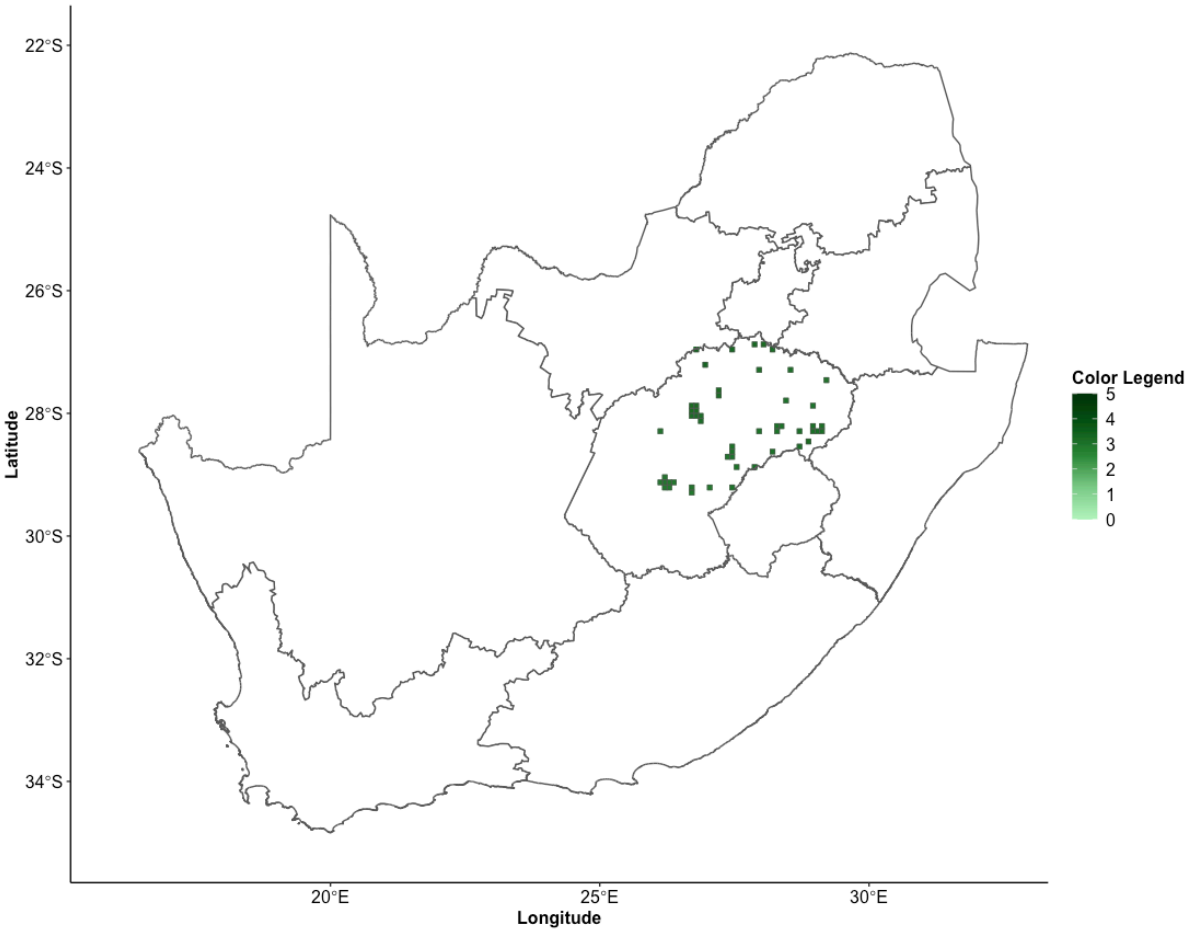
Supplementary Figure S19: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Hadeda Ibis (*Bostrychia hagedash*) across pentads with greater than 1 % urban cover in the provinces of Gauteng, Western Cape, KwaZulu-Natal, and Free State where the species was surveyed.



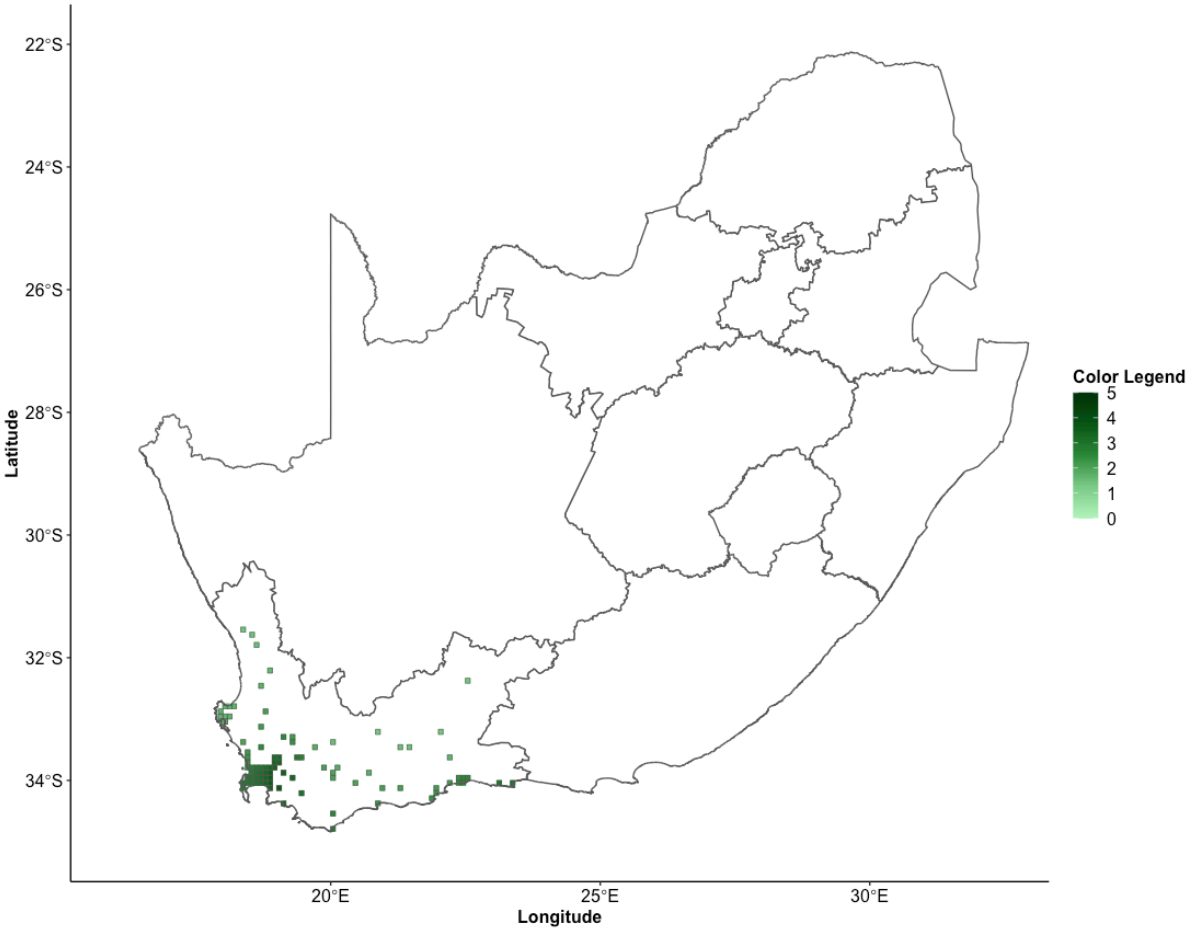
Supplementary Figure S20: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the House Sparrow (*Passer domesticus*) across pentads with greater than 1 % urban cover in the provinces of KwaZulu-Natal and Free State where the species was surveyed.



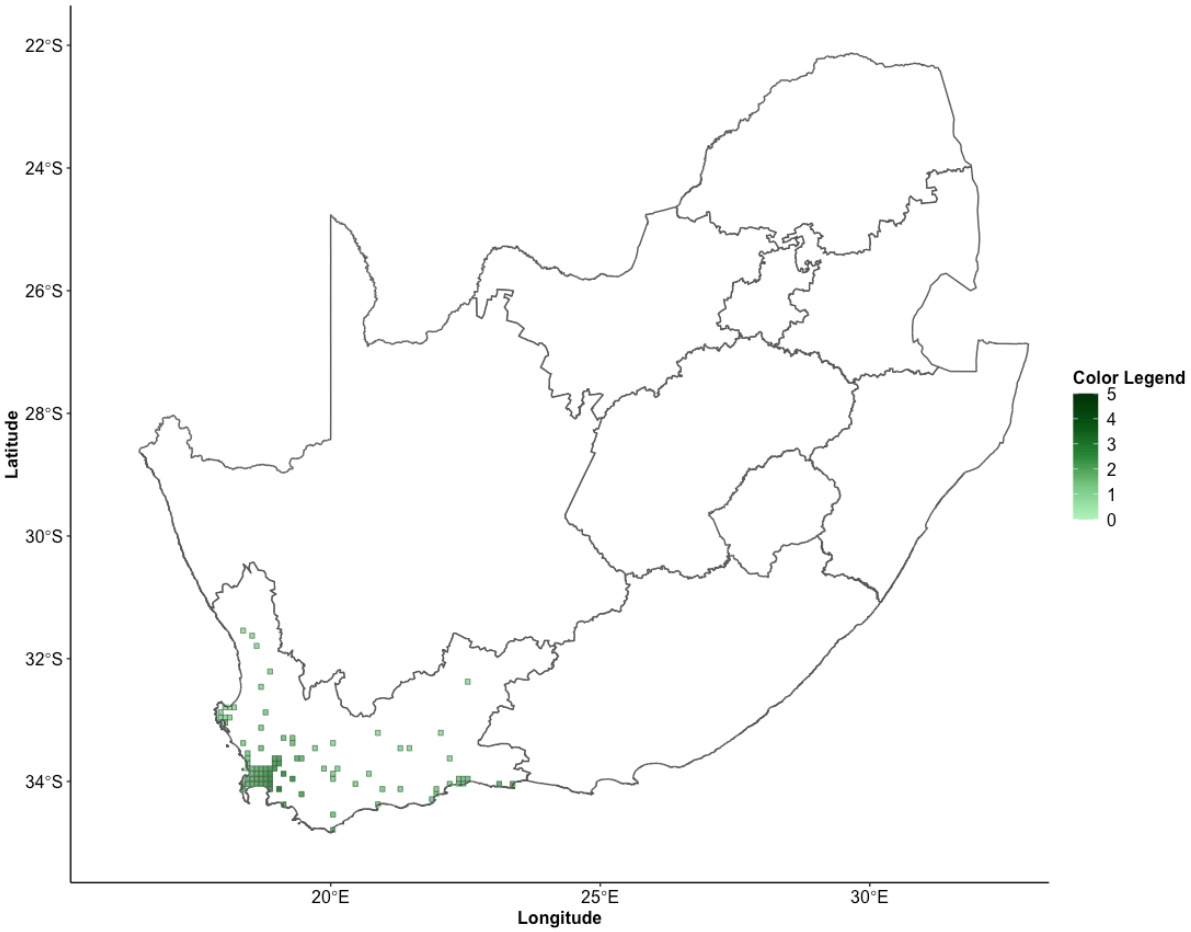
Supplementary Figure S21: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Lanner Falcon (*Falco biarmicus*) across pentads with greater than 1 % urban cover in the province of the Free State where the species was surveyed.



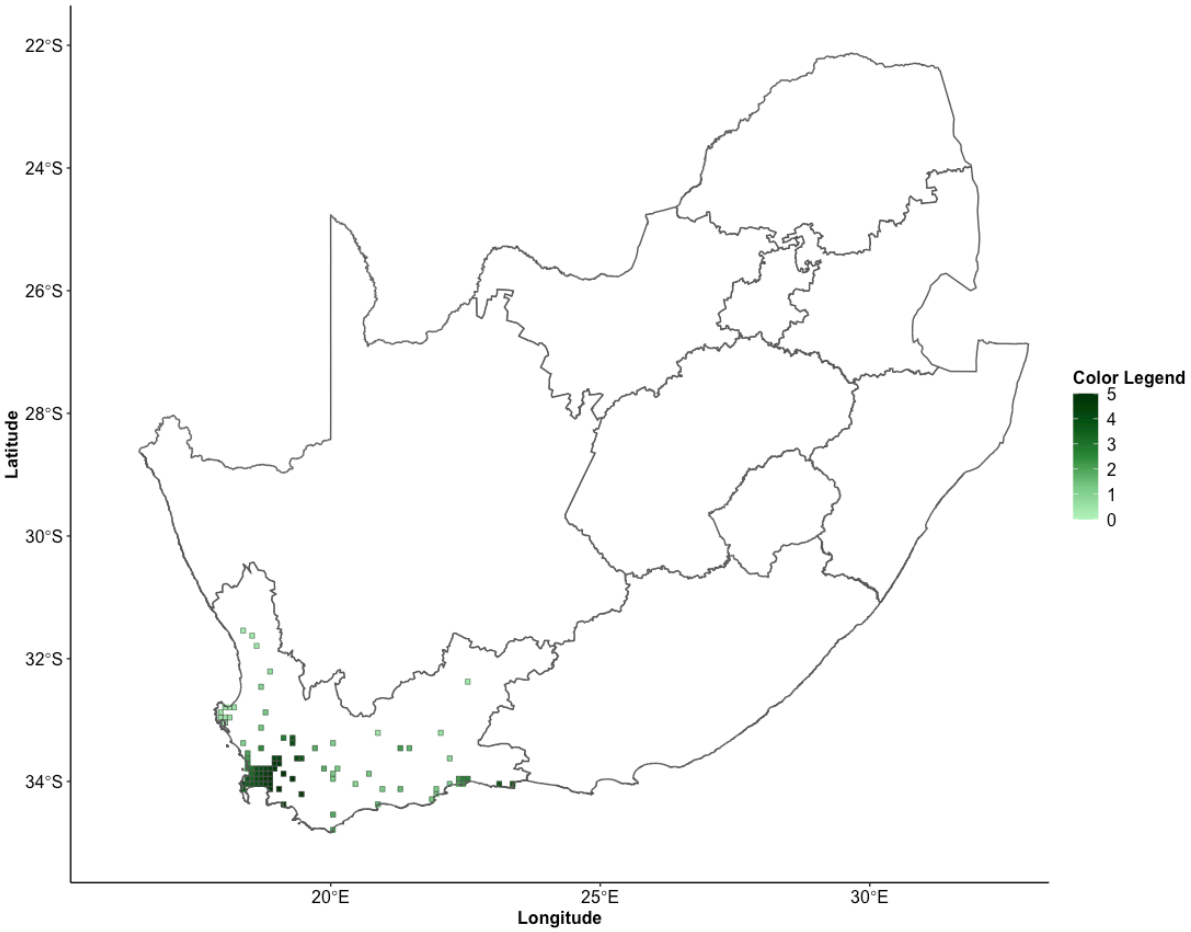
Supplementary Figure S22: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Little Swift (*Apus affinis*) across pentads with greater than 1 % urban cover in the province of the Free State where the species was surveyed.



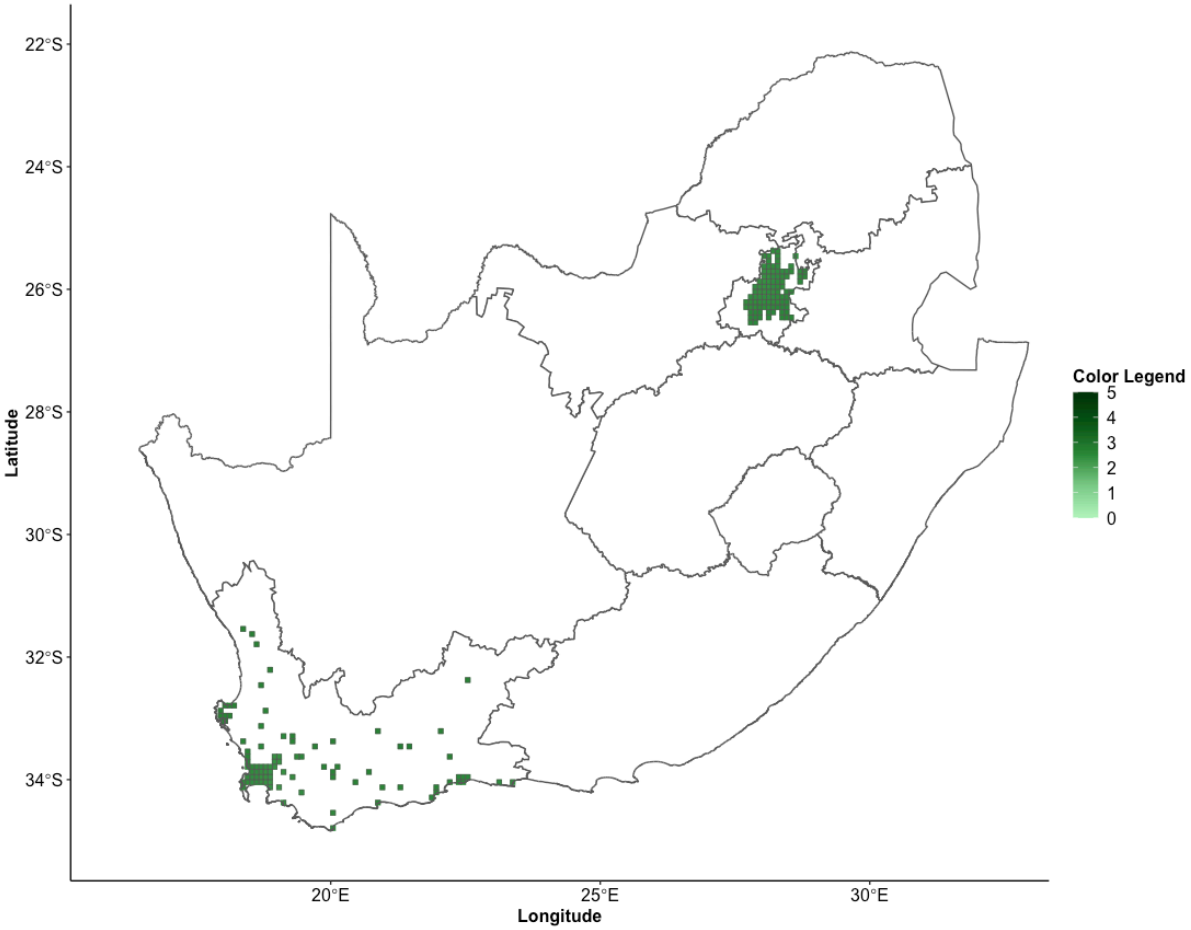
Supplementary Figure S23: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Malachite Kingfisher (*Alcedo cristata*) across pentads with greater than 1 % urban cover in the province of the Western Cape where the species was surveyed.



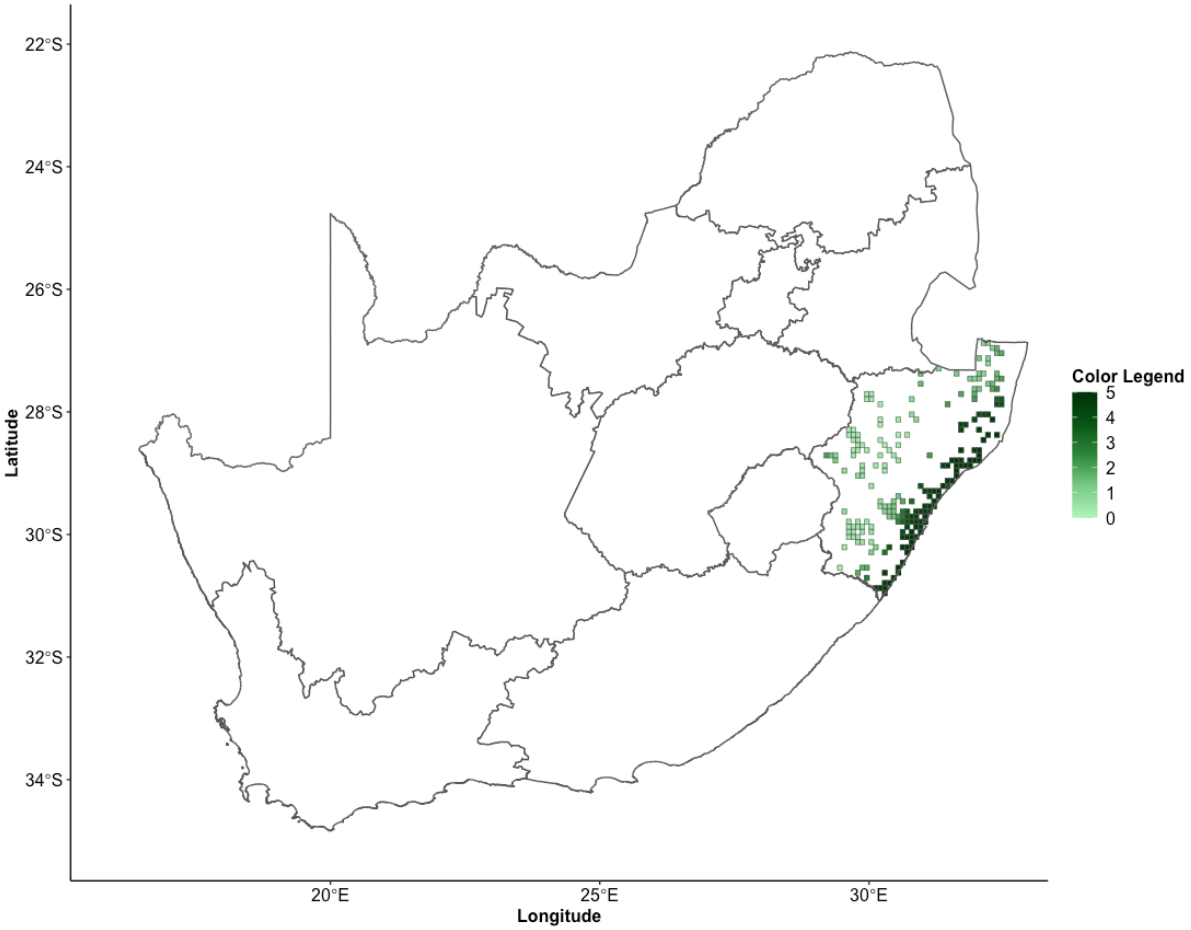
Supplementary Figure S24: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Mallard (Domestic Duck; *Anas platyhynchos*) across pentads with greater than 1 % urban cover in the province of the Western Cape where the species was surveyed.



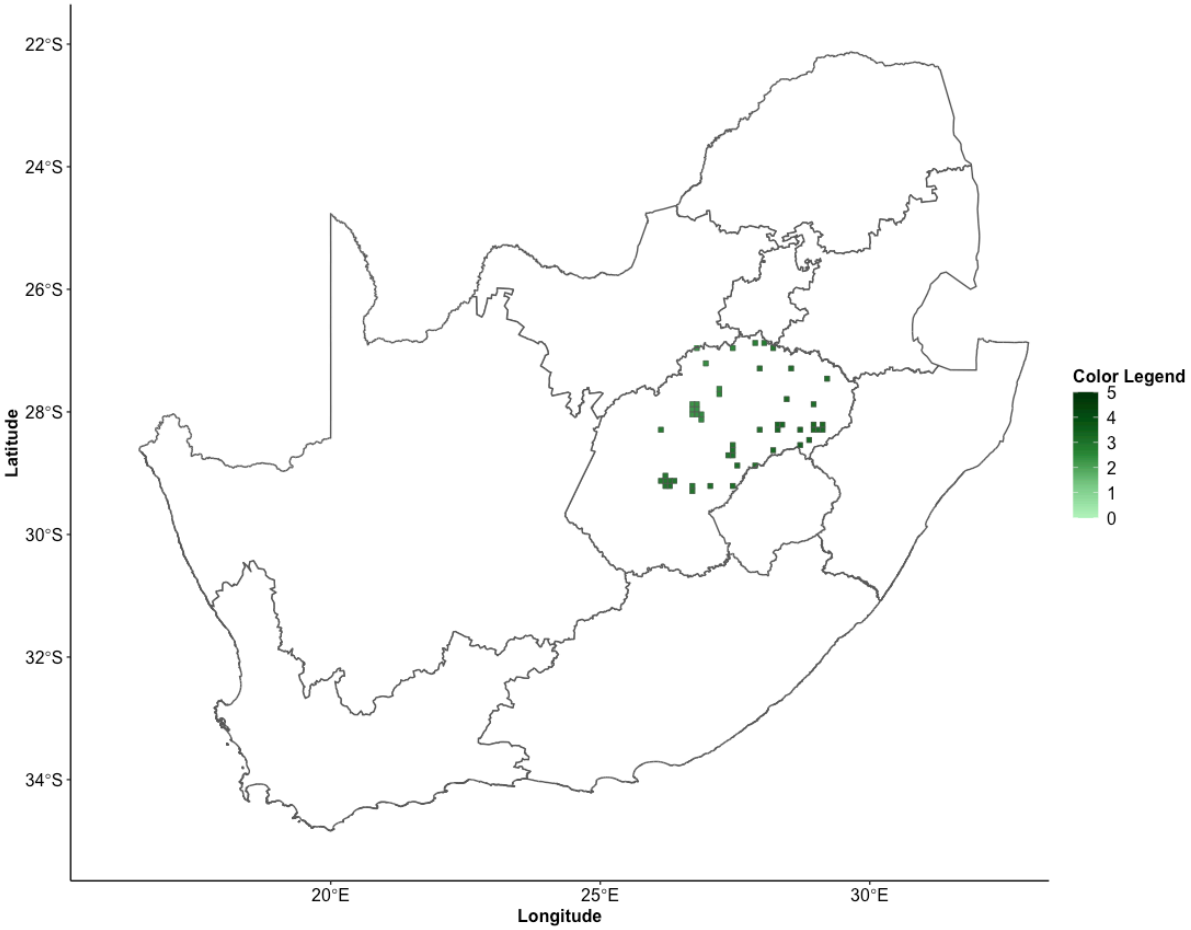
Supplementary Figure S25: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Orange-breasted Sunbird (*Anthobaphes violacea*) across pentads with greater than 1 % urban cover in the province the Western Cape where the species was surveyed.



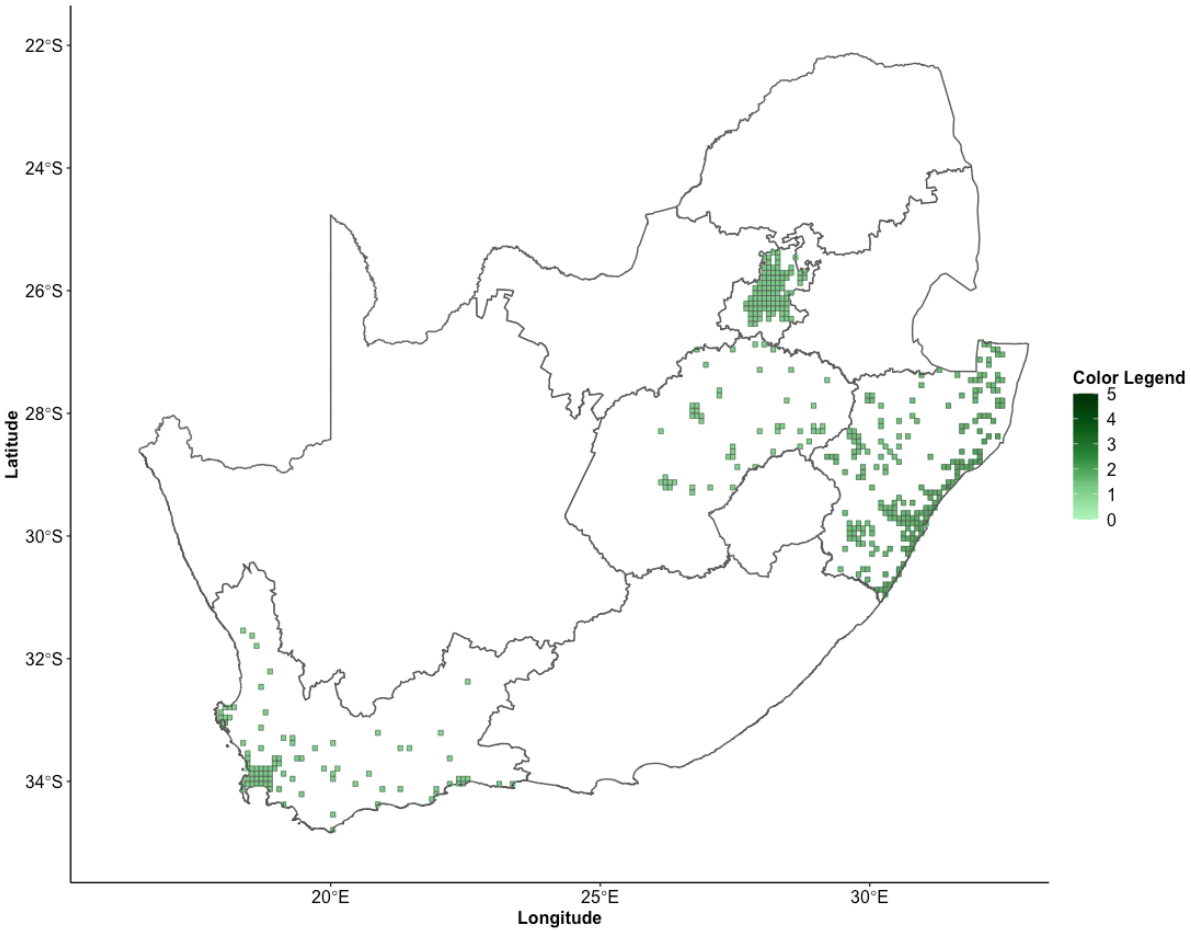
Supplementary Figure S26: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Pied Crow (*Corvus albus*) across pentads with greater than 1 % urban cover in the provinces of Gauteng and the Western Cape where the species was surveyed.



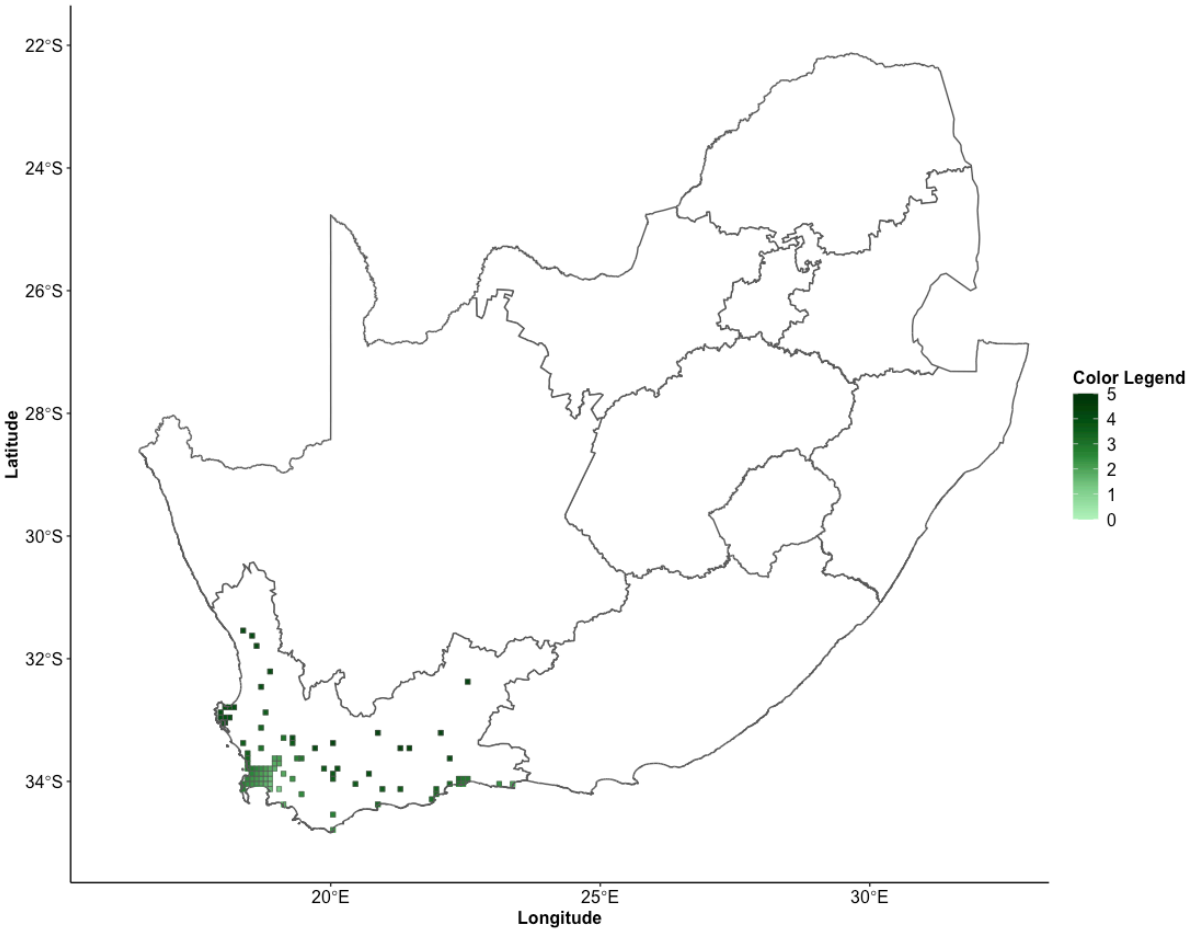
Supplementary Figure S27: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Purple-crested Turaco (*Turaco porphyreolopha*) across pentads with greater than 1 % urban cover in the provinces of Gauteng where the species was surveyed.



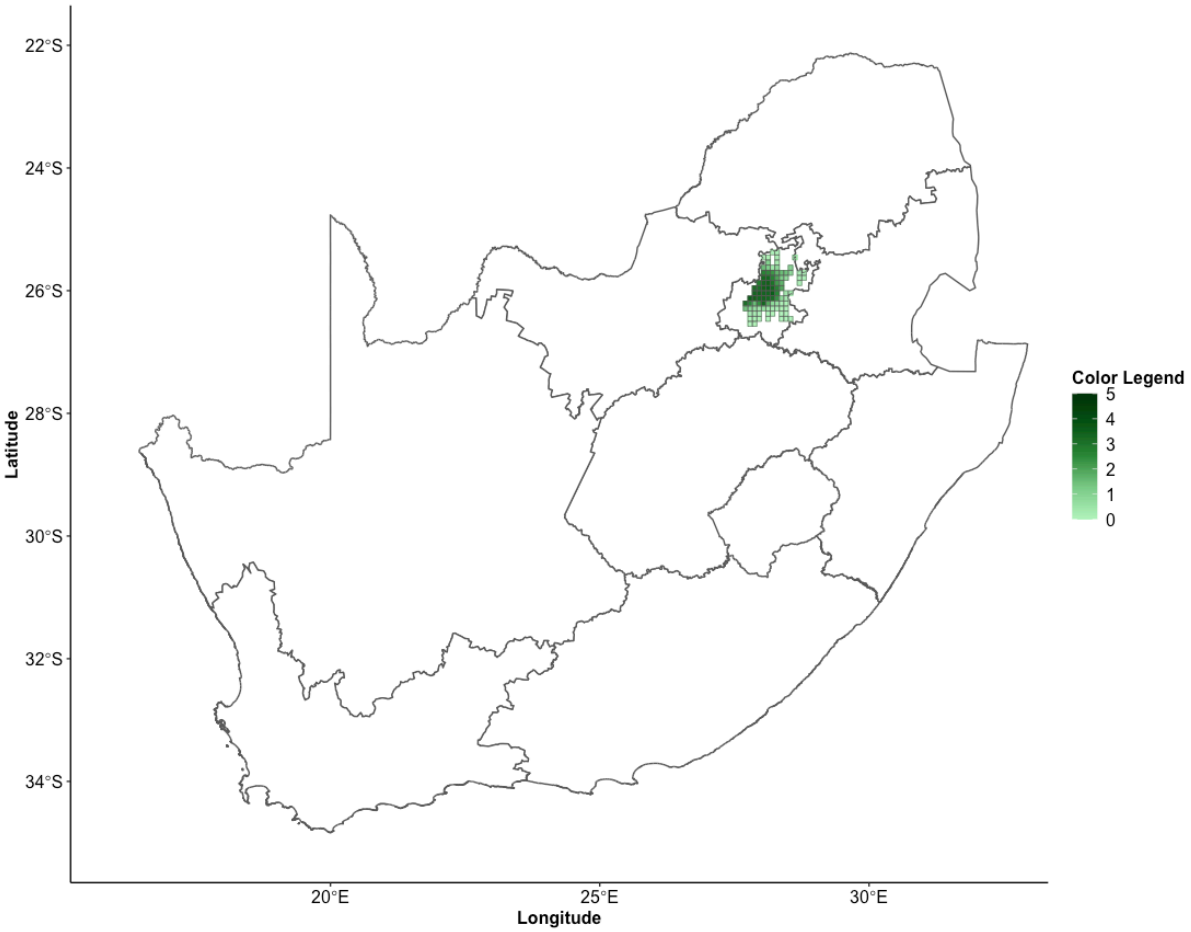
Supplementary Figure S28: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) scores (/5), derived from product of the likeability ratings and species occurrence, of the Red-knobbed Coot (*Fulica cristata*) across pentads with greater than 1 % urban cover in the province of the Free State where the species was surveyed.



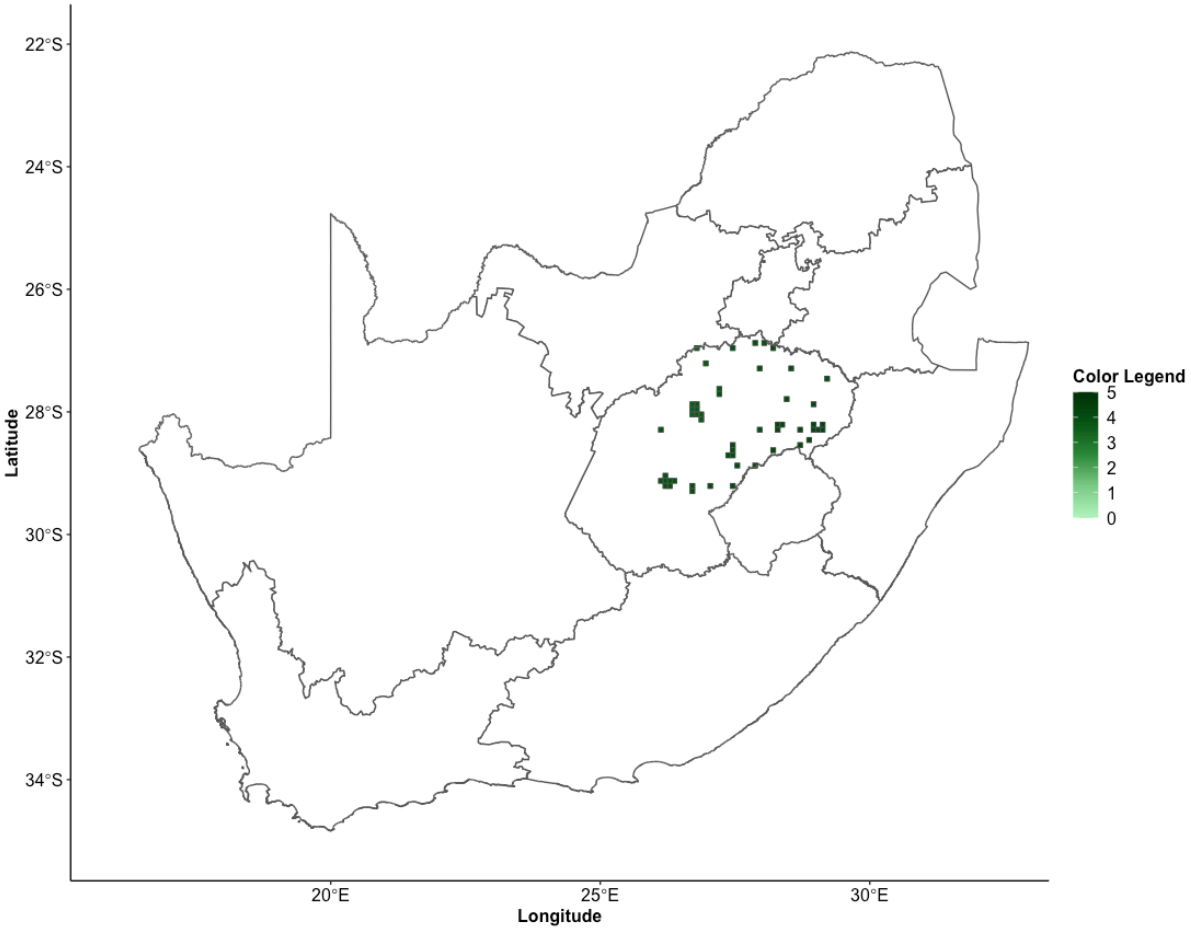
Supplementary Figure S29: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Rock Dove (*Columba livia*) across pentads with greater than 1 % urban cover in the provinces of Gauteng, the Western Cape, KwaZulu-Natal, and Free State where the species was surveyed.



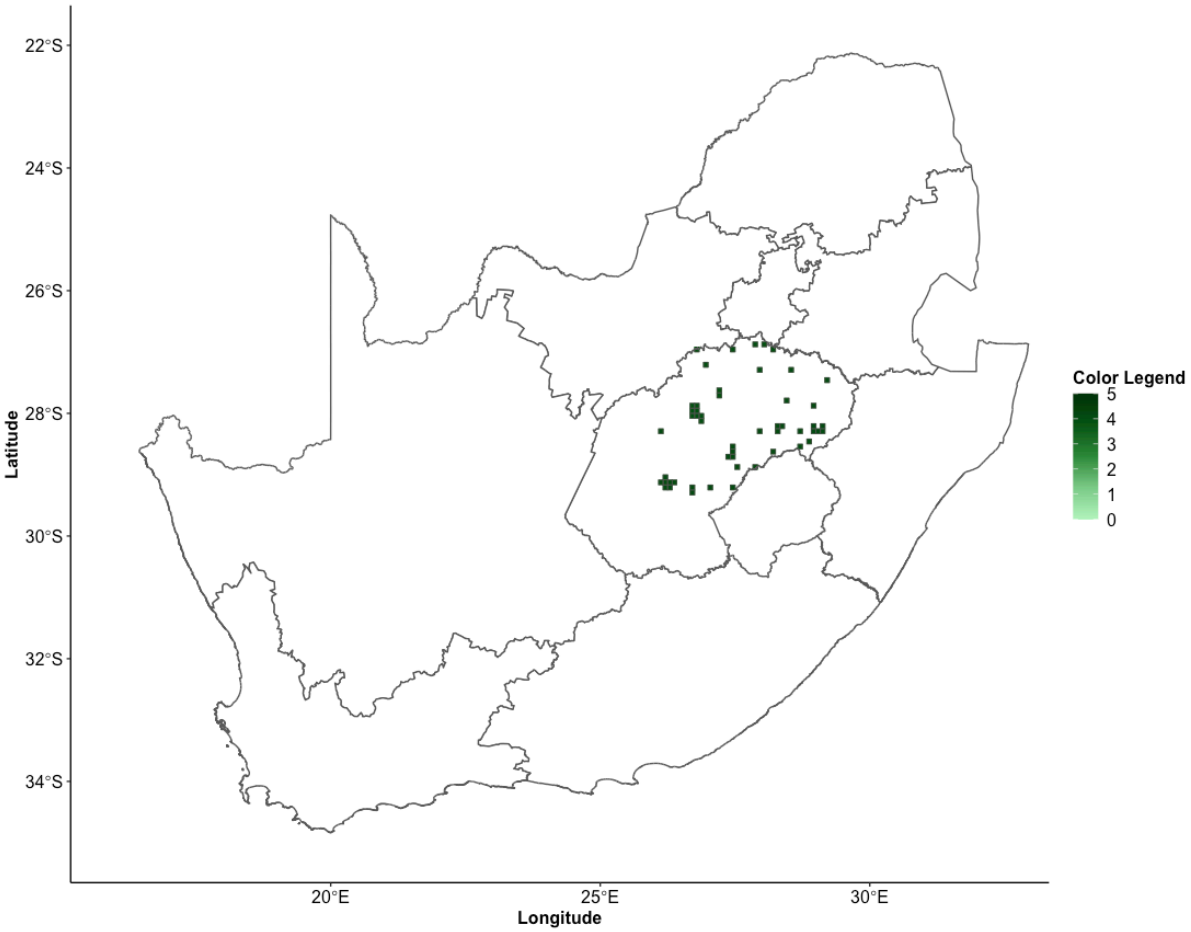
Supplementary Figure S30: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Rock Kestrel (*Falco rupicolus*) across pentads with greater than 1 % urban cover in the province of the Western Cape where the species was surveyed.



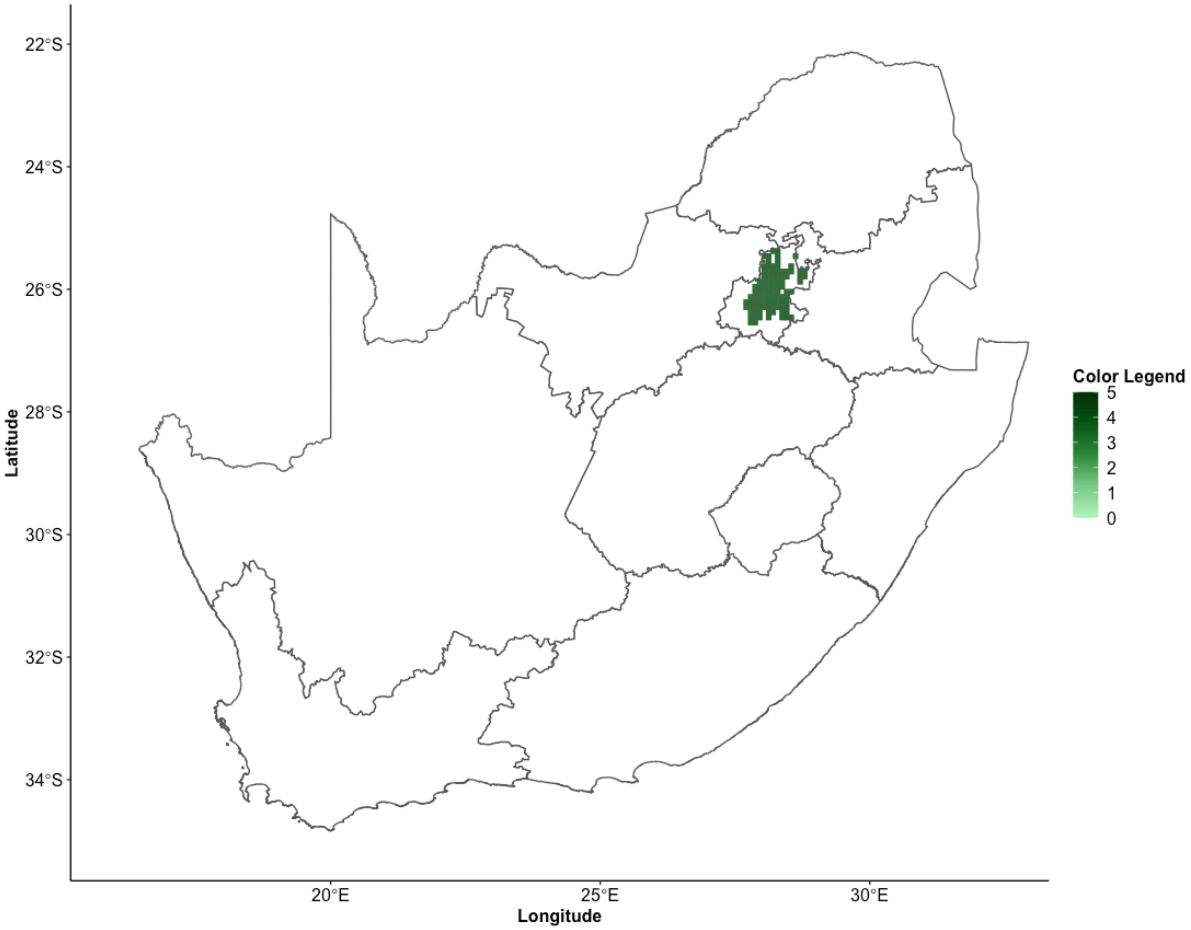
Supplementary Figure S31: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Rose-ringed Parakeet (*Psittacula krameri*) across pentads with greater than 1 % urban cover in the province of Gauteng where the species was surveyed.



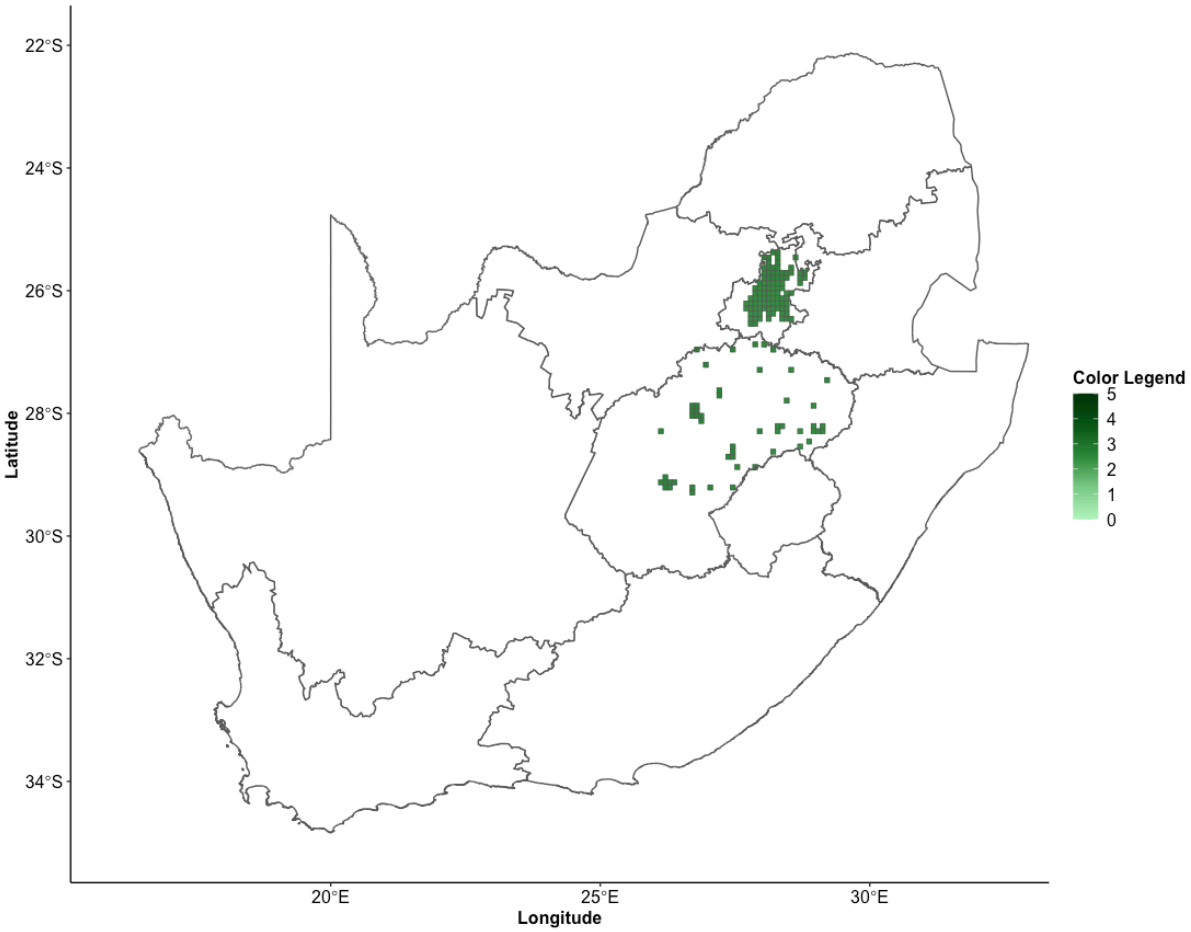
Supplementary Figure S32: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Southern Red Bishop (*Euplectes orix*) across pentads with greater than 1 % urban cover in the province of the Free State where the species was surveyed.



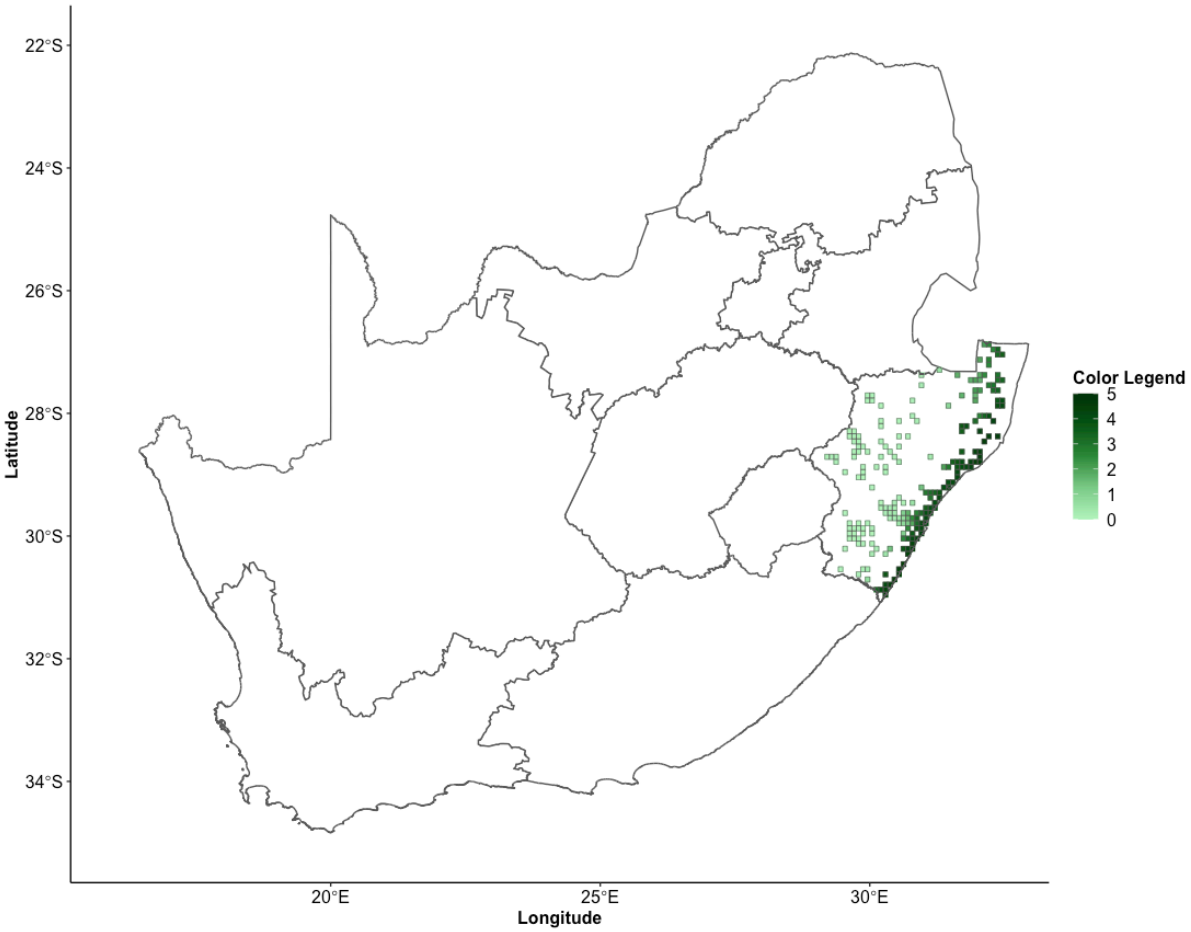
Supplementary Figure S33: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Southern-masked Weaver (*Ploceus velatus*) across pentads with greater than 1 % urban cover in the province of the Free State where the species was surveyed.



Supplementary Figure S34: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Spotted Eagle-owl (*Bubo africanus*) across pentads with greater than 1 % urban cover in the province of Gauteng where the species was surveyed.



Supplementary Figure S35: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Spotted Thick-knee (*Burhinus capensis*) across pentads with greater than 1 % urban cover in the provinces of Gauteng and the Free State where the species was surveyed.



Supplementary Figure S36: Map depicting the spatial distribution of the Cultural Ecosystem Services Index (CES Index) (/5), derived from product of the likeability ratings and species occurrence, of the Yellow-rumped Tinkerbird (*Pogoniulus bilineatus*) across pentads with greater than 1 % urban cover in the province of KwaZulu-Natal where the species was surveyed.

Appendix C: Additional Components

Within this appendix, you will find some additional supplementary components that are not tables or figures.

Section 1: Research Questionnaire

Below is an example of one of our four surveys distributed for response. Specifically, we provide the Johannesburg ACES questionnaire. For the other three questionnaires, all questions remain the same except for the replacement of bird species surveyed in Section 4 – you can see which species were surveyed in each of the different surveys in Appendix A, Supplementary Table 2. The following example provides an outline of all the information provided to prospective research participants, as well as all questions they were asked to respond to.

For reference:

- *= multiple choice question*

'Answer: …' = question was left open to respondents' interpretation for their response (either long- or short-form responses.

The Avian Cultural Ecosystem Services (ACES) Survey: Johannesburg

Section 1: Survey information and consent

Good day,

My name is Sage Naidoo. I am an MSc student in the School of Animal, Plant, and Environmental Sciences at the University of the Witwatersrand. I am conducting a study to evaluate and quantify the perceptions and values of South African residents for their urban bird communities under supervision of Professor Chevonne Reynolds.

I am inviting you, as a resident of the City of Johannesburg, to participate in this study and provide your personal perception, opinion, and rating of different bird species in your ecosystem. During the survey, you will be required to answer questions related to your personal perceptions of birds in general and also of different bird species. You will also be requested to provide some general demographic information (e.g., age, gender, race).

Please note, you do not have to be an avid birder to answer this questionnaire, we want to know your personal perceptions of birds in your environment.

As a participant, your personal identity will remain anonymous, and all responses provided will be treated with confidentiality where only myself and my supervisor will have access to the responses, with all responses being stored in a password-protected computer. Please note that your participation in this research is voluntary and you will not be compensated or receive any benefits for your participation in this study survey.

The questions that follow should take you approximately 15-30 minutes to complete depending on how detailed you want to be in your answers.

This research will be written up as my MSc thesis and will be available through the university website, or can be sent to you if you'd like, upon completion.

Should you have any further questions regarding this research, please feel free to contact me or my supervisor with the details listed below. Or contact the University (Non-Medical) Human Ethics Committee by telephone (+27 11 717 1408) or email (hrecnon-medical@wits.ac.za) for any concerns regarding the ethical procedures of this study.

Kind regards,

Sage Keenan Naidoo

Thank you for taking the time to read the above statement. In order to continue the questionnaire, kindly click the link to indicate your consent to participate in this study.

- o I agree to and provide my consent to participate in this study.

Section 2: Demographic Information

Please answer the following demographic questions.

Question 1: What is your age group?

Younger than 18 yrs

- 18-30 yrs
- 31-40 yrs
- 41-50 yrs
- 51-60 yrs
- 61-70 yrs
- 70+ yrs
- Prefer not to say

Question 2: What is your gender identity?

Answer: …

Question 3: What is your race (in a South African context)?

- Black
- White
- Coloured
- Indian
- Asian
- Prefer not to say
- Other: Answer: …

Question 4: What type of dwelling do you live in?

- Flat/apartment complex
- Stand-alone house
- Stand-alone house (within a gated community)
- Informal housing
- Plot
- Prefer not to say
- Other: Answer: …

Section 3: How do you value birds in your environment and what is your experience with birds?

In this section, we would like to understand how you perceive the value of birds in your environment and from your perspective, how birds are (or are not) of value to you.
We also want to know what your experience is with birds in your environment (noting you do not have to be an avid birder to have an opinion).

Question 1: Do birds have value to you?

- Yes
- No

Question 2: On a scale of 1 to 5, rate how valuable you think birds are within your environment.

- 1 = No value
- 2 = Low value
- 3 = Moderate value
- 4 = Good value
- 5 = High value

Question 3: In what ways do you think birds are valuable?

Answer: …

Question 4: The following statements complete the phrase "I value birds because…". Complete each statement by selecting whether your strongly disagree, disagree, are neutral, agree, or strongly agree with it. Please only select one option per statement. ***If using a cell phone, please scroll across to see all answer options.***

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
they are pleasing to the eye.	○	○	○	○	○
they have pleasant songs.	○	○	○	○	○
they indicate a change in season.	○	○	○	○	○
they make me feel better physically and mentally.	○	○	○	○	○
they control pests such as insects and rodents.	○	○	○	○	○
they provide spiritual values.	○	○	○	○	○
they are part of the ecosystem.	○	○	○	○	○
they provide an opportunity to learn more about nature.	○	○	○	○	○

they are like a familiar neighbour.	○	○	○	○	○
they are enjoyable to watch or identify.	○	○	○	○	○
they are a source of inspiration.	○	○	○	○	○

Question 5: In what ways do you think birds can cause problems or difficulties in your environment?
Answer: …

Question 6: The following statements complete the phrase "I find birds to be a nuisance because…".
Complete each statement by selecting whether your strongly disagree, disagree, are neutral, agree, or strongly agree with it. Please only select one option per statement.
If using a cell phone, please scroll across to see all answer options.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
they are unpleasant to look at.	○	○	○	○	○
they are too noisy or wake me up early in the morning.	○	○	○	○	○
they congregate in groups.	○	○	○	○	○
they can be aggressive or intimidating.	○	○	○	○	○
they damage my personal property.	○	○	○	○	○
they create unnecessary conflict with my pets.	○	○	○	○	○
they introduce unwanted/undesirable plants into my garden.	○	○	○	○	○
they are generally dirty/carry diseases.	○	○	○	○	○

Question 7: In your home/garden, do you take measures to attract birds?

- ○ Yes
- ○ No

Question 8: If you answered yes to the above question, what are ways you attract birds to your space (e.g., bird feeders/baths, etc.)?
Answer: …

Question 9: Do you participate in any birding activities (such as bird watching or bird ringing)?

- Yes
- No

Question 10: Approximately how many years have you participated in birding activities (if none, please state '0')?

Answer: …

Question 11: Approximately how many bird species (in general) have you encountered within South Africa:

- 0-10
- 11-30
- 31-50
- 51-150
- 151-300
- 301-500
- 501+
- Unsure

Section 4: Rating bird preferences (Final section)

In this section, we ask that you rate a selection of birds found in Johannesburg based on how appealing (i.e., the attractiveness, interest, or intrigue) the bird is to you on a scale of 1-5.

Scale description: 1 = No appeal, 2 = Low appeal, 3 = Moderate appeal, 4 = Good appeal, 5 = Very high appeal

Following your rating, you can provide a reason for your provided rating - this can be any reason that influenced your decision (e.g., the colours, shape, patterns, as well as any personal/cultural experiences/connotations you have with the bird).

We encourage you to provide your opinion - with as much or as little detail you want.

Photo credits: eBird

Question 1: Rate the appeal of the following bird – Common name = Spotted Thick-knee



- 1
- 2
- 3
- 4
- 5

Question 2: What do you find appealing, or not, about the Spotted Thick-knee?

Answer: …

Question 3: Rate the appeal of the following bird – Common name = Amethyst Sunbird



- 1
- 2
- 3
- 4
- 5

Question 4: What do you find appealing, or not, about the Amethyst Sunbird?
Answer: …

Question 5: Rate the appeal of the following bird – Common name = Grey Go-away-bird



- 1
- 2
- 3
- 4
- 5

Question 6: What do you find appealing, or not, about the Grey Go-away-bird?
Answer: …

Question 7: Rate the appeal of the following bird – Common name = Crested Barbet



- 1
- 2
- 3
- 4
- 5

Question 8: What do you find appealing, or not, about the Crested Barbet?
Answer: …

Question 9: Rate the appeal of the following bird – Common name = Cape Robin-chat



- 1
- 2
- 3
- 4
- 5

Question 10: What do you find appealing, or not, about the Cape Robin-chat?
Answer: …

Question 11: Rate the appeal of the following bird – Common name = African Hoopoe



- 1
- 2
- 3
- 4
- 5

Question 12: What do you find appealing, or not, about the African Hoopoe?

Answer: …

Question 13: Rate the appeal of the following bird – Common name = Rock Dove



- 1
- 2
- 3
- 4
- 5

Question 14: What do you find appealing, or not, about the Rock Dove?
Answer: …

Question 15: Rate the appeal of the following bird – Common name = Common Myna



- 1
- 2
- 3
- 4
- 5

Question 16: What do you find appealing, or not, about the Common Myna?
Answer: …

Question 17: Rate the appeal of the following bird – Common name = Rose-ringed Parakeet



- 1

- 2
- 3
- 4
- 5

Question 18: What do you find appealing, or not, about the Rose-ringed Parakeet?
Answer: …

Question 19: Rate the appeal of the following bird – Common name: Spotted Eagle-owl



- 1
- 2
- 3
- 4
- 5

Question 20: What do you find appealing, or not, about the Spotted Eagle-owl?
Answer: …

Question 21: Rate the appeal of the following bird – Common name = Pied Crow



- 1

- 2
- 3
- 4
- 5

Question 22: What do you find appealing, or not, about the Pied Crow?
Answer: …

Question 23: Rate the appeal of the following bird – Common name = Hadeda Ibis



- 1
- 2
- 3
- 4
- 5

Question 24: What do you find appealing, or not, about the Hadeda Ibis?
Answer: …

Question 25: Rate the appeal of the following bird – Common name = Peregrine Falcon



- 1
- 2
- 3
- 4
- 5

Question 26: What do you find appealing, or not, about the Peregrine Falcon?
Answer: …

Question 27: Rate the appeal of the following bird – Common name = Egyptian Goose



- 1
- 2
- 3
- 4
- 5

Question 28: What do you find appealing, or not, about the Egyptian Goose?
Answer: …

Question 29: Rate the appeal of the following bird – Common name = African Harrier-hawk



- 1
- 2
- 3
- 4
- 5

Question 30: What do you find appealing, or not, about the African Harrier-hawk?
Answer: …

Bonus Question: What is your favourite bird?
Answer: …

END OF SURVEY

Section 2: ChatGPT prompt

Below is an example, for the Hadeda Ibis (Bostrychia hagadash) of the detailed prompt provided to ChatGPT, alongside the respective species dataset, in order to categorise the open-ended survey response data pertaining to species likeability. Note that the general structure and content remained consistent for all 36 species, however, the examples provided at the end were specific to the species, derived from the actual list of responses for each individual species.

Hadeda Ibis
I need your assistance with categorising some open-ended, personal opinion-based, data that I collected.

Background:
I conducted a study to assess the perception and value of different bird species by individuals. Using surveys, I had people provide reasons as to why they liked, or did not like, a particular species. I need to now categorise this open-ended, opinion-based, response data so that I can analyse it.

Important Information:

1. There may be some variations in spelling or spelling errors. This is due to open-ended nature of the responses and people may have spelt things incorrectly or differently (e.g., UK vs US English). Despite this, the responses should still make sense based on the information I provide below. I request if you can attempt to work with/around spelling errors when categorising.
2. A single response can fall into more than one category – hence, it is vital that you categorise the response under every applicable category.
3. As such, you NEED to consider and read the full response (i.e., read the entire response in full before categorising).
4. It is IMPORTANT to note that the definitions, descriptions, examples, and pointers provided under each category are merely guiding prompts of what to look for GENERALLY - it is NOT the only information to look for, or that qualifies for each category. Please assess every response and place them in the category that is best descriptive or befitting the responses provided - inclusive of a single response being able to fit into more than one category.
5. PLEASE also note, you need to consider that there are synonyms, or rather people may use words that are synonymous with certain aesthetic features or behaviours or

other traits/symbolistic ideas, or ecological roles, etc. So, you need to please consider that there are different ways that people will have responded.

6. These are responses from real people with real emotions and real opinions, so the responses are NOT completely neat, so you need to use some critical thinking to assess the responses carefully to categorise them correctly!
7. I am providing keywords to look for each category - please also consider synonyms (provided or not) for these keywords to consider. I also provide words to avoid adding to a category.

<u>The categories/themes I would like you to categorise the response data into</u>:

<u>Appearance/Aesthetics</u>:

- Include responses mentioning any references to the appearance and aesthetics of the bird.
- This includes ANY PHYSICAL CHARACTERISTICS (body features/traits like the head, the face, legs, wings, tail, etc. anything that can be associated with the physical nature of the bird - i.e., consider all features on a bird (head, beak, tail, wing, legs, etc.), COLOUR (any mention of the colours on the bird - even if the response is simply 'colour'), size (anything/any terms that can be related to the size or shape of the bird, e.g., is it big, small, large, etc. any terms associated with a size), feathers (and alternative synonymous words such as plumage), patterns (any mentions regarding patterns on the birds like stripes, spots, etc.), etc. that is mentioned
- Look for any descriptive adjectives that may be associated with how something looks (e.g., beautiful, pretty, and any other adjectives that can be synonymous with aesthetic value or ideals of the bird)
- Again, that would be ANY descriptive terms that are referring to its look (you can consider terms that are synonymous with beauty - e.g., pretty, stunning, etc.)
- Please also consider "characteristic features" of the bird that may be mentioned. For example a crest (that may be referred to as a mane, mohawk, or other variations that people may find synonymous (some may say 'crown', or 'fan', etc.).
- Note: if they mention any specific colours on the colour spectrum – it should also be categorised here (any colour, or colour palette counts). In other words, if they mention any colour in existence – whether red, green, white, grey, orange, etc. (literally any colour) it is categorised as an appearance response
- Keywords: looks, appearance, colour, traits (wing, tail, crest, head, face, legs, beak), small, large, big, pattern, spots, stripes, beautiful (beauty), pretty, stunning, colourful, cute, feathers, plumage
- Common synonyms: crest = crown, fan, mohawk, mane, feathers = plumage, beak = bill
- Spelling variations: mane may be misspelled to Maine, colour = color
- Words to avoid in this category: dull, boring - this is a negative response (i.e., category negative/neutral)

Behavioural Characteristics:

- These are responses relating to any behaviours OR habits of the bird, or behaviours that a bird may perform
- Include responses about movement, flight, hunting, feeding, breeding, etc.
- Be sure to consider terms people may use that are synonymous with the above (and potential other) behaviours (e.g., people may use glide/soar instead of fly, or predatory habits instead of hunting, or nesting instead of breeding) - so look for ALL words that could be synonymous with any of the mentioned, possible other, bird behaviours/habits. Examples: feed can also be catch, hunt, forage, etc; flight can be soar, glide, drift, etc., breeding can be nest, building, mating, etc.
- This should also consider terms that may be associated with describing a behaviour (e.g., grace, charm, etc.) so any adjectives that can be associated with describing a behaviour
- This also includes any behaviours that may occur when the birds are in groups/flocks - so how the birds are interacting with one another.
- Please also be aware that some responses may use "metaphors" to describe certain behaviours (e.g., referring to flight pattern as drifting like leaves)
- Keywords: behaviour (behavior), habits, mate (mating), nesting (nest), breeding (breed), play, flight, grace, communicate, flock, chase, catch, forage, feed, hunt, habituate, adapt
- Common synonyms: flight = glide, soar, drift
- Words to avoid in this category: uncharismatic - this is a negative response (i.e., category negative/neutral)

Ecological Impact:

- Include responses about the bird's ecological role in the ecosystem, impact on other species, etc.
- This is also inclusive of the birds "provenance" in the area (I.e., is the bird a known alien/invasive species, or is it a native/endemic species)
- This is inclusive of them being an indicator of something (e.g., environmental health, change in season, etc.)
- Things to consider: are there mentions of ecosystem services provided, do the birds aid in improving or creating habitats, or are they performing more nuisance like actions that degrade the ecosystem? (e.g.,are they pollinators or do they control pests?), there role as ecosystem indicators etc.
- This should be responses that also refer to ecosystem services or values provided by the birds. PLEASE consider the ecosystem services that birds provide! They are pest control, pollinators, habitat creators, etc. Please use information from your servers to understand the different ecosystem services birds provide when categorising responses into this category - because people may mention specific services provided by birds, which would mean that the response falls under this category

- This should include any responses where it is mentioned that the bird aids/assists/helps to improve the environment in any way (this will be correlated to their ecosystem services, e.g., pest control, pollination, etc. - think about the ecosystem services of birds and assess the responses as such to see if any fit into this category).
- Examples: control insect populations (whether by eating, catching or removing from the environment), control pests (whether by eating, catching or removing from the environment), pollinate flowers, etc.
- Keywords: impact, service provider, pest control, pollinate, nectar, ecosystem health, ecological health, indicate, indicator, create, damage, degrade, invasive, alien, native, endemic, controls, mitigates, insect, pest, catch, remove
- Common synonyms: eat insects/pests, consume insects/pests, remove insects/pests

Cultural Significance/Symbolism:

- Include responses mentioning cultural beliefs, symbolism, etc.
- So look for responses that may have any links or connotations with a cultural/belief system
- Look for responses that are targeted towards mention of the symbolism of the species (e.g., does it maybe represent strength, virtue, fear, resilience, vitality, wisdom, etc. - find responses that may be similar or provide an indication of someone finding a symbolic meaning to the species).
- This can also include any references of the bird being a representative symbol (or icon, or other synonymous words) for a particular area (e.g., “The species is an icon of my home”, or “This species takes me back to my home”, or “is a symbol of Africa”)
- Keywords: culture (cultural), symbol, iconic, reminds me of, brings me back, strength, wisdom, icon, spiritual, belief

Emotional Impact (Personal significance):

- Include responses mentioning personal experiences, enjoyment, emotional effects, etc.
- This is including personal connections to the birds (based on experiences, enjoyments, emotional attachments, etc.)
- Consider the emotional tone of the responses - maybe people use distinct adjectives to describe how they perceive the bird
- These are responses that may have a strong personal connection to a species but is not necessarily linked to cultural or strictly the appearance of the bird (though appearance could be something that influences a personal stance)
- Consider any emotional/personal tones that may come across in the responses - what suggests personal significance or emotional impact are terms that can be associated with how a bird makes a person feel, or if it draws any particular strong emotions from the person.

- This would also be inclusive of responses regarding the bird evoking any emotions linked to the way the bird may present itself, or evoke emotion in a person (e.g., a bird being described under terms of royalty, authority, majesty, regalness etc.). These would be responses where the person talks about the bird from a standpoint of an emotional impact rather than physical or behavioural traits.
- Or may be any responses that are associated with a more negative emotion (as long as it is a reference to an emotional state, e.g., fear)
- This can also include responses where someone mentions the bird being linked to a pass-time activity (e.g., bird watching, bird ringing, bird identification (Bird ID), etc.). So consider if responses deal with "watching the birds" or "interacting with the birds" or anything along these lines which suggest that people are developing a connection to or creating experiences with the birds. So if a response deals with just seeing the bird and that it elicits some emotion, it would be in this category
- This also accounts for responses where a bird is favoured for being present in someone's home or garden, or something similar. Look for responses that suggest having the bird around is good (this ties into the point above of watching the bird or interacting with the bird). So if the bird is a visitor for example that frequents the area
- IMPORTANT FOR THIS CATEGORY: "love" does NOT automatically suggest an emotional or personal impact/connection. Responses will contain additional information to assist you with deciding an adequate categorisation. For example, if someone responded "I love the shape and eyes" - this is NOT an emotional impact response, it is an aesthetic response. Please consider the full response before categorising and if you are uncertain, please categorise it into the last category in this list.
- This includes seeing the bird come into your area and having them frequent your home and garden, or your place of work (e.g., getting joy from watching birds at the bird feeder)
- Keywords/terms: feel, to see, to watch, to hear, experience, have in my garden, majestic (majesty), regal, royal, king, watch, identify (or ID), emotional, personal, work with, see in my home, shares my garden, to look at, to see, bird(s) of prey, bird of pray, raptor
- Important: seeing the word "love" does NOT automatically mean personal connection or emotional impact (see point above)

<u>Vocalisation</u>:

- Include responses mentioning calls, sounds, noises, vocal patterns, etc.
- Consider that people may use synonyms for referring to a birds call (e.g., call, cry, song, chirp, etc.)
- So essentially anything in the responses that can be associated with the call sounds made by birds
- Keywords: song, call, cry, chirp, tweet, sounds

- Words to avoid in this category: noise (noisy), annoying - this is a negative response (i.e., category negative/neutral)

Prevalence/Rarity:
- Include responses mentioning how often the bird is seen, its rarity, etc.
- Are people providing reason surrounding a bird being common, or rare, or maybe they see/don't see the bird "often"
- Terms to consider that are related to seeing the bird: common, uncommon, rare, frequently, large flocks, often
- Keywords: common, rare, often, rarely, frequently, few, uncommon to see, don't see, have not seen

Negative/Neutral:
- Include negative or neutral opinions that don't fit into the other categories.
- Negative opinions would be anything that is distinctly negative relative to the species (e.g., boring, plain, aggressive, dangerous, etc.) - so look for responses where peoples opinions are generally negative relative to the other themes or categories that they may fall into
- Neutral responses are those where they state "neutral" or provide reasons that are synonymous with an opinion being neutral
- This category should include responses that also state "nothing"
- This should also be any responses where the bird is not known (i.e., if someone is unfamiliar with the bird, or does not particularly know the bird)
- This would also include responses where a person suggests that they don't know the bird or are unfamiliar with the bird
- If there are any negative descriptions of the birds appearance or behaviour (anything to suggest that the bird is not liked or is unfavourable to the respondent)
- Keywords: neutral, NaN, no response, don't know this bird, not familiar with bird, unfamiliar, nothing, everything, noisy, bully, nuisance, annoying, damage, degrade, mess

Here are some examples of how it should be categorised:
I show the response, the category(s) and reason for its categorisation. Please consider these examples – these are the categories these specific responses SHOULD fall into and why, so I ask that you consider the logic provided when categorising all the data.

Example 1:
- Response: 'Annoying call'
- Categories: Vocalisation, Negative/Neutral
- Why: They find the call annoying – which is a negative response regarding the call of the bird

Example 2:

- Response: ‘Pest control’
- Categories: Ecological impact
- Why: They appreciate the role of the bird as a pest controller in the environment

Example 3:

- Response: ‘Don’t mind them’
- Categories: Negative/Neutral
- Why: they are generally neutral about the bird

Example 4:

- Response: ‘a very South African bird’
- Categories: Cultural Significance/Symbolism
- Why: They view the bird as a symbol of South Africa

Example 5:

- Response: ‘useful’
- Categories: Ecological Impact
- Why: They find the bird ‘useful’ which may be referring to its role in the environment

Example 6:

- Response: ‘love them as they aerate my grass’
- Categories: Ecological Impact
- Why: they like the ecological role of the bird where it contributes towards aerating the grass

Example 7:

- Response: ‘Not my favourite’
- Categories: Negative/Neutral
- Why: They are not a fan of the bird – suggesting a negative opinion

What I want as an output:

For the provided dataset of the Hadeda Ibis, can you please:

1. categorise the responses into the above categories
2. provide me a table of the responses categorised - specifically a table where each response is associated with each category, using true/false to state whether the category is applicable to a response (please make sure to include a column with the original response first)
3. provide me with a ranked a count of the number of responses within each category

END OF CHATGPT PROMPT