

**Assessing the persistence of Blacksmith Lapwings (*Vanellus armatus*) and Crowned Lapwings (*Vanellus coronatus*) in an urban area, Pietermaritzburg, KwaZulu-Natal**

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## ABSTRACT

Urbanisation generally threatens biodiversity and causes shifts in species assemblages. Despite this, many species persist in urban areas. Species with broader tolerance generally show improved persistence. The capacity of species to survive in extreme physical changes along the urban-rural gradient varies greatly as their responses mainly depend on their specific ecological traits such as body mass, dietary niche, migratory strategy, habitat affinity, and behavioural plasticity. Little is documented on ground-nesting birds in urban areas. Lapwings are ground-nesting birds that appear to be persisting in urban landscape mosaics in South Africa. The persistence of Blacksmith (*Vanellus armatus*) and Crowned Lapwings (*V. coronatus*) in selected metropolitan areas of KwaZulu-Natal was assessed. Information about their occurrence, habitat use, distribution, and behaviour in urban mosaic landscapes was investigated by conducting monthly surveys and observations and with citizen science feedback. During the breeding season, the influence of anthropogenic activities and different land uses on the nesting ecology of lapwings breeding in the urban mosaic landscape of Pietermaritzburg, KwaZulu-Natal, was determined. Blacksmith Lapwings' presence in the urban mosaic landscape depended on water availability, temperature, habitat type, resource availability, and grass height. Both lapwing species required short grasslands in urban mosaic landscapes and nested in pairs in open areas. At certain times of the year, they congregated in single species flocks in some regions of the urban mosaic landscape, particularly open green spaces, for feeding and socialising. Despite all the anthropogenic factors affecting ground nesting birds in urban mosaic landscapes, lapwings show behavioural plasticity and use natural and managed green spaces for their persistence here. Bridging the gap between urban development and conservation practices is crucial in creating environments that can support the needs of humans and wildlife in mosaic urban landscapes.

## PREFACE

The data described in this thesis were collected in Pietermaritzburg, Republic of South Africa, from April 2022 to September 2023. Experimental work was carried out while registered at the School of Life Sciences, University of KwaZulu-Natal, Pietermaritzburg, under the supervision of Prof Colleen T Downs.

This thesis, submitted for the degree of Master of Science in the College of Agriculture, Engineering and Science, University of KwaZulu-Natal, School of Life Sciences, Pietermaritzburg campus, represents original work by the author and has not otherwise been submitted in any form for any degree or diploma to any University. Where use has been made of the work of others, it is duly acknowledged in the text.

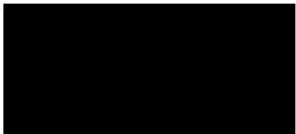


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Feziwe Phoswa

January 2024

I certify that the above statement is correct, and as the candidate's supervisor, I have approved this thesis for submission.



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Prof Colleen T Downs

Supervisor

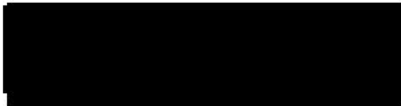
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**PUBLICATION 1- not submitted**

**A systematic review of lapwing research in Africa to determine trends and evidence of their response to changes in terrestrial ecosystems**

F Phoswa and CT Downs

*Author contributions:*

FP conceived the paper with CTD. FP collected and analysed data, and wrote the paper. CTD contributed valuable comments to the manuscript.

**PUBLICATION 2- not submitted**

**Use of the Southern African Bird Atlas Project (SABAP) to examine the distribution range and relative abundance of Blacksmith Lapwings and Crowned Lapwings across South Africa, Lesotho and Eswatini**

F Phoswa, ATK Lee and CT Downs

*Author contributions:*

FP conceived the paper with CTD and ATKL. FP collected and analysed data, and wrote the paper. ATKL provided guidance on analyses. CTD and ATKL contributed valuable comments to the manuscript.

**PUBLICATION 3- not submitted**

**Occurrence and persistence of Blacksmith Lapwings and Crowned Lapwings and their reproductive success in an urban mosaic landscape**

F Phoswa, ST Gumede and CT Downs

*Author contributions:*

FP conceived the paper with CTD and STG. CTD sourced funding. FP collected and analysed data, and wrote the paper. STG assisted with fieldwork. CTD contributed valuable comments to the manuscript.



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January 2024

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“And let us not be weary in well doing; for in due season we shall reap, if we faint not”

(Galatians 6:9)

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# CHAPTER 1

## Introduction

### 1.1 Urbanisation

Urbanisation is one of the most common factors threatening biodiversity (Kondratyeva et al., 2020). This process modifies natural areas into built areas, such as new settlements and other structures (Thompson et al., 2022). Urban development leads to fragmentation, which creates a mosaic of natural and/or managed landscapes with varying biodiversity levels (Andren, 1994; Downs et al., 2021). This changes the community composition (Olsson et al., 2021), affecting the local remnant populations of a species in the area and inducing the establishment of new ecological communities (Gaston, 2010; Thompson et al., 2022). Fragmentation caused by anthropogenic activities significantly affects native species because humans construct and modify their surroundings to support the demands and desires of society (Wilcoxon and Murphy, 1985; Jokomaki, 1999; Scanes, 2018). Hence, urbanisation has caused changes to various environmental pressures, often severely affecting biotic communities (Thompson et al., 2022). These include environmental pollution caused by chemical use, noise generated by traffic, and other forms of pollution (Olivier-Hagen et al., 2017; Zhang et al., 2022). Climate change has been identified as one of the threats to biodiversity and wildlife, and these include the increasing vulnerability of urban citizens to various risks and the loss of biodiversity (McKinney, 2002; Solecki et al., 2013; Shivanna, 2022).

Habitat modifications for human activities threaten the persistence and survival of various plants and animals (Maseko et al., 2020). Human civilisation has indeed contributed to the loss of vertebrate biodiversity and habitats through various factors such as hunting, fishing, ecosystem degradation, land use change, habitat destruction, and the use of pesticides and herbicides (Hunter, 2007; Threlfall et al., 2017). Urban areas have large portions of constructed anthropogenic infrastructure and are characterised by buildings, impermeable surfaces,

transportation and utility networks, lights, and a high density of the human population (Adams, 2006; Potgieter et al., 2020). The expansion of towns and cities often threatens the survival of communities and species, which leads to severe habitat loss, elimination of the majority of native species, and local extinction of some species (McKinney, 2006; Seto et al., 2012; Maseko et al., 2020; McPherson et al., 2021). In most developing countries, including China, urbanisation has transformed the existing rural population into urban populations and has advanced primary industries into secondary and tertiary industries, pushing human resources and wealth to gather in the cities (Zhang et al., 2022). In the southern hemisphere, many cities are mosaic urban landscapes with natural and managed green spaces, and some species persist despite the change in land use (Downs et al., 2021).

The reduction of the populations of native species has caused a process known as biotic homogenisation, which occurs when the non-native ‘weedy’ tolerant species replace the native ones (McKinney, 2006). This process is a major threat to biodiversity (Blair, 2001; McKinney, 2006; Trentino et al., 2013; Francis and Chadwick, 2015; Perez et al., 2021). Non-native species are more abundant in cities, although information about their invasion is not well known, and their invasion varies among the landscapes (Francis and Chadwick, 2015; Gaertner, 2017). Different land uses and urban-related factors such as impervious surfaces, increased population and density contribute to the success of most non-native species in urban areas (Gaertner, 2017). Introduced non-native plant species are mostly terrestrial species that spread through gardens and residential areas and grow along transportation networks such as roads and railways (Francis and Chadwick, 2015). Humans transport non-native animals between cities and keep them as pets; most pets receive resources from humans, which helps these species thrive in urban areas (Marques et al., 2020). Examples of studies about species invasion, non-native plants (Kowarik, 1995; van Wilgen et al., 2022) and non-native animal

species (Blair and Launer, 1997; Shivambu et al., 2020; Shivambu et al., 2021; van Wilgen et al., 2022).

Research on the effects of urbanisation on various taxa indicates that the number of non-native species in urban landscapes increases with urbanisation (McKinney, 2002; Pataki et al., 2020). On the other hand, the number of native species found in urban landscapes generally decreases, especially in the northern hemisphere, where cities have few natural or managed green spaces compared with many cities in the southern hemisphere (McKinney, 2002; Downs et al., 2021)

However, urbanisation is not all inherently bad. The capacity of species to survive in the extreme physical changes along the urban-rural gradient varies greatly as their responses mainly depend on their specific ecological traits such as body mass, dietary niche, migratory strategy, habitat affinity, behavioural plasticity, etc. (McKinney, 2006; Bregman et al., 2014; Sprau and Dingemanse, 2017). For instance, certain bird species respond differently to anthropogenic and natural disturbances and use a combination of traits to exploit urban landscapes (Battisti and Fanelli, 2016; Luna et al., 2021; Binley et al., 2023). Despite all the negative effects caused by urbanisation on the survival of the species, it is not always possible to predict how these species will respond to the changes in their environment (McKinney, 2006; Ouyang et al., 2018). In urban and suburban contexts, where they survive close to humans, many animals and plant species have adapted to new challenges, food sources, and predators and evolved certain behaviours to overcome threats (Hunter, 2007; Singh and Downs, 2016; Borden and Flory, 2021). The emergence of new resources and habitats may lead to an increase in the diversity of urban communities, but it is also possible for shifts to occur as specialised taxa perish and tolerant taxa are likely to flourish (Faeth et al., 2011). According to Hunter (2007), cities have been regarded as “ideal laboratories for studying natural selection”, as they have provided numerous surprising insights and attracted many researchers. The rapid

transformations exhibited by these cities provided valuable information on the selective and evolutionary processes (Hunter, 2007; Lambert et al., 2021). The field of urban ecology is becoming more relevant as it focuses on integrating human and wildlife populations into mutually supportive ecosystems (McPherson et al., 2021).

Across the world, urbanisation is rapidly spreading, and the role of ecosystems in providing services to humans has changed (Potgieter et al., 2020). Global cities are connected through political, economic, and technological systems as well as the biophysical processes that sustain life on Earth (Jansson, 2013). Beyond their borders, cities also have disproportionately negative effects on the environment at the local, regional, and global levels, and they are defined differently in different countries and regions, as are their limits (Elmqvist et al., 2015). Despite covering only a small portion of the planet's surface, urban areas account for a significant number of anthropogenic impacts on the biosphere (Seto et al., 2012). Many countries attempt to strike a balance between the needs of economic development and the duties to preserve biodiversity and guarantee ecosystem services to urban populations as urbanisation keeps on spreading (Elmqvist et al., 2015). One example is protected areas, and the growth in protected areas can decrease degradation and reduce the decline in biodiversity but cannot completely mitigate the risks (Geldmann et al., 2019). Urban greening programs have been implemented in some cities. Planting trees and conserving or creating natural or managed green spaces provide environmental benefits as they may reduce and help residents cope with climate change and environmental pollution effects (Pataki et al., 2021; Woodward et al., 2021).

Most of the new urban developments in the world occur in tropical and subtropical regions, particularly in Africa and Asia (Seto et al., 2012; McPherson et al., 2021). Due to the increasing number of people residing in urban areas, the urban populations of species have generally decreased, and the demands placed on natural resources have contributed to the decline of ecosystems (Güneralp et al., 2017; Rudel, 2018). More crucially, compared with

their temperate counterparts, tropical and subtropical cities display diverse, fundamentally distinct human and ecological conditions (Potgieter et al., 2020). In addition, the challenges experienced by cities in developing regions may differ from those experienced by those in developed regions (Gunalp et al., 2017; Potgieter et al., 2020).

The rapid growth of Africa's economies and human population has been identified as one of the factors that can threaten the continent's biodiversity and cause the biggest threats to the region's ecosystems (McPherson et al., 2021). The United Nations (2019) reported that the number of people in sub-Saharan Africa is expected to reach over two billion by 2050. In 2050, Nigeria is expected to become the third-most populated country after India and China (United Nations, 2019). Despite the various advantages of living in an urban area, it has been argued that people in these areas can still significantly impact the natural habitats (Sumasgutner et al., 2021). For instance, the construction of transportation networks, such as roads and railways in urban areas, can affect the water supply and cause water sources to be contaminated (Gunalp et al., 2017). Generally, habitat destruction occurs through infrastructure building and the gathering of natural resources for domestic or industrial use (Rawat and Agarwal, 2015). Urbanisation has the greatest impact on biodiversity and causes challenges in public health and sustainable development; thus, natural areas and wildlife in Africa are generally affected negatively by urbanisation (Amar et al., 2018)

One of the challenges facing conservation is the severity and frequency of human-wildlife interactions, especially negative ones that cause conflicts (Dickman, 2010; Charles et al., 2013; Mekonen, 2020). These result from how individuals understand wildlife interactions or differences between groups of people with different values, viewpoints, and goals for wildlife (Marshall et al., 2007; Charles et al., 2013). Generally, increased human population growth has affected wildlife and human-wildlife interactions (McPherson et al., 2021). Some perceive that wildlife can cause various damage, including damaging gardens, cars, and other

types of city properties (Temby, 2004; Charles et al., 2013; Schell et al., 2021). In addition, the noise and odours of certain species may cause a nuisance to some residents (Temby, 2004). Some residents also fear wildlife because they perceive it to threaten human safety, can cause collisions with vehicles, contaminate water and food, and transfer zoonotic diseases (Kruse et al., 2004; Pruett-Jones et al., 2007; Esposito et al., 2023). In urban settings, avifauna can generate issues that may lead to serious conflicts (Charles et al., 2013). Nest construction may cause damage to vegetation and infrastructure or cause unpleasant odours (Temby, 2004; Pruett-Jones et al., 2007; Hogg and Morton, 2011).

## **1.2 Suitability of urban areas for bird species**

In urban areas, natural vegetation cover is generally replaced by buildings, roads, and lawns that are not conducive to the survival of certain bird species (Lerman et al., 2014). Instead of native vegetation, landscapes are now characterised by aesthetically pleasing features that may have negative ecological consequences; however, some natural or managed green spaces may contribute to species persistence, environmental quality and human health (Nowak and Walton, 2005; Lerman et al., 2014; Isaifan and Baldauf, 2020; Downs et al., 2021). For instance, in addition to reducing the urban heat island, urban vegetation can also help sequester carbon, play an important role in human health and well-being, and reduce air pollution (Akbari et al., 2001; Isaifan and Baldauf, 2018).

Although some cities do not usually contain a diversity of native vegetation, they can still feature a mosaic of landscapes with natural and managed green spaces with high spatial heterogeneity (Su, 2021; Downs et al., 2021; Lepczyk et al., 2017). Golf courses, gardens, parks, and cemeteries are examples of managed green spaces that are good for wildlife (Singh and Downs, 2016; Alexander et al., 2019; Magle et al., 2019). Alexander et al. (2019) mentioned that North America and Europe have conducted numerous research studies on urban

green space types, and creating green spaces in urban areas can potentially help diversify the species of flora and fauna in these regions. Surprisingly, urban areas can significantly preserve biodiversity, primarily through planning, preserving, and managing urban green spaces (Aronson et al., 2017). In high-density urban areas, large patches of green spaces are often required to conserve biodiversity (App et al., 2022). However, species can coexist with humans and other animals in lower-density urban areas or mosaic urban landscapes with managed and natural green spaces (App et al., 2022; Downs et al., 2021). These areas are ideal for the persistence and conservation of various species (Soga et al., 2014; Downs et al., 2021; App et al., 2022).

According to estimates by the IUCN (2016), 27% of the world's animal species, including 13% of bird species, are threatened. It is also widely acknowledged that many species are at risk because of several factors, such as exposure to new stresses and their vulnerability to biological stresses (Ducatez et al., 2020). Although many native species or species with specific ecological requirements can be found in remnant habitats within the urban matrix, they are not commonly found in dense urban built areas (Parsons et al., 2006; Mbiba et al., 2021). According to most studies on urban communities, urbanisation generally results in an increase in overall avian biomass but a decline in species richness (Chace and Walsh, 2006; Vignoli et al., 2013). Urbanisation can have both positive and negative effects on bird populations, and these factors work together to determine which animals can persist, colonise or go extinct within an urban environment (Seress and Liker, 2015). Different animal species have a specific sensitivity to environmental disturbances based on their ecology, history, and other contextual factors (Battisti and Fanelli, 2016). According to empirical observations, some species are more vulnerable to urbanisation than others; they also tend to perish quickly in urban environments (urban avoiders), and some persist or thrive in modified environments and become more dependent on resources and habits in urban environments (urban exploiters), while others adapt

to these environments and use natural and anthropogenic resources (urban adapters) (McKinney, 2006; Koranyi et al., 2021). Those adaptations to urban settings and utilising the resources found in urban areas are why many researchers created a three-way grouping of the species along the urban-rural gradients (McKinney, 2006; Geschke et al., 2018). In particular, habitat specialisation is considered an important trait for bird species; specialist species show different sensitivity to environmental disturbance than ecological generalists (Battisti and Fanelli, 2016). However, some specialist bird species persist in urban mosaic landscapes (Downs et al., 2021). Despite their specialised nesting habits, some ground-nesting bird species in South Africa, like Spotted Thick-knees (*Burhinus capensis*), show behavioural plasticity and use resources and habitats available in suburbia to persist there (Josiah and Downs, 2022, 2023).

Some argue that there is a lack of viable species that can adapt to urbanisation (Palacio, 2020). The urban tolerance hypothesis states that certain ecological traits in the environment filter the action of other species (Bonier et al., 2007; Croci et al., 2008; Palacio, 2020). Urbanisation should favour species that can adapt to environmental changes, such as the presence of generalist species that are known to be able to survive and reproduce in different environmental conditions (Bonier et al., 2007; Palacio, 2020). Urban exploiters or adapters are more likely to survive and reproduce successfully in modified environments than urban avoiders (Blair, 1996; Croci et al., 2008; Leveau and Ibanez, 2022). The ability to forage and live in the presence of humans makes an urban exploiter different from other species; they can also take advantage of the available resources (Blair, 1996; Kark et al., 2007; Palacio, 2019).

In contrast, there is another hypothesis that was presented by Battisti and Fanelli (2016) for the co-existence of species, known as the 'intermediate disturbance hypothesis', which states that generalism is maximum at the levels of disturbance and suggests that habitat specialisation can explain the diversity and coexistence of various kinds of animals within a

community. This is because disturbing habitats limit the range of species that can survive in them, so only specialist species can survive in these areas, and generalists can survive and reproduce in intermediate environmental conditions (Bonier et al., 2007; Palacio, 2020). This hypothesis is supported by the increasing number of studies that show that urban areas favour the development of synanthropic specialists instead of generalists (Guette et al., 2017; Guo et al., 2022), especially in urban mosaic landscapes (Downs et al., 2021). Therefore, urban communities that are established in areas with moderate levels of disturbances should be composed of a mix of less competitive species and more dynamic habitats (Battisti and Fanelli, 2016).

It is also widely acknowledged that many species in urban areas are at risk because of various factors, such as exposure to new stresses and their vulnerability to biological threats (Ducatez et al., 2020). Phenotypic plasticity plays a significant role in the adaptation of the species to novel environments; in the case of organisms that encounter difficulties in their environment because of environmental changes, plasticity can help them adapt to new conditions. (Ghalambor et al., 2007; Bressler et al., 2020). By using behavioural plasticity, animals can respond to environmental threats such as food shortages and extreme weather conditions (Ducatez et al., 2020). Behavioural plasticity has been documented in a wide variety of animals and behaviours such as nest selection, communication, breeding phenology, etc. (Bressler et al., 2020). However, some types of plasticity can be considered non-adaptive; this means that an individual's fitness might be lowered while they adapt to a new environment (Ghalambor et al., 2007; Acasuso-Riveco et al., 2019), for example, high-pitched bird calls in urban areas; singing at high frequencies can help birds perceive signals in noisy conditions but it is not guaranteed that birds would thrive in urbanised areas using these frequencies (Moiron et al., 2015). On the other hand, adaptive plasticity occurs when an organism responds behaviourally to a new environment to enhance its fitness (Acasuso-Riveco et al., 2019). For

example, House Finches (*Haemorhous mexicanus*) make use of human materials to build nests; and raptors, swifts and swallows use buildings and artificial sites to nest (Reynolds et al., 2018). Thus, these populations persist because of plasticity in nesting behaviours, which enhances the reproduction and survival of these species in urban areas (Bressler et al., 2020). Bird species are considered one of the taxa that are an excellent model system for studying the effects of behavioural plasticity because they are found close to humans, are easy to observe, and have various adaptive behaviours that aid nesting, foraging, and acoustics (Marzluff, 2001; Seress and Liker, 2015).

### **1.3 Ground nesting birds**

Birds are one of the most conspicuous groups of vertebrates in the modern world. They are found in a variety of ecological niches and are widely distributed over the globe (Brusatte et al., 2015). There are various types of birds, ranging from broad generalist (use many habitats) to strictly specialised ones (inhabit a few types of habitats and usually have specific dietary requirements) (Battisti and Fanelli, 2016). Different birds have different characteristics, and their environment influences their appearance and ecology (Brusatte et al., 2015).

The behaviour that birds perform when it comes to nesting and reproduction is significant for their survival, and some urban bird species are known to display unique nesting behaviours (Bressler et al., 2020). Birds make nests using different colours, shapes, and strata. Their nests are usually constructed in the form of domes, cups, burrows, or scrapes, and the variations in the appearance of these structures are regarded as an extended phenotype (Biddle et al., 2018). As mentioned, some birds, such as raptors and swifts, can use anthropogenic structures, including buildings and bridges, to build their nests (Reynolds et al., 2018; Bressler et al., 2020; Senoge and Downs, 2023). Furthermore, they often use anthropogenic waste to line their nests. In some species, such as House Finches, plastic and twine or even cigarette

butts are used to build or line their nests, and most nests are structurally made to reduce the risk of parasites getting into their young (Reynolds et al., 2018; Bressler et al., 2020).

Ground-nesting birds prefer to build their nests on open ground, which in some species nests are relatively free of vegetation and visual obstructions, as this provides them with a clear view of their surroundings and allows them to respond when they notice potential predators (Maclean, 1985; Brown, 2000). To avoid predation, many ground-nesting birds create their nest as shallow scrapes in the ground and use natural materials to conceal the nests, and eggs are often cryptic with colouration and patterns that blend in with the surroundings (Brown, 2000; Skrade and Dinsmore, 2013; Troscianko et al., 2016; Gomez-Serrano and Lopez-Lopez, 2017; Gomez et al., 2019). In urban areas, ground-nesting birds face challenges because of high predation risks, and human disturbances because of habitat transformations (Gil and Brumm, 2014). The transformation of natural habitats to patches of managed green spaces may limit the spaces for nesting in some species, forcing ground nesters to nest closer to human disturbances that lead to exposure to different risks (Mullu, 2016; Pretelli et al., 2021). Ground-nesting birds may be disturbed by human activities in urban settings during the nesting season; if disturbances persist, these species can abandon their nests, which reduces reproductive success and causes population declines (Marzluff et al., 2001; Proppe et al., 2013).

In ground-nesting birds, nest predation can negatively affect their breeding success, and high predation pressures can lead to the destruction and abandonment of their nesting attempt, as most of them depend on low vegetation for nesting (Angelstam, 1986; Gil and Brumm, 2014; Smith et al., 2016; Tobajas et al., 2020). Endangered ground-nesting birds may have limitations in recovering if the destruction of their nests persists (Tobajas et al., 2020). Previously, studies that focused on nest predation have struggled to assess which predators were involved in the nest predation (Angelstam, 1986); however, new technologies like camera traps allow nest monitoring (Josiah and Downs, 2023). Snakes are considered one of the main causes of the

loss of nests in various ecosystems, and so the relatively lower abundance of snakes in the cities contributes to the improvement of the chances of successful nesting (Smith et al., 2016). However, domestic cats (*Felis catus*) are one of the major predators in urban landscapes (Perkins et al., 2021; Bonnington et al., 2013; Luna et al., 2021). To counteract predation, they employ different types of nest defence mechanisms to reduce the risks of nest predation (Gomez-Serrano and Lopez-Lopez, 2016; Smith and Edwards, 2018; Kostoglou et al., 2020). The survival of the individual ground-nesting bird species depends on their fitness and how they make use of the anti-predatory behaviours and strategies associated with their reproduction (Gomez et al., 2018).

#### **1.4 Lapwings**

Lapwings (Order Charadriiformes) belong to the genus *Vanellus*, which has about 22 species of plovers or lapwings, many of which frequently breed in agricultural regions with grasslands or pastures (Perrins and Middleton, 1984; Sonobe and Usui, 1993; Mishra, 2018). Generally, a range of cultivated/farmland habitats is home to lapwings, most of which are widespread and reasonably common birds (Linsley, 1999). Sheldon et al. (2007) noted that the population of lapwings in the UK and Europe decreased, and this was because of changes in agricultural practices. Generally, lapwings nest in open spaces, avoiding field boundaries and croplands (Kubelka, 2020). Lapwings are a family of medium- to large-sized wading birds with strongly patterned cryptic plumage short and short, straight bills (Sinclair, 2011). They have relatively large eyes, rounded heads, and necks that are short and thick (Maclean, 1993; Hockey et al., 2005). Eggs are laid on the ground in open habitats. They lay 2-4 brownish or greenish bluff eggs with black and greyish dots. Chicks differ from adults and are precocial (Blaker, 1966; Maclean, 1993). Lapwing species frequently migrate, leaving their breeding grounds at the end

of the breeding season and migrating to a different location to spend the winter; they then return to their nesting grounds the following spring (Linsley, 1999; Tjorve et al., 2008).

#### ***1.4.1 Blacksmith Lapwings***

Blacksmith Lapwings (*Vanellus armatus*) belong to the family Charadriidae of the subfamily Vanellinae (Fig. 1.1). The distribution of the Blacksmith Lapwings extends across Africa, from southern Kenya to Angola and South Africa (SABAP2, 2022a; BirdLife International, 2022; Fig. 1.2). However, they are relatively rare and have an uneven distribution in some of the more arid regions of the continent, such as the Northern Cape and the Namib Desert (Turpie et al., 2005).

Blacksmith Lapwings do not usually occur in mountainous or desert areas; they generally occur in areas with moist habitats close by (Ward et al., 1997; SABAP1, 2022), and they are also found in short natural grasslands, sport fields and airports (SANBI, 2018; Meissner et al., 2021). The species preferred habitat is moist, short grasslands and mudflats on the edge of waterbodies, including ponds, lakes, rivers, salt pans, dams, and estuaries (Del Hoyo et al., 1996; Meissner et al., 2021). The availability of the abovementioned habitats may be seasonal as some rely on rainfall availability, which causes these species to migrate locally (Turpie et al., 2005). Their irregular movements vary depending on the rainfall intensity and the availability of suitable habitats (SANBI, 2018). Blacksmith Lapwings can be sedentary, migratory and locally nomadic (SANBI, 2018). Blacksmith Lapwings are commonly noisy and conspicuous (Turpie et al., 2005). These gregarious birds often congregate in flocks but can also be found solitary or in pairs (Cantlay et al., 2019).

Blacksmith Lapwings are mainly insectivorous or omnivorous. Their foraging habits show that they typically run for a short distance or wade in shallow water; they then make quick movements to catch their prey, which include small animals such as snails and insects (Cantlay

et al., 2019). They shake their feet to draw prey to the surface when hunting in shallow waters. Blacksmith lapwings are unlikely to be misidentified for another species because of their bold markings in black, white, and grey on their plumage (Turpie et al., 2005; Fig. 1.1). Their underparts are strongly patterned in white and black, and their wings are a combination of grey and black (Maclean, 1993; Turpie et al., 2005). Males and females are generally similar, but females tend to be larger and heavier than males (SANBI, 2018; Meissner, 2021). Blacksmith Lapwings are monogamous, and pair bonds remain intact for as long as the individuals live. They breed in spring and become territorial during the breeding season. Nests are usually placed under a bush or on bare ground and spaced 400 m apart (Turpie et al., 2005; SANBI, 2018). There is generally a paucity of research on Blacksmith Lapwings (Table 1.1).



**Figure 1.1:** Blacksmith Lapwings (Adult-left, Juvenile-right) (Illustrations: (left) Claude Daussin and (right) Vilaro Etel).

**Table 1.1:** Examples of previous research on Blacksmith Lapwings.

<b>Authors and study</b>	<b>Aim/approach</b>	<b>Findings</b>
<p><b>Tjorve et al. (2008).</b> The energetic implications of precocial development for three shorebird species breeding in a warm environment.</p>	<p>Investigating the effects of body size, parental behaviour, and timing of breeding on the growth of the chicks and energetics of three precocial shorebird species in a warm sub-tropical environment: Kittlitz's Plover, Blacksmith Lapwings, and Crowned Lapwings.</p>	<p>Blacksmith is the least active carer, while the Crowned Lapwings and Kittlitz Plover are more active. Compared with the other two species, Blacksmith Lapwings had slow growth and longer pre fledging periods because of increased energy expenditure in cool temperatures and decreased foraging efficiency</p>
<p><b>Cantlay et al. (2019).</b> Visual fields and foraging ecology of Blacksmith Lapwings <i>Vanellus armatus</i></p>	<p>Determine visual fields and foraging ecology of Blacksmith Lapwings</p>	<p>Foot trembling serves to expand the effective foraging area of the birds beyond the limits of its visual range.</p>
<p><b>Meissner et al. (2021).</b> Sexual dimorphism and sex determination in Blacksmith Lapwings <i>Vanellus armatus</i> (Burchell, 1822) (Charadriiformes: Charadriidae)</p>	<p>Verify the utility of the carpal spur to sex the monomorphic Blacksmith Lapwings and/or to determine a more suitable method.</p>	<p>Suggested that the male had a 14 mm or longer sharp ivory-tipped spur.</p>



**Figure 1.2:** Geographic range of Blacksmith Lapwings (Source: BirdLife International, 2022).

### ***1.4.2 Crowned Lapwings***

Crowned Lapwings (*Vanellus coronatus*) belong to the subfamily Vanellinae of the family Charadriidae (Fig. 1.3), a ground-nesting species that occurs in southern and eastern Africa (Fig. 1.4). Crowned Lapwings are restricted only to Africa, and they can be found in various parts of southern Africa through East Africa, from Kenyan to southern Angola and South Africa (BirdLife International, 2022; Fig. 1.4).

Crowned Lapwings do not typically occupy habitats associated with water but are generally found in open grasslands (Ward, 1987). Crowned Lapwings inhabit mostly open grasslands and patches of scrub and open woodland, and they are also well-adapted to human-made habitats, such as parks, airports, and golf courses (De Swardt, 2010). This species sometimes shows local movement with sightings up to 13 km away, and they often move away

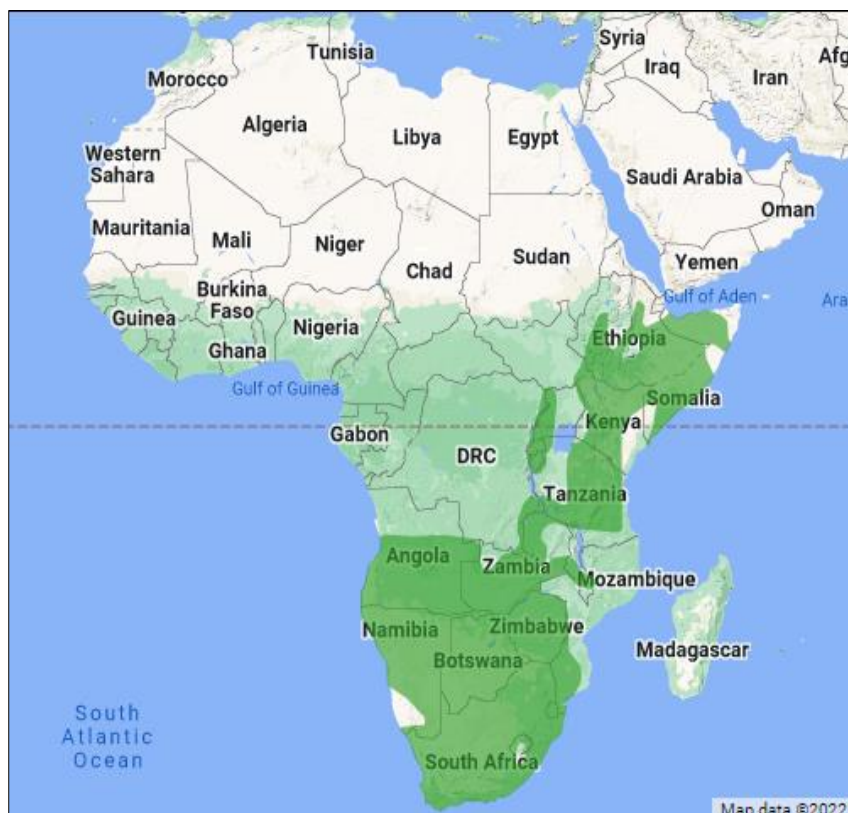
from areas if the grass becomes too tall or may move into recently burned areas (Turpie and Ryan, 2005).

Crowned Lapwings are 29-31 cm in size, weigh 150-220 g, and have a wingspan of 78 cm (Turpie and Ryan, 2005). The upper parts are usually brown, while the chest and breast have a black line dividing them from the white belly (Turpie and Ryan, 2005; SANBI, 2022). Crowned Lapwings have a black forehead and crown, white coronal circlet under the tail, and their underwings coverts are white, white tail with a broad black band, red legs, and red bill with a black tip (Urban et al., 1986; SANBI, 2022; Fig. 1.3). Juveniles are generally much duller than adults, with a crown that is buff-barred, and pale yellowish; while their legs and the base of the bill are yellow (Turpie and Ryan, 2005; Sinclair, 2011)

Crowned Lapwings tend to be solitary nesters, but occasionally breed in large groups (De Swardt, 2010). During the breeding season, they are aggressively territorial (De Swardt, 2010). There is general knowledge about their breeding season (peak egg laying occurs primarily between August and December), incubation duration, and nesting period, but little is known about their breeding success (Ward, 1989; De Swardt, 2010), and generally, there are relatively few studies on the species (Table 1.2).



**Figure 1.3:** Crowned Lapwings (Adult-right; Juvenile-left) (Source©: (Left) Gagnon Bernard and (Right) Vilaro Etel).



**Figure 1.4:** Geographic range of Crowned Lapwings (Source: BirdLife International, 2022).

**Table 1.2:** Examples of previous research on Crowned Lapwings since 2000.

Authors and study	Aims/Approach	Findings
<p><b>Brown and Downs (2003).</b> Daily and seasonal differences in body and egg temperature in free-ranging Crowned Lapwings (<i>Vanellus coronatus</i>)</p>	<p>Measured abdominal body temperature (Tb) and real egg temperature (Tegg) of free-ranging adult incubating birds on both a daily and a seasonal scale. (South Africa)</p>	<p>Daily differences in body temperature (Tb) are probably a result of daily circadian rhythms and the use of nocturnal heterothermy, while seasonal differences were explained by changes in ambient temperature and possibly circannual rhythms. Differences between and within species may not be a result of phylogenetic differences as previously reported but may be a result of relatively short-term changes in response to ambient temperature changes.</p>
<p><b>Brown and Brown (2004).</b> Nest defence in Crowned Lapwings (<i>Vanellus coronatus</i>)-influences of nesting stage and ambient temperature</p>	<p>Examined the nest defence behaviour (South Africa)</p>	<p>Temperature in the environment limits the nest defence by parents</p>
<p><b>Tjorve et al. (2008).</b> The energetic implications of precocial development for three shorebird species breeding in a warm environment</p>	<p>Investigated effects of body size, parental behaviour and timing of breeding on the growth of the chicks and energetics of three precocial shorebird species in a warm sub-tropical: Kittlitz's Plover, Blacksmith Lapwings and Crowned Lapwings. (South Africa)</p>	<p>Blacksmith is the least active carer, while the Crowned Lapwings and Kittlitz's Plover are more active. Compared with the other two species, Blacksmith Lapwings had slow growth and longer pre fledging period because of the combination of increased energy expenditure in cool temperatures and decreased foraging efficiency.</p>
<p><b>De Swardt (2010).</b> Notes on the breeding and breeding success of Crowned Lapwings <i>Vanellus coronatus</i> in the southern suburbs of Bloemfontein</p>	<p>Monitored nest and the breeding success of Crowned Lapwings. (South Africa)</p>	<p>Lower success rate influenced by the availability of domestic cats and other disturbances (Fast moving cars kill chicks)</p>

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<b>Horrocks (2016).</b> Usurpation of a Crowned Lapwing <i>Vanellus coronatus</i> nest by African Wattled Lapwings <i>V. senegalensis</i>	Instance of nest usurpation involving two ground-nesting species, the Crowned Lapwing <i>Vanellus coronatus</i> and the African Wattled Lapwing <i>V. senegalensis</i> (hereafter, Wattled Lapwing) (Zambia)	Inter-specific nest competition, in that the usurping species was not limited by nesting site, or nesting materials, and given the minimal costs likely associated with nest construction, there appeared little benefit to the usurping species of taking over an already occupied nest site.
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### 1.5 Study motivation

In a world dominated by habitat loss, overharvesting, and other human-caused environmental changes, the survival of wildlife will be unavoidably disrupted (Reynolds et al., 2018). By 2050, 66% of all people on Earth are expected to live in urban areas because of the world's growing urbanisation (United Nations, 2018). Urbanisation has become an increasing concern for the study of avian biology, which includes various aspects such as life history strategy, survival, breeding success, and individual health (Reynolds et al., 2018). Urban avian–human conflict is a developing issue, although studies of conflicts are often situation and species-specific and concentrate on landscape factors that either cause or worsen the issue (Charles et al., 2013). Due to their diversity and prevalence in urban areas around the world, birds are therefore mostly used to employ the development of the conflict explanation model, as they are noticeable and diverse compared with other urban species (Marzluff, 2001; Sumasgutner et al., 2023).

Blacksmith Lapwings and Crowned Lapwings are listed as the ‘least concern’ in South Africa, according to the IUCN (IUCN, 2016; BirdLife International, 2022). They have a relatively large distribution range, and the populations appear to be increasing, which makes them less vulnerable (BirdLife International, 2022). The increase in their population numbers, especially in anthropogenically modified environments, including urban mosaic landscapes, suggests that these ground-nesting birds can persist in these landscapes. The behavioural

plasticity likely facilitates their persistence in urban mosaic landscapes. This study assessed different aspects of the ecology and behaviour of these two lapwing species in urban mosaic landscapes to understand how they persist and reproduce successfully in anthropogenically modified habitats.

## **1.6 Aim and objectives**

This study assessed the persistence of Crowned and Blacksmith Lapwings in urban mosaic landscapes in South Africa.

The objectives were to address the following questions:

1. How prevalent are Blacksmith Lapwings and Crowned Lapwings in urban mosaic landscapes in South Africa? The distribution, range change, and abundance across South Africa were determined.
2. What is the occurrence of Crowned Lapwing and Blacksmith Lapwing, as well as their persistence, habitat use, distribution, breeding, and behaviour in the urban mosaic landscape of Pietermaritzburg?
3. How do human activities and different land uses affect the nesting ecology of Crowned and Blacksmith Lapwings breeding in the urban mosaic landscape of Pietermaritzburg?

## **1.7 Thesis format**

The thesis is formatted with the data chapters drafted as manuscripts for submission to international peer-reviewed journals. These are preceded by an introduction chapter and followed by a chapter discussing the findings and summarising the results. Because of this thesis format, a certain degree of repetition, especially in the methods section, was unavoidable. However, this is deemed to be of little concern as this format allows the reader to read each chapter separately without losing the overall context of the thesis. Chapter 2 is a systematic

review of lapwings in Africa, while Chapter 3 investigates the range distribution of the two lapwing species. Chapter 4 examines their abundance and breeding in an urban mosaic landscape. Chapter 5 is a synthesis with discussion, conclusions and recommendations.

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## CHAPTER 2

### **A systematic review of lapwing research in Africa to determine trends and evidence of their response to changes in terrestrial ecosystems**

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**Running header:** Lapwing research in Africa

## 2.1 Abstract

Humans have altered natural habitats to satisfy their needs, affecting global ecosystems and biodiversity. Grasslands have been affected by fragmentation, habitat loss, and landscape changes, which have an impact on grassland birds. Most lapwings (*Vanellus* spp.), a taxon of grassland, ground-nesting birds, have declined because of habitat modifications. We systematically reviewed lapwing research in Africa to determine the trends and evidence of lapwing responses to changes in terrestrial ecosystems. We assessed the peer-reviewed research focused on African lapwing species and the geographical and research foci of publications from January 1970 to June 2023. Our results revealed that African lapwing research activities fluctuated, with a peak in the 1980s and 2000s, with relatively little research in recent years. Research efforts on different species were biased by country, with ~64% of publications being conducted in South Africa, with more research on Crowned (*Vanellus coronatus*) and Blacksmith (*V. armatus*) Lapwings. Only 61.5% (n = 8) of lapwing species were reported in research conducted in Africa from 1970 to mid-2023. Among them, Northern Lapwing (*V. vanellus*) has a breeding population that is near-threatened. The Sociable Lapwing (*V. gregarius*) is critically endangered and also breeds in Africa. Out of all the species, Crowned Lapwings were studied the most. The available publications highlighted the behaviour, breeding, habitat selection, and diet of various African lapwing species. These species can coexist and exhibit defensive behaviours to avoid predation; their diets are mainly invertebrates, such as insects, and they tend to move if habitats are unfavourable for them. Lapwings adjust their behaviour in response to their surroundings. These adaptive behaviours, such as foraging abilities, nesting behaviours, and plasticity, enhance their fitness to survive and reproduce in anthropogenically modified landscapes. Significant gaps were highlighted in our research, with increasingly fewer publications of lapwings in Africa despite continuing anthropogenic land use change.

**Keywords:** Human-modified habits, Charadriids, *Vanellus*, Lapwings, Ecology, Conservation

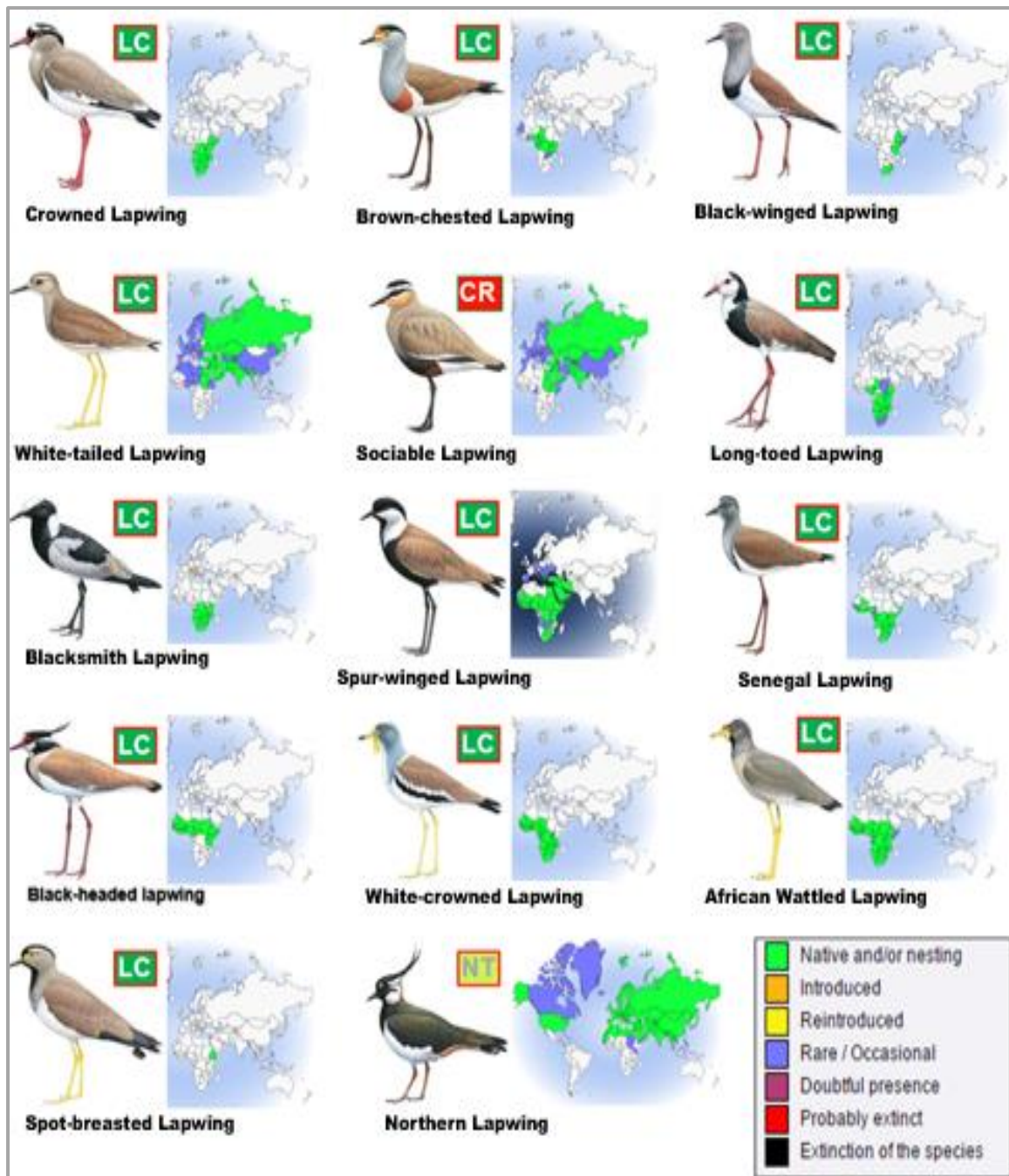
## 2.2 Introduction

Humans have altered natural areas to satisfy their needs, resulting in declining ecosystem integrity and biodiversity (Douglas et al., 2023). Of all global ecosystems, grasslands are one of the most modified ecosystems on earth because of intensive agriculture and anthropogenic land conversion (Bardgett et al., 2021), which has affected many species negatively and caused drastic reductions in populations of grassland species (Azpiroz et al., 2012; Squires et al., 2018; Correll et al., 2019; Wang et al., 2022). Globally, land-use changes and habitat loss are the major threats to grasslands, which cover 26% of global landscapes (Panunzi, 2008), and the decline of grassland-dependent species such as birds has been reported in Asia, Oceania, and Africa (Goriup, 1988; Azpiroz et al., 2012; Huntley and Barnard, 2012; Silva et al., 2023). In southern Africa, most grassland biomes are cultivated and/or converted for domestic livestock grazing, with few remaining unthreatened and intact (Maphisa et al., 2017; Douglas et al., 2023). Species invasion, fragmentation, infrastructure developments, and climate change further threaten grasslands (Douglas et al., 2023).

Lapwings belong to the family Charadriidae. They are ground-nesting birds that reside in open areas such as grasslands and farmlands, and are also associated with wetlands (Sheldon et al., 2004; Mishra et al., 2018). Most grassland bird species have declined in recent years because of land-use intensification, wetlands drainage, egg collecting, and changing agricultural practices affecting their reproductive and breeding success (Cherkaoui and Hanane, 2011; Schindler et al., 2023). Globally, wetlands are disappearing because of conversion of land by humans (Xu et al., 2019; Wang et al., 2021). In Europe, there has been a noticeable decline in wading birds (Order Charadriiformes) (Franks et al., 2018; Jellesmark et al., 2022). Lapwings' population fluctuations have been noted, and their decline is mostly

related to habitat alterations by humans from increased agricultural productivity, groundwater drainages, and shrub invasions (Mishra et al., 2018). This makes them more of a high conservation concern because their nests are affected by agricultural intensification, and their historical population decline was associated with nest predation during their breeding seasons and hunting on their migratory routes (Kolecek et al., 2021; Hunt et al., 2023).

The lapwings (Sub-family Vanellinae) consist of about 25 species from two genera- *Vanellus* and *Erythrogonys* in South America, Asia, Africa, Malaysia, and Australia (Lok and Subaraj, 2009), with 14 species that breed in and/or native to Africa (Fig. 2.1; Sinclair and Ryan, 2010). They inhabit grasslands, lakes, and sandy areas, and can breed in agricultural areas (Sonobe and Usui, 1993; Mishra et al., 2018). Although urbanisation and other factors have caused a decline in the population of these species, more effort is needed to conserve these species in human-dominated areas (Shrubb, 2009; De Swardt, 2010; Sheldon et al., 2013). Their conservation is associated with land restoration, predator control, and the availability of natural and managed green spaces in urban areas to accommodate these species (Franks et al., 2018; Jellesmark et al., 2022; Birdlife International, 2023).



**Figure 2.1:** The 14 lapwing species that occur/breed in Africa, including their IUCN Red List status (Note: LC= Least concern, CR= Critically endangered, NT-Near Threatened) and geographic range (Sources: © Avibase - Oiseaux.net; Birdlife international; Picture credits: Birds of the World, Cornell Lab of Ornithology).

Africa contains a rich diversity of lapwing species and different ecosystems that offer a range of habitats for these species. Africa faces conservation challenges, including habitat

degradation, human-wildlife conflicts, climate change and urbanisation, which make this region a focal point for conservation efforts. The International Union for Conservation of Nature (IUCN) (2016) stated that 12 of the Lapwing species are of the least concern in Africa, with the Sociable Lapwing (*Vanellus gregarius*), which is critically endangered and winters in north-east Africa, and the Northern Lapwing (*Vanellus vanellus*) which is Near Threatened, winters in north Africa. Our study focused on past and present research on lapwings in Africa to gain insight into their distribution, trends in their population and their habitat preferences, and to identify gaps in knowledge and highlight areas for future research. We were also interested in understanding the ecological roles of lapwing species and the threats they face because of anthropogenic effects on terrestrial landscapes in Africa. A rapid change of landscapes in Africa because of anthropogenic activities and environmental changes highlights the critical need to conduct research on lapwing populations in this region to facilitate immediate and effective conservation measures. We predicted that the research varies both in Africa and within the target species, and research bias may have an impact on the attempt to learn more about these species within their distribution range.

### **2.3 Methods**

We initially conducted a broad systematic keyword literature search in Google Scholar® <https://scholar.google.com/>. We repeated this using the Web of Science® <http://webofscience.com/> and Scopus® databases <https://www.scopus.com/> to find any additional relevant articles that might have been missed while browsing other databases (Accessed in April 2023). We searched the peer-reviewed literature on lapwings from 1970-mid-2023, containing keywords “Lapwings” “Plovers” “Lapwings in Africa” and “Plovers in Africa”. We sourced a range of publications, including popular articles, book chapters, reviews, letters, conference papers, etc., to ensure that all the relevant research was accessed, and the

most available information on peer-reviewed publications gathered from these. We limited publications to peer-reviewed articles and reviews focused on lapwings in English or with an English abstract. We included some anecdotal records in peer-reviewed journals as well. We also included theses/ dissertations with important information about lapwings and excluded any other documentation. We included publications that focused on multiple lapwing species, such as those that show interactions and coexistence of the lapwing species within a particular area.

The results recorded initially were for a global literature search, but as the review focused on Africa, we refined our search and included only publications of lapwing species in African countries. After refining our search, we identified authors and the country where the study was based to determine the geographic distribution of each publication. We identified the aspect of research examined or focused on (e.g., breeding, feeding, habitat selection, etc.). Additionally, we used the year of publication for each study to highlight when most studies were published. Data were recorded in a Microsoft© Excel spreadsheet. We used descriptive statistics to show trends from the data gathered.

## **2.4 Results**

### **2.4.1 Publications**

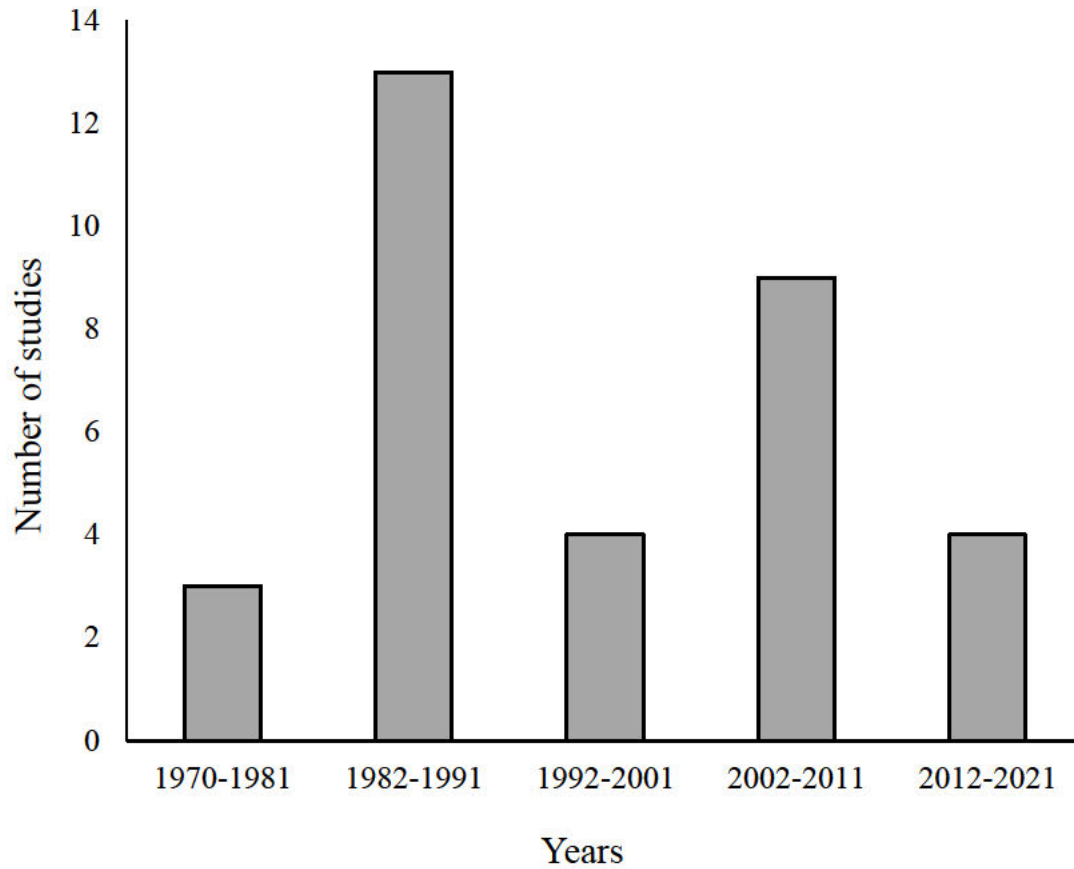
We found 33 relevant publications about lapwings in Africa from 1970 -2023 (Table 2.1). Our results show no continuous increase in the number of studies, but 1982-1991 (39.4%) and 2002-2011 (27.3%) had more studies than other years (Fig. 2.2). In Africa, fewer studies focused on lapwings during the early years (1970-1981, 9.1%). In the last 12 years, only four (12.1%) studies on African lapwing species were published, and there were no publications in 2022 and 2023 (Jan-Jun).

**Table 2.1:** Summary of lapwing (*Vanellus* spp.) publications in Africa (January 1970-June 2023) (n = 33)

References	Species name	Common name	Country	Year	Aspect of research
Anderson and Kok, 1990	Crowned Lapwings	<i>V. coronatus</i>	South Africa	1990	Breeding
Anderson and Kok, 1992	Crowned Lapwings	<i>V. coronatus</i>	South Africa	1992	Morphology
Brown, 1972	Blacksmith Lapwings	<i>V. armatus</i>	South Africa	1972	Breeding
Brown and Brown, 2004	Crowned Lapwings	<i>V. coronatus</i>	South Africa	2004	Breeding
Brown and Downs, 2002	Crowned Lapwings	<i>V. coronatus</i>	South Africa	2002	Growth and development
Brown and Downs, 2003	Crowned Lapwings	<i>V. coronatus</i>	South Africa	2003	Breeding
Brown and Downs, 2004	Crowned Lapwings	<i>V. coronatus</i>	South Africa	2004	Nesting
Byron and Downs, 2002	Crowned Lapwings	<i>V. coronatus</i>	South Africa	2002	Risk management
Cherkaoui and Hanane, 2011	Northern lapwings	<i>V. vanellus</i>	Morocco	2011	Ecology and breeding
de Swardt, 2010	Crowned Lapwings	<i>V. coronatus</i>	South Africa	2010	Breeding
Downs and Ward, 1997	Crowned Lapwings	<i>V. coronatus</i>	South Africa	1997	Breeding
Horrocks, 2016	Crowned Lapwings, African Wattled lapwings	<i>V. coronatus</i>	Zambia	2016	Nest predation
Kok and Anderson, 1989	Crowned Lapwings	<i>V. coronatus</i>	South Africa	1989	Diet
Meissner et al., 2021	Blacksmith Lapwings	<i>V. armatus</i>	South Africa	2021	Sexing
Messemaker, 2004	Sociable Lapwings	<i>V. gregarius</i>	Cameroon	2001	Records
Mimbani et al., 2009	Senegal Lapwings	<i>V. lugubris</i>	Central Gabon	2009	Nesting (Nest defense)
Moore and Vernon, 1973	Crowned Lapwings	<i>V. coronatus</i>	Zimbabwe	1973	Nesting

Pearson, 1983	Blacksmith Lapwing, Spur-winged Lapwing	<i>V. armatus</i> , <i>V. spinosus</i>	Kenya	1983	Breeding
Reynolds, 1984	Blacksmith Lapwings	<i>V. armatus</i>	Kenya	1984	Ecological records
Riddell, 2018	Spur-winged Lapwings	<i>V. spinosus</i>	Zimbabwe	2018	Ecological records
Thomas, 1983	Blacksmith Lapwings	<i>V. armatus</i>	Namibia	1983	Behaviour
Tjorve et al., 2008	Blacksmith Lapwings, Crowned Lapwings	<i>V. armatus</i> , <i>V. coronatus</i>	South Africa	2008	Behaviour and breeding
Walters, 1990	Long-toed, Blacksmith Lapwings	<i>V. crassirostris</i> , <i>V. armatus</i> , <i>V. coronatus</i>	Kenya	1990	Predation (Anti-predator behaviour)
Walters, 1982	Long-toed, Blacksmith, Crowned Lapwings	<i>V. crassirostris</i> , <i>V. armatus</i> , <i>V. coronatus</i>	Kenya	1982	Breeding, behaviour
Walters, 1979	Long-toed Lapwings	<i>V. crassirostris</i>	Kenya	1979	Behavioural ecology
Ward, 1987	Crowned, Blackwinged, Lesser Blackwinged Lapwings	<i>V. coronatus</i> , <i>V. melanopterus</i> , <i>V. lugubris</i>	South Africa	1987	Biology and systematic relationships
Ward, 1988	Blacksmith Lapwings	<i>V. armatus</i>	South Africa	1988	Behaviour
Ward, 1989a	Crowned Lapwings, Blackwinged Lapwing, Lesser Blackwinged (Senegal) Lapwings	<i>V. coronatus</i> , <i>V. melanopterus</i> , <i>V. lugubris</i>	South Africa	1989	Breeding

Ward, 1989b	Crowned, Blackwinged, Lesser Blackwinged (Senegal) Lapwings	<i>V. coronatus</i> , <i>V. melanopterus</i> , <i>V. lugubris</i>	South Africa	1989	Feeding ecology
Ward, 1992	Crowned Lapwings, Blackwinged Lapwings, Lesser Blackwinged (Senegal) Lapwings, African Wattled Lapwings, Blacksmith Lapwings	<i>V. coronatus</i> , <i>V. melanopterus</i> , <i>V. lugubris</i> , <i>V. senegallus</i> , <i>V. armatus</i>	South Africa	1992	Ecology
Ward and Maclean, 1988	Crowned Lapwings, Blackwinged Lapwings	<i>V. coronatus</i> , <i>V. melanopterus</i> , <i>V. lugubris</i>	South Africa	1988	Coexistence/behaviour
Ward and Maclean, 1989	Crowned Lapwings, Blackwinged Lapwings, Lesser Blackwinged (Senegal) Lapwings	<i>V. armatus</i>	South Africa	1989	Habitat selection
Waterman and Mai, 2020	Crowned Lapwings	<i>V. coronatus</i>	South Africa	2020	Behaviour

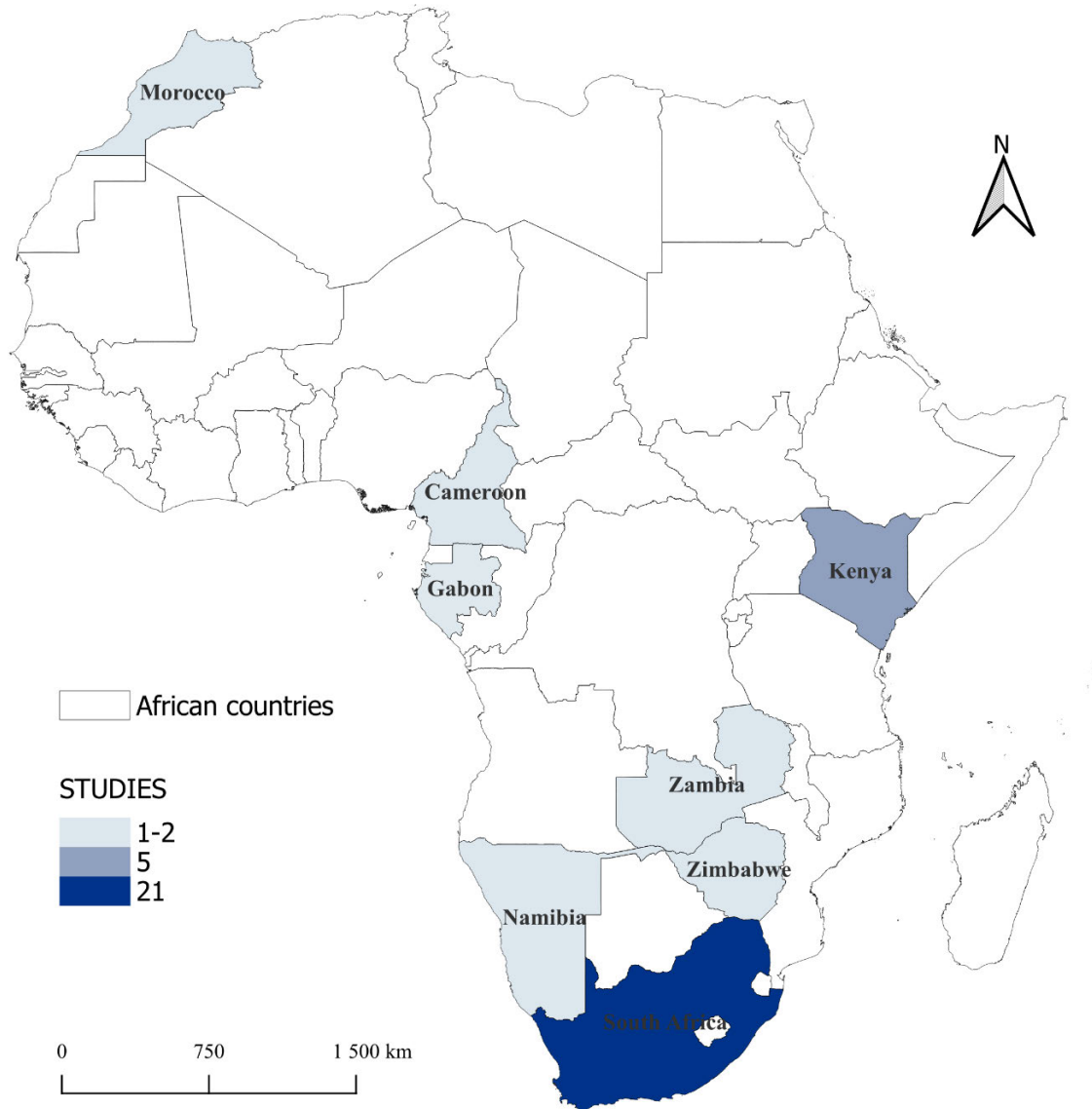


**Figure 2.2:** Number of African lapwing publications per 10 years (covering the last 53 years).

No publications were published in 2022 and 2023 (Jan-Jun).

### 2.4.2 Geographic distribution of research

Most studies on lapwings in Africa were conducted in South Africa (n = 21 studies; 64%), followed by Kenya (n = 5 studies; 15%), Zimbabwe (n = 2 studies; 6%) and at least one publication from Cameroon, Gabon, Morocco, Namibia, Zambia (n = 1 studies for each; 3% each) (Fig. 2.3). Each country had a specific species each publication focused on.

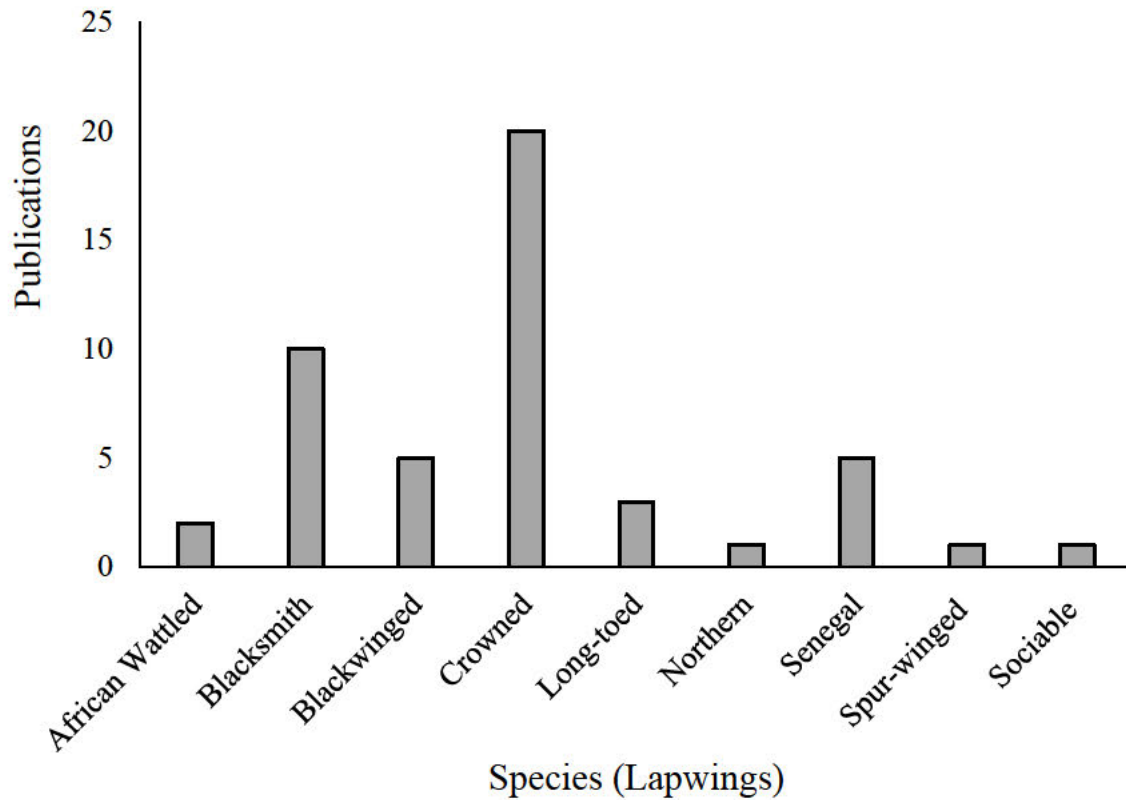


**Figure 2.3:** The distribution of lapwing species publications in peer-reviewed journals across African countries, studies from 1970 to mid-2023. (Note: Countries are highlighted based on the number of peer-reviewed publications found).

### 2.4.3 Species and research foci

We tried to source publications based on the 14 lapwing species that occur and/or breed in Africa (Fig. 2.1), but only nine of these species had relevant publications. The Northern Lapwing, which is near-threatened, and the Sociable Lapwing, which is critically endangered, both had one publication based in Africa from 1970 to mid-2023. The lapwing species most frequently published were Crowned Lapwings (*V. coronatus*) (n = 20), followed by Blacksmith Lapwing (*V. armatus*) (n = 10), Senegal Lapwing (*V. lugubris*) (n = 5), Black-winged Lapwing (*V. melanopterus*) (n = 5), Long-toed Lapwing (*V. crassirostris*) (n = 3), African Wattled Lapwing (*V. senegallus*) (n = 2), and Spur-winged Lapwing (*V. spinosus*) (n = 1) (Fig. 2.4).

We found most lapwing research focused on breeding, which was biased to only two or three species, while other research focused on behaviour, feeding, and habitat selection. For the critically endangered Sociable Lapwing, the only publication in Africa was on the record and first sighting, but none about aspects of their ecology.



**Figure 2.4:** Number of studies on the respective lapwing species in Africa from 1970 to mid-2023.

## 2.5 Discussion

Understanding how lapwing species react and respond to their surroundings and changing habitats is key to the designation of conservation strategies. Globally and in Africa, less research has focused on their response to anthropogenic land use changes caused by urbanisation. Human populations are rapidly increasing in Africa, especially in West and East Africa (Li et al., 2022). Globally, the human population in urban areas expands each year, and the population is expected to increase by 68% by 2050 (DESA, 2018). Undoubtedly, changes are projected to be experienced because of urbanisation and an increase in anthropogenic activities, which will make many bird species vulnerable.

From 1970 to mid-2023, few publications of lapwings in Africa. The majority of the publications were short term (< 2 years). We included the anecdotal observations which are a

short-term studies (< 1 year). Awoyemi and Ibanez-Alamo (2023) highlighted important gaps in urban ecological research in Africa and noted that the lower rate of research in Africa might be caused by different socio-economic factors, such as a lack of skilled people and reduced investment in research. Several bird guides, for example, Sinclair and Ryan (2010), showed lapwing species identification and distribution in Africa but no detailed aspects of their ecology. Most peer-reviewed, lapwing-focused research in Africa was published in the 1980s and early 2000s, with fewer in the last decade and no publications published in 2022 and 2023. Fieldwork and data collecting from 2020 appeared to have been delayed as a result of the COVID-19 epidemic interfering with research efforts. The lapwing research focused on South Africa, and mostly on Crowned Lapwings and Blacksmith Lapwings. Most lapwing research focused on breeding, which was biased to only two or three species, while other research focused on behaviour, feeding, and habitat selection. Based on the publications found, no research has been done on the conservation of the critically endangered Sociable Lapwings in Africa. The only publication regarding this species was about the anecdotal observation (first sighting) in Cameroon (Messemaker, 2004). The study by Cherkaoui and Hanane (2011) proposed some conservation action for the near-threatened Northern Lapwings in Africa to conserve the single population of this species that breeds in Morocco.

The scope of this systematic review was limited to peer-reviewed publications focused on lapwings in Africa. As such, the review did not include information from non-peer-reviewed sources such as books, even though some of these non-peer-reviewed sources may provide relevant information about the species. Information found in books (bird guides), and publications containing bird lists (not included in the review) offer a useful overview of the lapwing species found in Africa, e.g., McLachlan and Liversidge (1978), Cyrus and Robson (1980), Cramp and Simmons (1983), Hayman et al. (1986), Urban et al. (1986), Hockey et al.

(1989), Maclean (1993), Harrison et al. (1997), Underhill et al. (1999), Barnes (2000), Tarboton (2001), Turpie et al. (2005), Turpie and Ryan (2005), and Dowsett et al. (2008).

Geographic distribution bias of African lapwing peer-reviewed publications was found with few publications from other countries where the species occur, such as the Blacksmith Lapwings and Crowned Lapwings, which had publications mainly in South Africa, and Long-toed Lapwings, with publications only in Kenya. Approximately 64% of the lapwing species publications focused on South Africa, with ~36% focused on other remaining countries, and many countries with no publications conducted. South Africa is listed as one of the developing countries in Africa and richer in research outputs and facilities for data collection, with over 60% of research outputs from 1996-2010, compared with other countries in this region (Van Zyl, 2012), and we assume this the reason for more publications found in South Africa.

Only nine species publications were recorded during our African literature search. Although these species are understudied, the available literature gives insight into how they use their habitats and surroundings. Lapwings are urban adapters because they use the resources available in human-modified habitats; however, they generally require managed green spaces (short grasslands) in urban mosaic landscapes (de Swardt, 2010; BirdLife International, 2023). The behavioural plasticity and dietary flexibility contribute to the survival of these species (Walters, 1979; Ward, 1989b; Kok and Anderson, 1989; Tjorve et al., 2008; Waterman and Mai, 2020). They have defensive adaptive behaviours to avoid predation, and they can distract predators aggressively and escape predation (Walters, 1990). In open habitats, these species are likely to be vulnerable to predators but have learned to coexist and gain the ability to notice and avoid predation (Ward and Maclean, 1988). This helps them have a high chance of survival and higher reproductive success (Ward, 1989a). During breeding, adults increase nesting defence gradually over the incubation period (Brown and Brown, 2004). These species are bi-parental ground nesters with cryptic and aggressive nest defence, but the ambient

temperature impacts these species' behaviour; nest defence occurs at above or below 25°C (Ward, 1987). Lapwing species can simultaneously occur in the same space with one another, coexist, and feed on the same diet (insects) without fighting or competing for food (Ward, 1989b; Kok and Anderson, 1989). Interspecific activity was documented between ground squirrels (*Xerus inauris*) and Crowned Lapwings. Ground squirrels can benefit from the alarm calls of the lapwings, and they can increase their chances of survival by responding to their alarm calls, which makes them vigilant for possible danger (Waterman and Mai, 2020). Although there was an occurrence of usurpation of nests between African Wattled Lapwing and Crowned Lapwing, it was noted that the benefits were minimal because the eggs did not survive, benefiting neither species (Horrocks, 2016).

In our review, we found that other lapwing species are severely affected by the changes in their habitats and suffer a decline in their populations (Messemaker, 2004; IUCN, 2016). However, some species benefitted from anthropogenic land use change; for example, Crowned Lapwings were found in the managed green spaces of airports, although they can pose threats to aircraft (Bryon and Downs, 2002). In Africa, some lapwing species adapt relatively well to human-modified habitats with short, grassy, green, relatively large spaces (natural or managed), enhancing their fitness through behavioural plasticity (Ward, 1989a; Ward, 1992; Gupta et al., 2022; Bar-Ziv et al., 2022; Halassi et al., 2022).

Northern Lapwings have a wide range in Asia and Europe, but a small breeding population occurs in Africa (Morocco). They migrate to Africa to breed during winter (Thevenot et al., 2003; Cherkaoui and Hanane, 2011). The Northern Lapwing is near threatened (IUCN, 2016). This is a consequence of a loss in nests because of human disturbances, predation, and cattle grazing agricultural practices, which causes a decline in breeding productivity (del Hoyo et al., 1996; Cherkaoui and Hanane, 2011). Furthermore, Sociable

Lapwings are listed as critically endangered because their population is decreasing because of human hunting pressures on their migratory routes (BirdLife International, 2023).

Blacksmith Lapwings and Crowned Lapwings are not threatened because of their increasing range and population (IUCN, 2016). These species occur over most of southern Africa, with fragmented populations in most southern African countries. Blacksmith Lapwings inhabit marshes, areas near lakes and rivers, as well as moist, short grasslands. In urban areas, they are mostly found in managed green spaces (sports fields, golf courses and airports) (Brown and Brown, 2004). Similarly, Crowned Lapwings are mostly found in managed and natural green spaces (sports fields, open grasslands and airports) in urban mosaic landscapes, but are not generally found close to water sources (Anderson and Kok, 1990; Brown and Downs, 2004; Ward, 1989a,b).

The foraging behaviour exhibited by lapwings, including Blacksmith Lapwings and Crowned Lapwings, is called the 'foot-trembling' behaviour, its function is to extend the bird's foraging area beyond the limits of its visual field (Cantlay et al., 2019). These species are insectivorous and play an important role in controlling insect populations in their surroundings. The open habitats used by these species to nest are risky because of being exposed to different predators such as Black Sparrowhawks (*Accipiter melanoleucus*), Pied Crows (*Corvus albus*), cats (*Felis catus*), water monitors (*Varanus salvator*), etc. (de Swardt, 2010) but they have developed ability to detect the predators and have employed different strategies to avoid predation (Ward, 1989a). The above-mentioned predators reduce the hatching and nesting success of these species, and some incidents have been reported by de Swadt (2010), such as the chicks being killed on the streets by fast-moving cars. Despite the challenges Blacksmith Lapwings and Crowned Lapwings face in human-modified habitats, they employ different behavioural strategies to overcome threats.

### **2.5.1 Conclusions**

Our systematic review of peer-reviewed publications focussed on lapwings in Africa and highlighted important gaps in studies of lapwings in association with human-modified habitats in Africa. More research is needed on lapwings because there are increasingly fewer studies in African countries, and more species need to be studied to understand their ecology and persistence with ongoing anthropogenic land use change. Most lapwing research was conducted in the 1980s and early 2000s, which contributed to understanding the life history of these species. However, there was less research in the past decade, which raises concerns because recent ecological aspects are also needed to understand whether these species' populations are continuing to decline or not. The behaviour, breeding, population parameters, and conservation need to be considered for future research, and studies focusing on other poorly studied species are needed. These research aspects will improve understanding of the threats and conservation implications for the populations of various African lapwing species. A review by Awoyemi and Ibanez-Alamo (2023) focused on urban ecology studies in Africa and showed this continent generally lacks research in urban ecology, with studies mainly published from wealthier/developed countries. If African researchers make greater inputs to urban ecology, a better understanding will be gained about the species that reside and persist in these areas, especially in managed and natural green spaces in the urban mosaic landscapes, which will help with conservation, management and planning (Downs et al. 2021). IUCN Red List helps direct researchers to the species that require more conservation efforts, and they have executed the plans for the future conservation of those lapwing species that are severely declining in population numbers and distribution range (IUCN, 2016). Researchers need to take action, expand research on species in urban mosaic landscapes, and understand their ecology and threats.

## 2.6 Acknowledgements

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## CHAPTER 3

### Use of the Southern African Bird Atlas Project (SABAP) to examine the distribution range and relative abundance of Blacksmith Lapwings and Crowned Lapwings across South Africa, Lesotho and Eswatini

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**Running header:** Blacksmith and Crowned lapwing distribution across South Africa, Lesotho and Eswatini

### 3.1 Abstract

Human-modified habitats now dominate ecosystems on Earth. These modifications result in permanent changes to available habitats, which in turn causes shifts in species assemblages. Wildlife monitoring is important to determine the threats causing a decline in wildlife populations, especially those species facing extinction risks. Citizen science projects involve volunteers, commonly known as citizen scientists, actively participating in various research processes and data collection activities to produce relevant scientific outcomes, especially monitoring species. National bird atlas projects in South Africa carried out by citizen scientists are the Southern African Bird Atlas Project 1 and 2 (SABAP1: 1987–1992, and SABAP2: 2007–present). These projects provide overviews of avian distribution across southern Africa. Spatial records in this database show changes in species distribution (range), and by comparing reporting rates (the proportion of checklists reporting a species, which is an index of relative abundance) between these projects to estimate population change. We assessed Blacksmith (*Vanellus armatus*) and Crowned Lapwings (*V. coronatus*) presence and distribution range in southern Africa by comparing the presence and reporting rates between historical data (SABAP1) and present data (SABAP2). We found distribution range changes and overall relative abundance decline for both species. The causes of these declines include anthropogenic land transformation and prolonged drought in some regions, which may have caused the shift of these species.

**Keywords:** Citizen science, monitoring, SABAP1, SABAP2, reporting rates, relative abundance, South Africa

### **3.2 Introduction**

Ecosystems on Earth are now dominated by human-modified habitats (Bonier et al., 2007). These modifications result in permanent changes to available habitats, which in turn causes shifts in species assemblages (Andren 1994; Simkin et al. 2022). Globally, anthropogenic activities have greatly impacted biodiversity (Cebalos et al. 2015; Prakash and Verma 2022). Anthropogenic land transformation, including deforestation, urbanisation, and agricultural expansion, destroys natural habitats and causes fragmentation of many ecosystems, reducing biodiversity (Laurance et al. 2018; Prakash and Verma 2022). Urbanisation is one of the main causes of biodiversity loss as it drives habitat modifications and generally causes the extinction of local species (McKinney 2006; McPherson et al. 2021).

Wildlife monitoring is important to determine declines in wildlife populations and the threats causing this, especially those species facing extinction risks (Shresth and Lapeyre 2018; Robinson et al. 2018; Lindenmayer et al. 2020). The ability to monitor the population is important to conservation biology because it provides essential information about a species' status, especially for threatened species (Shrestha and Lapeyre 2018; Kuhl et al. 2023). Information and data gathered provide long-term trends about species abundance and geographical distribution, which helps in tracking and understanding the different crises of global biodiversity (Robinson et al. 2018; Moussy et al. 2021). Field surveys, citizen science information, satellite tracking, and genetic analyses are various methods used to monitor the species (Moussy et al. 2021). Over the years, technological developments have contributed to studying habitats and species that require conservation efforts and dealing with biodiversity threats (Lahoz-Monfort and Magrath 2021). The broad internet access has made it easier to conduct ecological monitoring through citizen science, which is increasingly used to monitor (record and study) wildlife populations across large geographic and temporal ranges (Sun et al. 2021). Generally, technological advancements have caused species monitoring efficiency and

accuracy, and a range of techniques and tools (e.g., earth-based and satellite-based sensors) can be used to enhance data collection (Sullivan et al. 2009; Stephenson 2020). Generally, the targets are the priority species and sites, the provision of conservation resources, and an assessment of the impact of monitoring (Moussy et al. 2021; Hoffmann 2022). Monitoring programs are required to understand how environmental changes affect wildlife populations, and surveying animals at different times is necessary for monitoring wildlife populations to determine population trends or population changes (Lindenmayer and Likens 2010; Amar et al. 2016; Peralta et al. 2023). Monitoring depends on accuracy, and methods must remain constant over time (Bonnivie 2011). However, challenges and errors that arise when using the methods and associated protocols are not always possible to mitigate (Amar et al. 2016; Johnston et al. 2022).

Despite technological advances, citizen science is important for monitoring many species over their distribution range (Downs et al. 2014; Feldman et al. 2021). In the 18th and 19th centuries, naturalists and other science enthusiasts contributed to collecting data about the species, leading to the rise of citizen science to monitor species (Bonney et al. 2009). Citizen science projects involve volunteers, commonly known as citizen scientists, actively participating in various research processes and data collection activities to produce relevant scientific outcomes (Silvertown 2009; Sullivan et al. 2014; Fraisl et al. 2022). In the early 20<sup>th</sup> century, the Christmas Bird Count in the United States of America (USA) was established to encourage the public to participate in bird monitoring, and this advanced the knowledge about USA avian populations and their migratory and movement patterns (Silvertown 2009). The contribution to data collection provided a solid foundation for citizen science and highlighted the importance of amateur researchers in expanding scientific research fields. Technology advancement and the development of the internet in the late 20<sup>th</sup> century contributed to the revolution of citizen science and brought citizens closer to scientific processes (Sullivan et al.

2009; Strasser et al. 2019; Sanabria-Z et al. 2022). Online tools (e.g., eBird, which was launched in 2002) allowed people to contribute to bird observations and create valuable datasets for avian research using standardised procedures based on each species site and/or count of the species (Sullivan et al. 2009; 2014; Callaghan et al. 2017). Citizen science is expanding, and its various projects have the potential to generate large and valuable datasets in research and conservation (Sullivan et al. 2014; Brooks et al. 2022). These datasets have been shown to be effective and unrivalled in their ability to examine important conservation and species biodiversity issues, especially in Africa, where funding for conservation biology is limited (Brooks et al. 2022). One of the national bird atlas projects in South Africa carried out by citizen scientists is the Southern African Bird Atlas Project 1 and 2 (SABAP1 and SABAP2) (Brooks et al. 2022).

It is widely acknowledged that many species in urban areas are at risk because of various factors, such as exposure to new stresses and their vulnerability to biological threats (Ducatez et al. 2020). Lapwings are one of the ground-nesting bird species documented to be persisting in urban areas, and the survival of these species depends on their fitness and how they make use of the anti-predatory behaviours and strategies associated with their reproduction (Gomez et al. 2018). Urbanisation may negatively affect ground-nesting bird species' survival by causing population declines because of a lack of open natural spaces for nesting and foraging (Leveau and Ibanez 2022). Noise, predation and pollution of potential habitats make it difficult for some species to breed successfully (Jokimaki and Huhta 2000; Jokimaki et al. 2005; Richard et al. 2021). Across Africa, a general trend is that the urban environment is associated with lower species richness, although there are many urban adapted bird species (Lee et al. 2021).

The urban environment can also benefit some bird species, and in Africa, certain urban environments are associated with increased bird species richness (Chamberlain et al. 2019).

The increase in species in urban mosaic landscapes is driven by the conservation of natural green spaces and corridors as well as the creation of new habitats, such as managed green spaces, including wetland habitats, that provide resources and protection against predation (Leveau et al. 2019; Downs et al. 2021; MacKinnon et al. 2023). By using behavioural plasticity, animals can respond to environmental threats such as food shortages and extreme weather conditions, enhancing their survival (Ducatez et al. 2020). Given the risks and opportunities associated with urbanisation and habitat changes caused by anthropogenic activities, we were interested in determining the trends in the distribution range and presence of regional populations of Blacksmith *Vanellus armatus* and Crowned Lapwings *V. coronatus* with time.

Our study aimed to assess Blacksmith Lapwings and Crowned Lapwings relative abundance changes across their distribution range in South Africa by examining and analysing the SABAP data. Given rapid human population growth and urbanisation, we hypothesised a change in the population and distribution range of the species when historical data (SABAP1) and present data (SABAP2) were compared.

### **3.3 Methods**

#### ***3.3.1 Study species***

Blacksmith Lapwings (family Charadriidae) occur widely across southern, eastern and parts of central Africa (Hall 1959; Turpie et al. 2005; BirdLife International 2016), with their breeding range distributed from Kenya and Angola southwards (Ward et al. 1997; Turpie et al. 2005; SABAP, 2023). Blacksmith Lapwings prefer moist, short grasslands and mudflats on the edge of waterbodies, including ponds, lakes, rivers, salt pans, dams, and estuaries (Del Hoyo et al. 1996; SANBI 2018; Meisser et al. 2021). They also inhabit short grasslands that can be natural or burnt, as well as modified grasslands such as mown grass, sports fields, and airports (Turpie

et al. 2005). They do not usually occur in mountainous or desert areas; they generally occur in areas with moist habitats close by (Turpie et al. 2005). The availability of the mentioned habitats is seasonal, and they depend on rainfall availability, which causes this species to move locally (Turpie et al. 2005). These gregarious birds frequently gather in flocks, but they can also be found singly or in pairs (Cantlay et al. 2019). They forage on small aquatic and terrestrial invertebrates such as snails, worms, and insects (Hall 1964; Urban et al. 1986; Cantlay et al. 2019). Blacksmith Lapwings breed in winter and early spring and become territorial during the breeding season, and nests are usually placed under a bush or on bare ground (Turpie et al. 2005).

Crowned Lapwings (family Charadriidae) occur in southern and eastern Africa, in areas where there are short overgrazed or burnt grasslands (Hayman et al., 1986; BirdLife International, 2016). This species is usually resident but can move locally when conditions become unfavourable; for example, in some areas with a more or less permanent supply of water or when the grass becomes taller, local populations may be sedentary (Hanley 1990; Turpie and Ryan 2005). Crowned Lapwings mainly inhabit open grasslands and patches of scrub and open woodland but also use human-made habitats, such as parks, airports, golf courses, and roadsides (Turpie and Ryan 2005; De Swardt 2010). They do not typically occupy habitats associated with water, but they do appear around pans and dry salt marsh vegetation (Urban et al. 1986; Turpie and Ryan 2005). Crowned Lapwings are generally solitary nesters, monogamous (rarely polygamous) and aggressively territorial during the breeding season (Ward 1989; De Swardt 2010). Nests are scraped in the ground, and they use grass, small stones, and dried dung to line nests (Tarboton 2001).

Blacksmith Lapwings and Crowned Lapwings are listed as 'Least Concern' globally, according to the IUCN (IUCN 2016; BirdLife International 2023). They have relatively large distribution ranges, and their populations are relatively large and appear to be increasing

(BirdLife International 2023). The increase in their population numbers, especially in anthropogenically modified environments, including urban mosaic landscapes, suggests that these species are ground-nesting birds that can persist in urban mosaic landscapes.

### **3.3.2. Data analyses**

The first and second Southern African Bird Atlas Projects (SABAP1: 1987–1992, and SABAP2: 2007–present) are citizen science projects where birders submit lists to a central database managed by the Fitzpatrick Institute, University of Cape Town, Cape Town, South Africa. These projects provide overviews of avian presence and distribution ranges across southern Africa (Brooks et al. 2022). SABAP1 were data collected from 1987-1992 in a quarter-degree grid cell resolution (QDGC, 15' by 15'). SABAP2 data were collected in a pentad format with a 5' by 5' resolution grid. The latter data were converted into QDGC grids to compare SABAP1 and SABAP2 by combining the results of the nine pentads nested in a QDGC. Comparison of these spatial data over time can show changes in species distribution range (Brown et al. 2019). Spatial records show distribution range changes. Population changes can be inferred by comparison of reporting rates (proportion of checklists reporting a species so an index of relative abundance) between SABAP 1 and 2.

We obtained data about the relative abundance and occurrence of the two lapwing species from SABAP1 and SABAP2 for South Africa, Lesotho and Eswatini from SABAP2 online website: <https://sabap2.birdmap.africa/species> (01/06/2023).

To account for sampling uncertainty, we used the methods of Brown et al. (2019) to perform bootstrap sampling of the range of QDGCs sampled >4 times during SABAP1 and 2, calculating the proportional difference for each sample as:

$$\frac{\text{mean}(\text{SABAP2 reporting rate}) - \text{mean}(\text{SABAP1 reporting rate})}{\text{mean}(\text{SABAP1 reporting rate})}$$

Similarly, we calculated the change in occurrence as:

$$\frac{\text{(number of SABAP2 QDGCs)} - \text{number of SABAP1 QDGCs}}{\text{(number of SABAP1 QDGCs)}}$$

We also examined confidence in change scores (Z scores, (Underhill and Bradfield 1998)) as well as population change parameters (C scores, (Underhill and Brooks 2016)), using the modified version presented by Lee and Hammer (2022). The C score better accounts for the non-linear relationship between actual abundance and reporting rates (Underhill and Brooks 2016). Results from these are presented visually as maps and density plots of the resulting bootstrapping. The 95% confidence intervals for the range change metrics are presented. When these do not overlap with 0, they are considered significant. The data were analysed using R (Version 4.2.2) (R Core Team 2023).

To analyse the relative abundance and range change throughout the last 16 years (2008-2023), we used SABAP2 full protocol cards (Lee et al. 2023). We compared the SABAP2 period from 2007 to 2014 and 2015 – 2023. Regions where each species was recorded during SABAP1 but not SABAP2 were removed, so the SABAP2 reporting rates for this exercise may be higher for the within SABAP2 comparison. We used R (R Core Team 2023) to analyse the data by computing maps of reporting rate change and changes in matrices.

## **3.4 Results**

### ***3.4.1 Blacksmith Lapwings***

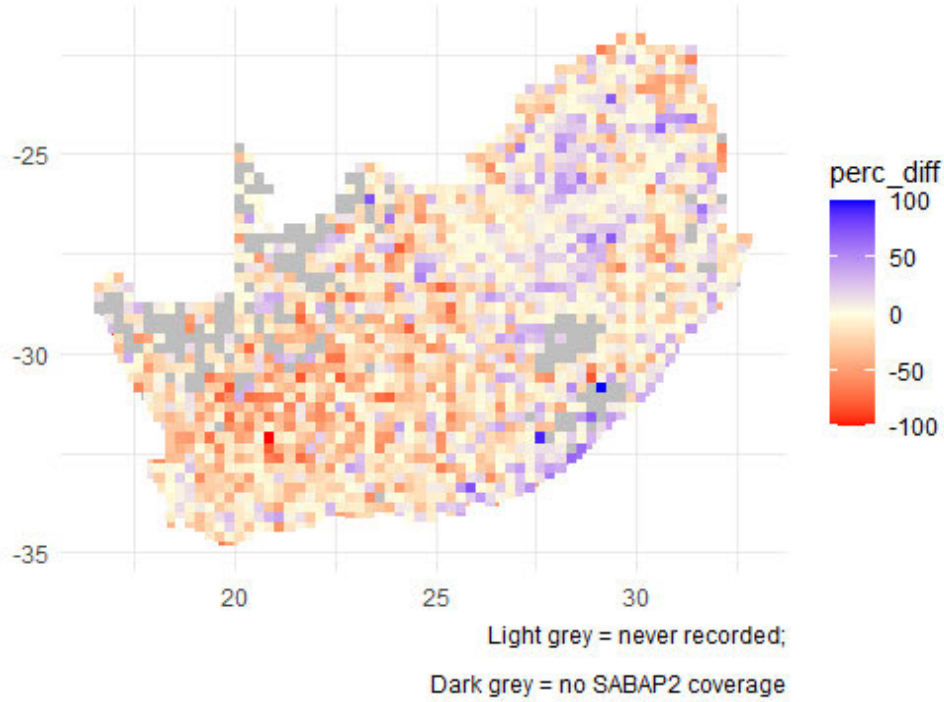
Blacksmith Lapwings were recorded in 1673 QDGCs during the SABAP1 (1987 – 1992), but only in 1498 for the entirety of SABAP2 (2007 – 2023). Reporting rate was also lower for the SABAP2 period (reporting rate change 95% CI: -0.045 – -0.043; Z score: -0.452 – -0.412; C score: -0.334 – -0.313). The median reporting rate was lower across the historical range for SABAP2 (33.3%) than for SABAP1 (45.7%). Similarly, Blacksmith Lapwings were recorded

in 6811 pentads for the SABAP2 period from 2007 to 2014 but only 5911 pentads for the 2015 – 2023 period. For this comparison, within its SABAP2 range, the reporting rate was 55% for the early period but only 51% for the more recent period. Overall, these statistics strongly suggest a population in decline, with the spatial patterns suggesting this is occurring across the species range (Figure 3.1), but particularly between SABAP1 and SABAP2, with notable reporting rate differences from the more arid Northern Cape part of its range (Figure 3.1a).

**a)**

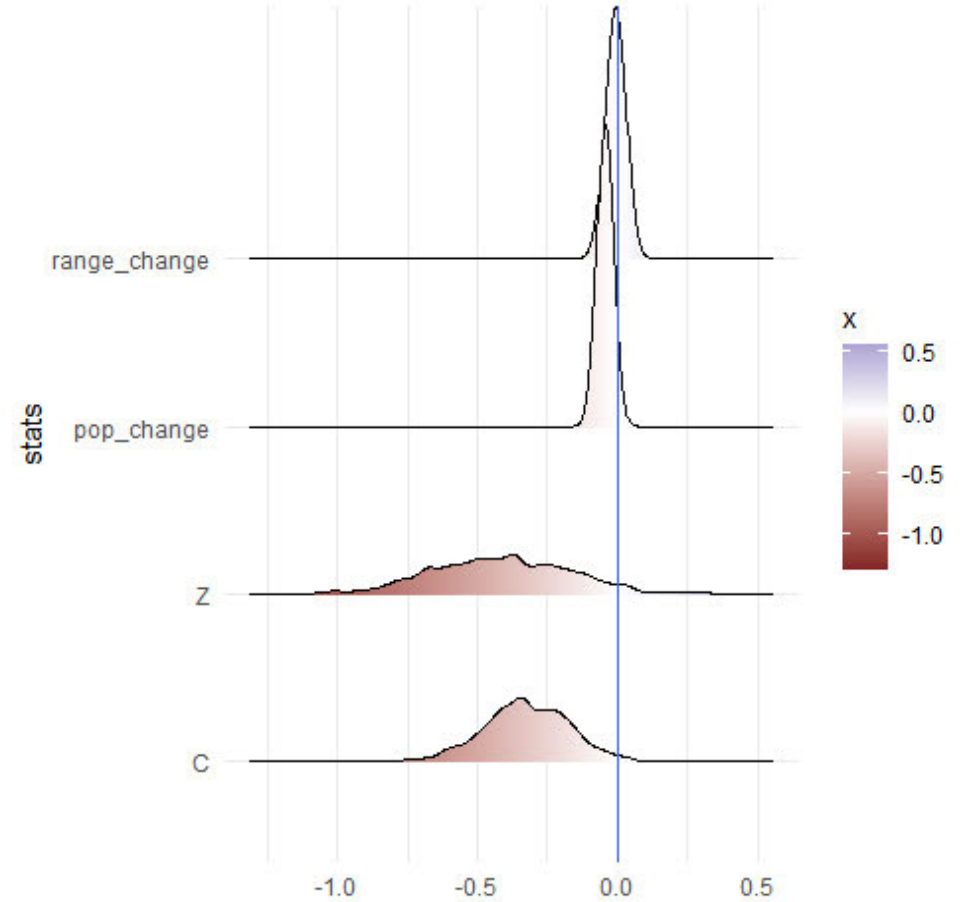
### Blacksmith Lapwing

Percent reporting rate differences between SABAP1 and SABAP2



### Blacksmith Lapwing

Change metrics: SABAP1 to SABAP2.

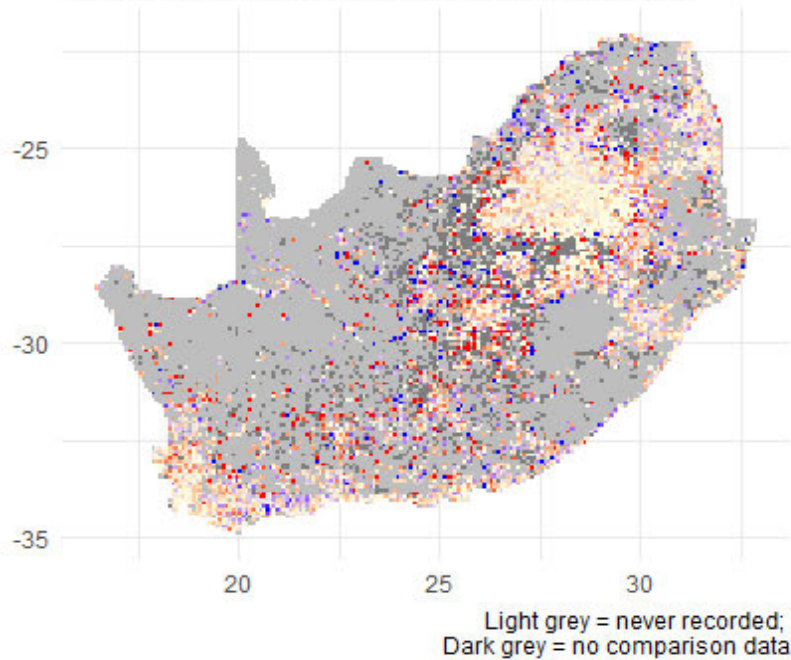


Below 0 indicates decrease, above 0 indicates increase

**b)**

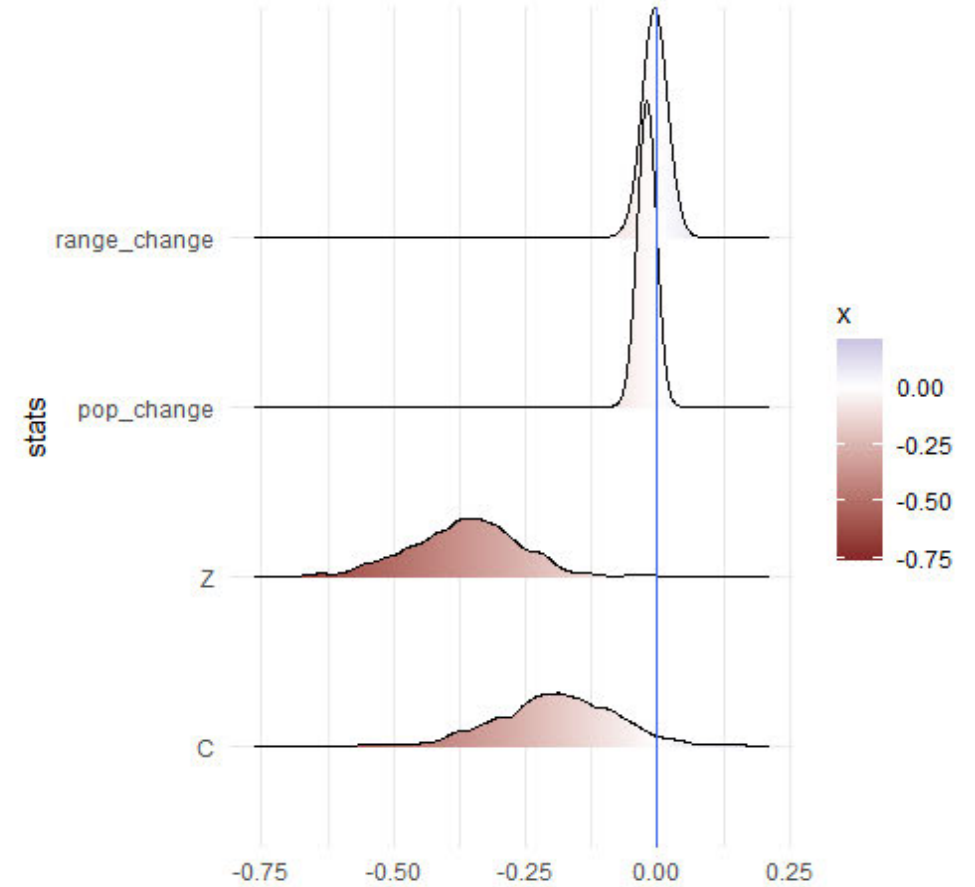
### Blacksmith Lapwing

Percent reporting rate differences within SABAP2



### Blacksmith Lapwing

Change metrics: within SABAP2.



Below 0 indicates decrease, above 0 indicates increase

**Figure 3.1:** Maps showing a. Quarter Degree Cell level reporting rates differences (percentages, 'perc\_diff') between SABAP1 and SABAP2 and b. representation of pentad level reporting rates differences (percentages, perc\_diff) within SABAP2, comparing 2007 – 2014 and 2015 – 2023 for Blacksmith Lapwings in southern Africa. (Note: Positive values represent an increase in percentage reporting rate difference (represented by blue shades, dark and light blue cells), while negative values indicate a decrease in percentage reporting rate difference (represented by red shades, dark and light red cells). Stability in the reported rate between SABAP1 and SABAP2 is expressed by yellowish cells. Cells with no SABAP2 Coverage and no records for the atlas data are represented by light and dark grey cells. Plots (Change metrics): The bootstrap samples of range change, changes in reporting rate between SABAP1 and SABAP2, C-scores (relative change in abundance), and Z-scores are the confidence based on sampling efforts. Positive values (Above 0) indicate an increase, while negative values (Below 0) indicate a decrease).

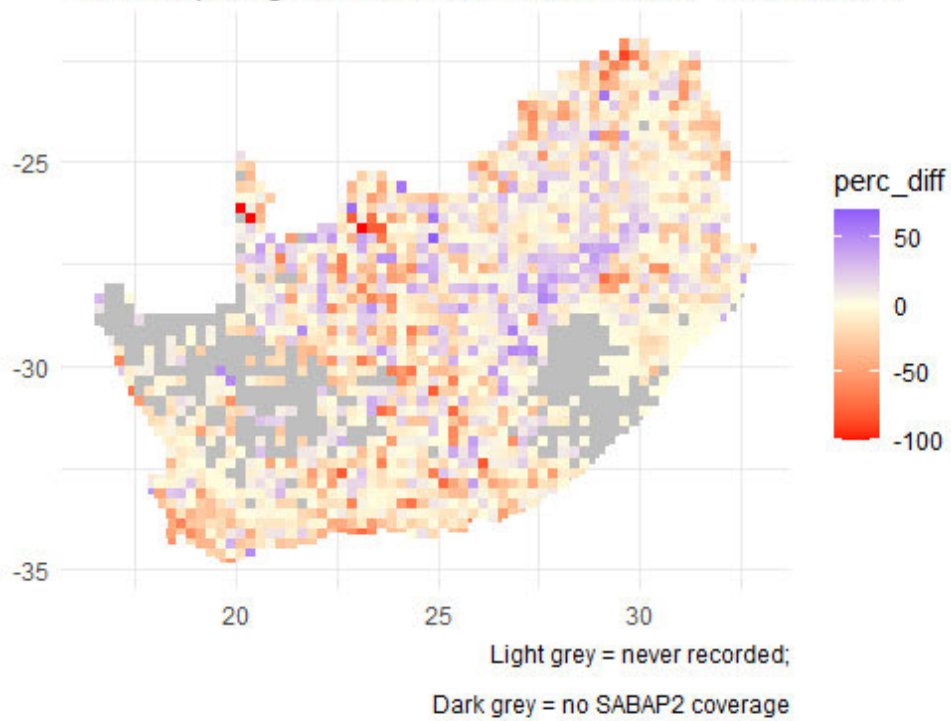
### ***3.4.2 Crowned Lapwings***

Crowned Lapwings were recorded in 1507 QDGCs during SABAP1 (1987 – 1992) and 1537 for the entirety of SABAP2 (2007 – 2023). Reporting rate was also lower for the SABAP2 period (reporting rate change 95% CI: -0.033 – -0.03; Z score: -0.975 – -0.932; C score: -0.215 – -0.184). The median reporting rate was lower across the historical range for SABAP2 (23.8%) than for SABAP1 (32.6%). Similarly, Crowned Lapwings were recorded in 5983 pentads for SABAP2 from 2007 to 2014, but only 5333 pentads for 2015 – 2023. For this comparison, within its SABAP2 range, the median reporting rate was 40% for the early period and 41.7% for the more recent period. Particularly between SABAP1 and SABAP2, there was a noticeable disappearance from its historic range in the Eastern Cape (Figure 3.2a). There was a slight decrease in relative abundance, and the spatial patterns suggest this is occurring across the species range (Figure 3.2).

**a)**

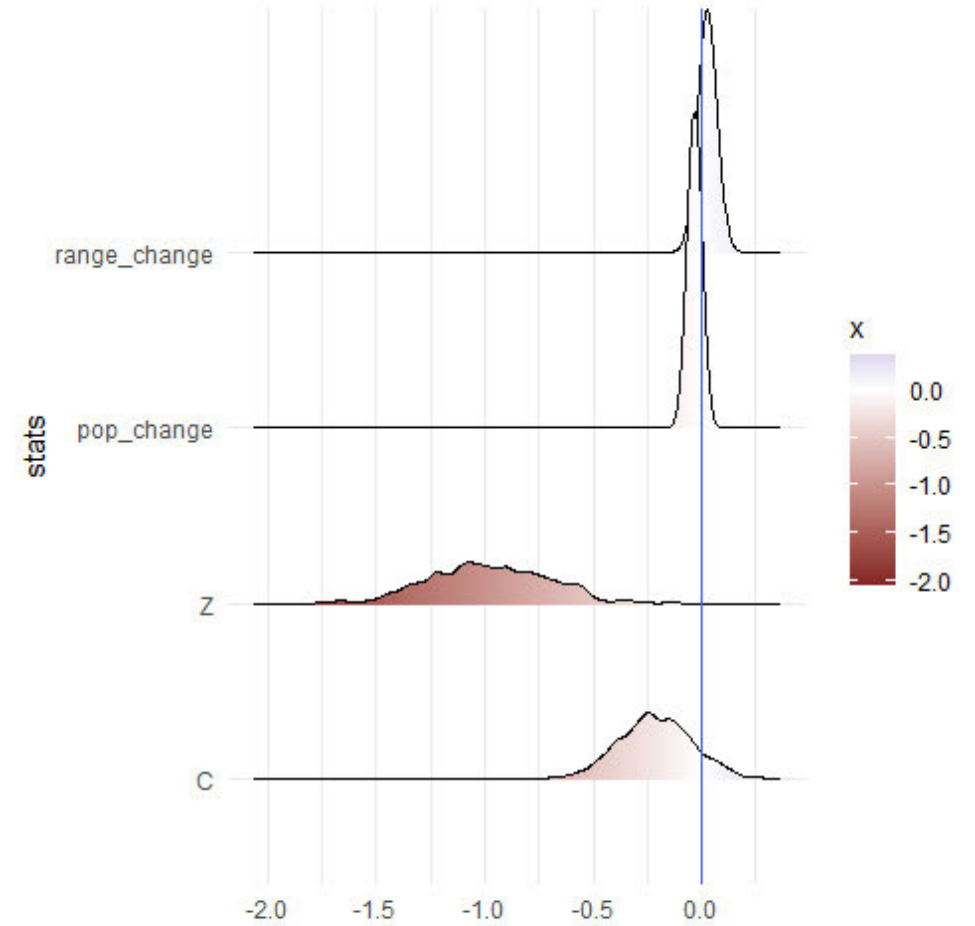
### Crowned Lapwing

Percent reporting rate differences between SABAP1 and SABAP2



### Crowned Lapwing

Change metrics: SABAP1 to SABAP2.

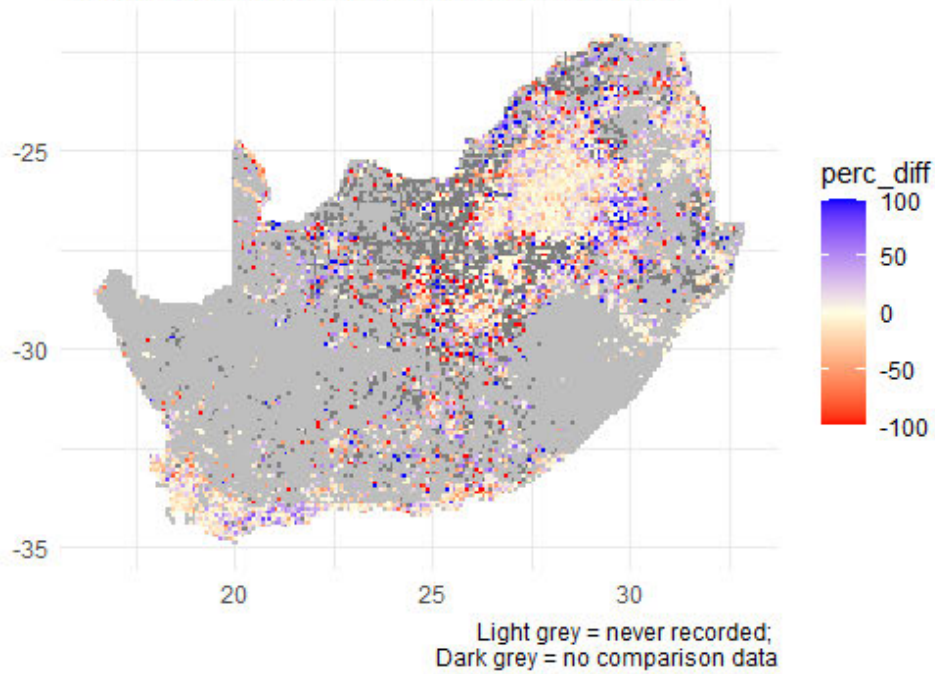


Below 0 indicates decrease, above 0 indicates increase

**b)**

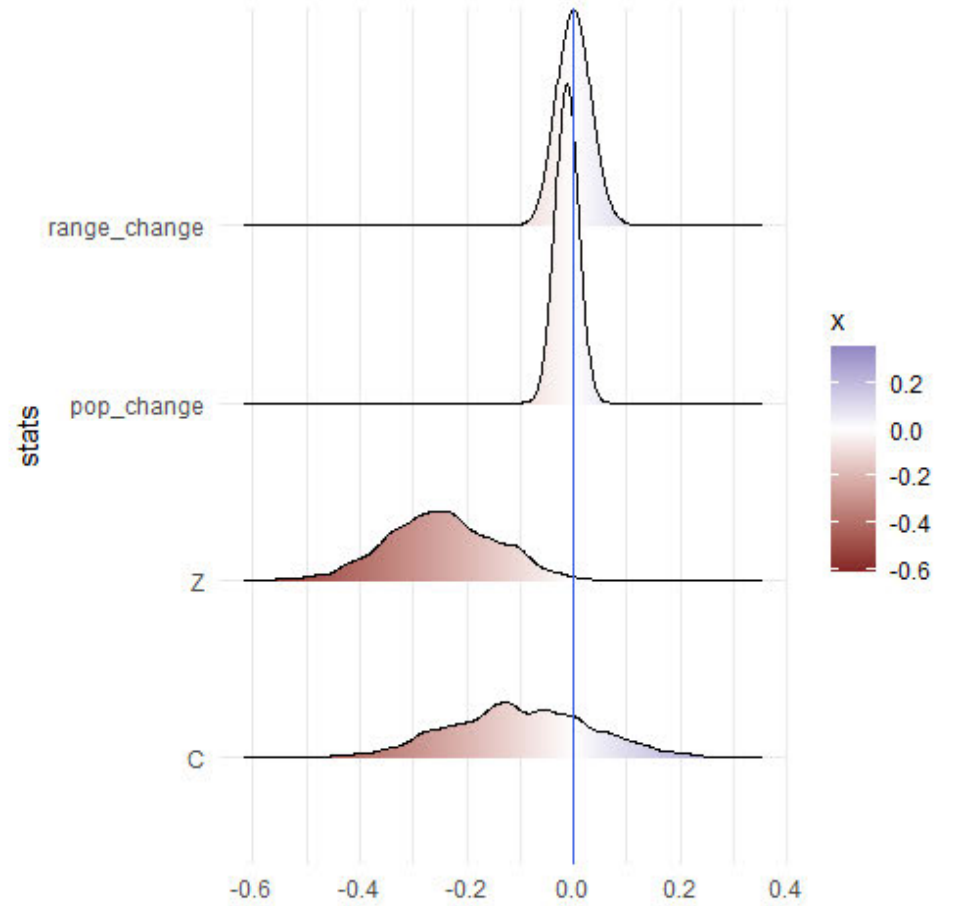
### Crowned Lapwing

Percent reporting rate differences within SABAP2



### Crowned Lapwing

Change metrics: within SABAP2.

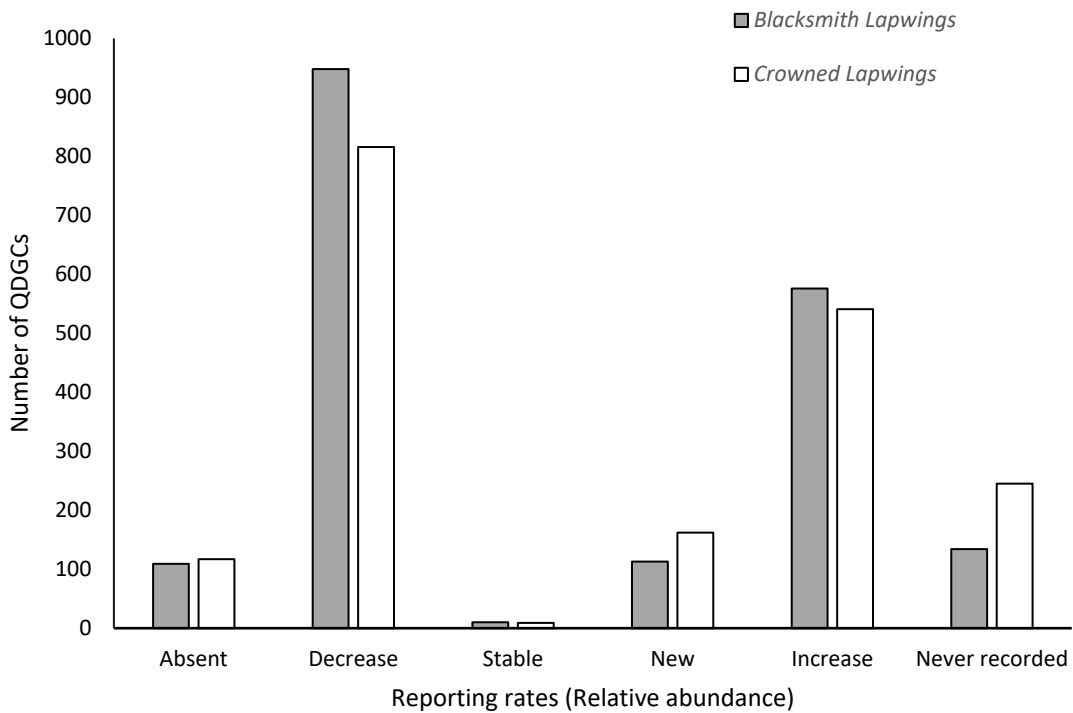


Below 0 indicates decrease, above 0 indicates increase

**Figure 3.2:** Maps showing a. Quarter Degree Cell level reporting rates differences (percentages, 'perc\_diff') between SABAP1 and SABAP2 and b. representation of pentad level reporting rates differences (percentages, perc\_diff) within SABAP2, comparing 2007 – 2014 and 2015 – 2023 for Crowned Lapwings in southern Africa. (Note: Positive values represent an increase in percentage reporting rate difference (represented by blue shades, dark and light blue cells), while negative values indicate a decrease in percentage reporting rate difference (represented by red shades, dark and light red cells). Stability in the reported rate between SABAP1 and SABAP2 is expressed by yellowish cells. Cells with no SABAP2 Coverage and no records for the atlas data are represented by light and dark grey cells. Plots (Change metrics): The bootstrap samples of range change, changes in reporting rate between SABAP1 and SABAP2, C-scores (relative change in abundance), and Z-scores are the confidence based on sampling efforts. Positive values (Above 0) indicate an increase, while negative values (Below 0) indicate a decrease).

### ***3.4.3 Reporting rates and QDGCs***

Blacksmith Lapwings were recorded in more QDGCs than Crowned Lapwings (Table 3.1). For Blacksmith Lapwings, 32.8% of the QDGCs (n = 576) increased, and 54% decreased (n = 948) in reporting rates. In comparison, 33% of the QDGCs showed an increase (n = 541), and 49.6% showed a decrease (n = 816) in reporting rates for Crowned Lapwings (Figure 3.3; Table 3.1). More QDGCs showed a decrease (n = 1764) than those that showed an increase (n = 1117) in reporting rates for both species. Additionally, there were also cells reflecting new records in SABAP2 data, absence in SABAP2 data, no changes in either atlas data and others which were invalid entries (< 4 cards) or never recorded cells (Figure 3.3; Table 3.1). Based on the changes in reporting rates, there was an overall decrease in relative abundance in South Africa, Lesotho and Eswatini from SABAP1 and SABAP2.



**Figure 3.3:** Comparison of the reporting rates changes (relative abundance) of Blacksmith Lapwing (grey bars) and Crowned Lapwings (white bars) between SABAP1 and SABAP2 at the Quarter Degree Scale. (Note: The ‘absent’ means the species that were only recorded in SABAP1 but not in SABAP2, ‘New’ means species that were observed in quarter degree grid cells (QDGC) in SABAP2. ‘Decrease’ means the observations in QDGC were lower in SABAP2 than those in SABAP1, ‘Increase’ means the observations in QDGC were higher in SABAP2 than those in SABAP1, ‘Stable’ indicates no change in the observations between SABAP1 and SABAP2, ‘Never recorded’ indicates cells that were never recorded in both SABAP1 and SABAP2. Data accessed 11 October 2023).

**Table 3.1:** Summary of changes in reporting rates in quarter degree grid cells for Blacksmith Lapwings and Crowned Lapwings in South Africa, Lesotho and Eswatini. A total of 1756 QDGCs and 1645 QDGCs for Blacksmith Lapwings and Crowned Lapwings, respectively. Each category is represented by the total number of cells in percentages (%). (Data for the Table were accessed on 11 October 2023).

Species	Number of QDGCs		Change (%)			No change (%)	
	<i>n</i>	Increase	Decrease	New records	Stable	Absent	
Blacksmith Lapwing	1756	32.8	54.0	6.4	0.6	6.2	
Crowned Lapwing	1645	33.0	49.6	9.8	0.5	7.1	

### 3.5 Discussion

In this study, we compared the occurrence and presence of Blacksmith Lapwings and Crowned Lapwings in South Africa, Lesotho and Eswatini over time. Our findings suggest a change in present data compared with historical data. The comparison of reporting rates (relative abundance) between historical data (SABAP1) and present data (SABAP2) detected a decrease in the relative abundance of both lapwings in South Africa, Lesotho and Eswatini. This was represented by a greater number of QDGCs or regions with reduced reporting rates. New sightings in SABAP2 were detected, indicating that the two species also colonised areas. Additionally, the absence of the two species was observed in some regions in SABAP2.

Comparison of SABAP1 and SABAP2 data has shown species declines (e.g., Martial Eagle (*Polemaetus bellicosus*) (Amar et al. 2016), Black Stork (*Ciconia nigra*) (Lee et al. 2023) as well as increases (African Black Oystercatcher (*Haematopus moquini*) (Brown et al. 2019)) in some bird species. However, there are some data interpretation caveats (Brooks et al. 2022). Fluctuations in relative abundance in SABAP data may not clearly reflect the decline in the

absolute population because it may be challenging to link the reporting rates of citizen scientists for species with the actual population of the species (Lee et al. 2017). Thus, the decline in the reporting rates from historical data to the present may be because of a lack of observations or poor species detection (Brooks et al., 2022).

As detection was not limited to a specific area but rather covered large areas in South Africa, Lesotho and Eswatini, it is unlikely that the decrease in the two species was caused by poor detection in all these areas. Moreover, evidence from change metrics showed confidence in change (Z-score), as well as population change parameters (C-score), which were less than 0, indicating the changes in population and range, and declines in populations were observed.

The study by Lee and Hammer (2022) showed declines in various African lapwing species (*Vanellus* spp.). According to Lee et al. (2021), no lapwing was classed as an urban adapter. Lapwings are terrestrial birds that are found on open grasslands, woodlands, marshes, along streams and river edges, on farmlands or in green spaces in urban mosaic landscapes (Maruyama et al. 2010; Mishra et al. 2018; Phoswa unpublished data). In Germany, the decline in farmland birds began in the 1980s because of habitat degradation in wet grasslands that causes insufficient breeding success (Bohner et al. 2023). Agricultural intensification often leads to habitat loss and fragmentation, which causes water and soil contamination and impacts arthropod species, an important diet for many bird species that persist in farmlands (Simpson 2022). Globally, the population and biodiversity of bird species in agricultural landscapes are declining (Buschmann et al. 2023). Early in the 1990s, the fluctuations in the population of lapwings were detected (Gibbons et al. 1996); the main factor contributing to the change was anthropogenic activities, which caused habitat changes through groundwater drainage, afforestation and shrub invasions (Mishra et al. 2018). According to European Union (EU) reports, land degradation caused a 30% decline in these bird species between 1990 and 2015 (Buschmann et al. 2023). Northern Lapwings (*Vanellus vanellus*) are one of the

grassland/farmland bird species that are found in many northern parts of the world, and there was an approximate 80% decline in numbers of this species between 1990 and 2018 (Kamp et al. 2021). It is believed that the declines are still occurring (Kamp et al. 2021). Furthermore, hunting and trapping also contribute to the population declines of lapwing species (Shydlovskyy and Kuzyo 2016). Nesting site influences how species react to urbanisation, and ground-nesting birds generally have a strong negative response to urbanisation (Leveau 2022). Certain bird species that nest on the ground may suffer from habitat loss in urban areas if they require natural herbaceous vegetation to nest, as this type of vegetation is often being replaced by lawns (Leveau and Ibanez 2022). However, ground-nesting birds such as Spotted Thick-knees (*Burhinus capensis*) can increase their density and expand their breeding range in managed green spaces in mosaic urban landscapes (Josiah and Downs 2023), although they are affected by negative human and domestic pet interactions while nesting (Josiah and Downs 2022, 2023).

### ***3.5.1 Population changes observation (SABAP citizen science projects)***

We used the methods of Brown et al. (2019) to perform our analyses. The percentage reporting rates differences between SABAP1 and SABAP2 for Blacksmith Lapwings and Crowned Lapwings were greater in the eastern part of South Africa, namely the Free State, Gauteng, Limpopo, around coastal areas of KwaZulu-Natal and Eastern Cape provinces. Gauteng is an urbanised region with built-up areas, but it also contains conservation/ restored patches that are important for biodiversity conservation (Botha and Haussmann 2023). In this region, Blacksmith Lapwings occur in both grasslands and marshy areas (Botha and Haussmann 2023). In most parts of the Northern Cape, Eastern Cape, Western Cape, Eswatini and Lesotho, Blacksmith Lapwings were scarce or localised, with most cells having no SABAP2 coverage and no records for the atlas data. In the late 1940s and 1950s, this species increased its

distribution range to the Karoo and Cape Town areas (Hall 1959). Still, more recently, some areas with whitish and red hues in Fig. 3.1 are cells indicating low reporting rate percentage differences between SABAP1 and SABAP2 across the Great Karoo. Schwarzenberger and Dean (2003) reported the presence of this species in gardens, orchards and nearby agricultural fields in the Karoo. In recent decades, dry conditions were recorded in the Karoo with ongoing droughts, which resulted in unsuitable habitats for breeding, although there are artificial water sources, sewage treatment plants, etc., which might benefit the species (Archer et al. 2022). There is no direct explanation for why there is a slight decline in population in the Eastern Cape, but based on assumptions, anthropogenic activities might be an influence or reduced citizen scientists making observations as seen for some other species (Downs et al. 2014).

Blacksmith Lapwings and Crowned Lapwings decline between SABAP1 and SABAP2 was moderate compared with the lack of significant widespread declines observed in SABAP2 data from 2008-2023. Comparing within SABAP2, the recent data (2015-2023) had lower reporting rates than the earlier years of SABAP2 (2007-2014) for both species. As observed in the comparison of historical and recent data, Gauteng Province had more blue cells, representing the increase in reporting rates for both species. Blacksmith and Crowned lapwings had fewer blue cells on their respective maps, which indicated a slight increase and stability in reporting rates for recent data (2007-2014 vs 2015-2023) in Gauteng. Visual observations of the regions where the Blacksmith Lapwings and Crowned Lapwings were not recorded for SABAP2 highlighted large areas of Lesotho, Northern Cape, Eastern Cape and Eswatini.

The findings on the distribution range and abundance of Crowned and Blacksmith Lapwings in South Africa further highlighted that their populations are presently declining within their distribution range, and the observation from the change maps and change metrics with Z-scores and C-scores indicated the overall decline in the population of Blacksmith Lapwings and Crowned Lapwings in many regions. The local extinctions of the species are

predicted to be caused by global changes and anthropogenic habitat transformations (Dean and Milton 2008). Comparing the occurrence, Blacksmith Lapwings are mostly widespread and are more local in their range than Crowned Lapwings.

These lapwing species are not threatened (Least concern) according to IUCN (2016), which means that there is no substantial risk of extinction due to their huge geographic range and widespread distribution throughout sub-Saharan Africa. Despite the wide distribution of these two lapwing species, they have not been extensively studied, and there is limited research about their abundance and population size in their distribution range, which may be one of the constraints in the estimation of atlas data accuracy.

The overall population of Blacksmith Lapwings and Crowned Lapwings are believed to be stable or increasing in some areas despite the possibility of local declines caused by habitat degradation. However, since the latest IUCN report in 2016, the population trends may have changed. Therefore, re-assessment is required to ensure that information about the species is updated and accurate for further conservation initiatives. The findings in the present study are concerning because they imply a decline in both species; thus, more research is required to identify the reasons for the species' recent decline.

### **3.6 Acknowledgements**

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### **3.7 Conflicts of interest**

No conflicts of interest.

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## CHAPTER 4

### Occurrence and persistence of Blacksmith Lapwings and Crowned Lapwings and their reproductive success in an urban mosaic landscape

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**Running header:** Persistence of lapwings in an urban mosaic landscape

## 4.1 Abstract

The majority of people on earth reside in the cities, and urbanised landscapes continue to expand. Urban development leads to fragmentation, which creates a mosaic of natural and/or managed landscapes with varying biodiversity levels. Environmental changes have the greatest impact on bird populations, and agricultural intensification is one of the factors contributing to a decline in bird populations. The effects are reflected in the declining population of open-habitat species. Despite this, various bird species persist in certain cities, often by using behavioural plasticity. Blacksmith Lapwings (*Vanellus armatus*) and Crowned Lapwings (*V. coronatus*) are two of the species documented persisting in urban areas in South Africa. The study focuses on assessing the persistence of these lapwing species in a mosaic of urban landscapes of Pietermaritzburg, KwaZulu-Natal, South Africa, from April 2022 to September 2023. Our objectives were to study their occurrence, habitat use, and behaviour in human-modified habitats and determine the influence of human activities and different land uses on their nesting ecology in this urban mosaic landscape. We surveyed different sites and recorded data on their monthly abundance, habitat use, behaviour and nesting ecology (during breeding seasons). We found Blacksmith Lapwings and Crowned Lapwings co-exist with each other in urban areas and persist in human-modified landscapes, and they vacate if habitats are unfavourable for them. Their abundance was seasonal, with greater abundance during non-breeding than during the breeding season. These species nested on open short grasslands with nests that were a shallow scrape in the ground. They could choose suitable spaces for nesting, so hatching success was greater than reproductive success, as the eggs and hatchlings were affected by both environmental factors and/or predation. Despite this, both species persist in open, short grasslands in natural and managed green spaces in this urban mosaic landscape.

**Keywords:** Urban mosaic landscapes; Ecological aspects; Lapwings; Land-use; Nesting; Breeding success

## 4.2 Introduction

The majority of people on Earth reside in the cities, and urbanised landscapes continue to expand (United Nations 2019). Urban development leads to fragmentation, which creates a mosaic of natural and/or managed landscapes with varying biodiversity levels (Andren 1994; Downs et al. 2021). Most natural habitats and vegetation covers are replaced by impervious landscapes such as roads and buildings, and large portions of constructed anthropogenic infrastructures create new ecosystems (Potgieter et al. 2020). The ongoing urban development causes changes to environmental community composition (Concepcion et al. 2015; Olsson et al. 2021), affecting the local remnant species population in the area and inducing the establishment of new ecological communities. Approximately 75% of terrestrial habitats have experienced substantial human modification or destruction (Díaz et al. 2019). According to Sanderson et al. (2002), crop and livestock production is the primary cause of habitat loss, followed by pollution, human infrastructure, deforestation, recreational activities, etc. (Wilcove and Master 2005). This generally causes rapid declines and extinction of plant and animal species because of the global change in the ecosystem and ongoing landscape degradation (Hersperger et al. 2018; Li et al. 2022). Environmental changes have the greatest impact on bird populations, and agricultural intensification is one of the factors contributing to the decline in bird populations, and the effects are reflected in the declining population of open-habitat species (Stanton et al. 2018; Morelli et al. 2021; Lees et al. 2022).

Despite the negative impacts urbanisation has on biodiversity, cities do contain numerous species, some of which are more productive and have greater populations, and they do expand their adaptation and exploitation quickly in urban areas than they would elsewhere (Bateman and Fleming 2012; McDonald et al. 2020). For example, urban areas may provide specific features that meet the demands of a certain species and may offer different types of

protection from threats typically posed by urbanisation (Spotswood et al. 2021). The persistence of certain species in urban areas is evidence of their remarkable flexibility and ability to coexist with humans, and other species move to urbanised areas to gain access to more resources and avoid predation (Cavalli et al. 2018; Schell et al. 2021). In urban and suburban contexts, where they survive close to humans, many animals and plant species have adapted to new challenges, food sources, and predators and evolved certain behaviours to overcome any threats (Singh and Downs 2016; Borden and Flory 2021, Josiah and Downs 2022). Therefore, the capacity of distinct species to survive in the extreme physical changes along the urban-rural gradient varies greatly as their responses mainly depend on their specific ecological traits such as body mass, dietary niche, migratory strategy, habitat affinity, and behavioural plasticity (McKinney 2006; Bregman et al. 2014; Sprau and Dingemanse 2017).

Certain bird species generally respond differently to anthropogenic and natural disturbances and use a combination of traits to exploit mosaic urban landscapes (Battisti and Fanelli 2016; Binley et al. 2023). The most important traits involve locating suitable spaces for breeding. In response to urban ecosystems, birds either perish or adapt in the cities and even exploit/take advantage of the resources available in urban landscapes (McKinney 2006). It is widely acknowledged that cities with high spatial variability of green spaces can support many plant and animal species (Lepczyk et al. 2017). Birds are considered good indicators of the ecological status of urban areas and are among the animal species that survive in urban areas (Mekonen 2017). They are good landscape-scale biodiversity indicators (Fraixedas et al. 2020). Ground nesting birds such as Spotted Thick-knees (*Burhinus capensis*) can increase their density and expand their breeding range in managed green spaces in mosaic urban landscapes (Josiah and Downs 2023).

Urban habitats are unique because wildlife typically faces selection pressures quite different from those they have already evolved under, and those pressures affect individuals'

fitness, survival, and reproduction (Ibanez-Alamo and Soler 2010). Therefore, for species to survive in urban environments, selection pressures must be fit and able to shift their behaviour over time (Lowry et al. 2012). Species with limited behavioural plasticity have a disadvantage in adaptation compared with those species with flexibility in their behaviour (Lowry et al. 2012). By using behavioural plasticity, animals can respond to environmental threats such as food shortages and extreme weather conditions (Sol et al. 2013; Ducatez et al. 2020). Behavioural plasticity has been documented in various animals and includes behaviours such as nest selection, communication, breeding phenology, etc. (Bressler et al. 2020). However, some types of plasticity are non-adaptive, which means that an individual's fitness might be lowered while they adapt to a new environment, while other types of plasticity are adaptive, and that occurs when an organism responds behaviourally to a new environment to enhance its fitness (Acasuso-Riveco et al. 2019).

Bird species nesting in urban environments face challenges and need behavioural flexibility; for example, ground nesters are influenced by the availability of nesting grounds, habitat suitability, and their adaptability to changed environments (Han et al. 2019; Ding et al. 2023). Behaviour associated with breeding in urban areas shapes the species' persistence, and numerous species display distinctive behaviours associated with their persistence in urban areas (Bressler et al. 2020). Many specific nesting guilds in urban areas, including ground nesters, face great stressors because of various habitat alterations (Crocì et al. 2008; Cooper et al. 2020). In urban settings, as they nest on the ground, they sometimes face challenges such as habitat alterations because of anthropogenic activities and predation risks that arise with the changes in environmental conditions (Ding et al., 2023). The effects humans have on species residing in urban areas may affect nesting success in many species because of the abovementioned stressors (Hockin et al. 1992). Despite that, species persisting in urban areas tend to exhibit adaptable reproductive traits. Many urban birds use a range of nest sites and different breeding

phenologies, as well as making use of the nesting materials or sites available in the urban environment (Bressler et al. 2023)

Our study focused on two ground-nesting birds: the Blacksmith Lapwing (*Vanellus armatus*) and the Crowned Lapwing (*V. coronatus*). The study's main aim was to assess the persistence of the selected lapwing species in the mosaic urban landscape of Pietermaritzburg, KwaZulu-Natal, South Africa. Our two objectives of this study were to (1) study their occurrence, persistence, habitat use as well as behaviour; and (2) determine the influence of human activities and different land use on the nesting ecology of lapwings breeding in urban mosaic landscapes. The study species appear to be persisting in urban areas. Therefore, we predicted they would occur and breed in managed or natural green spaces in the mosaic urban landscape with short grasslands.

## **4.3 Methods**

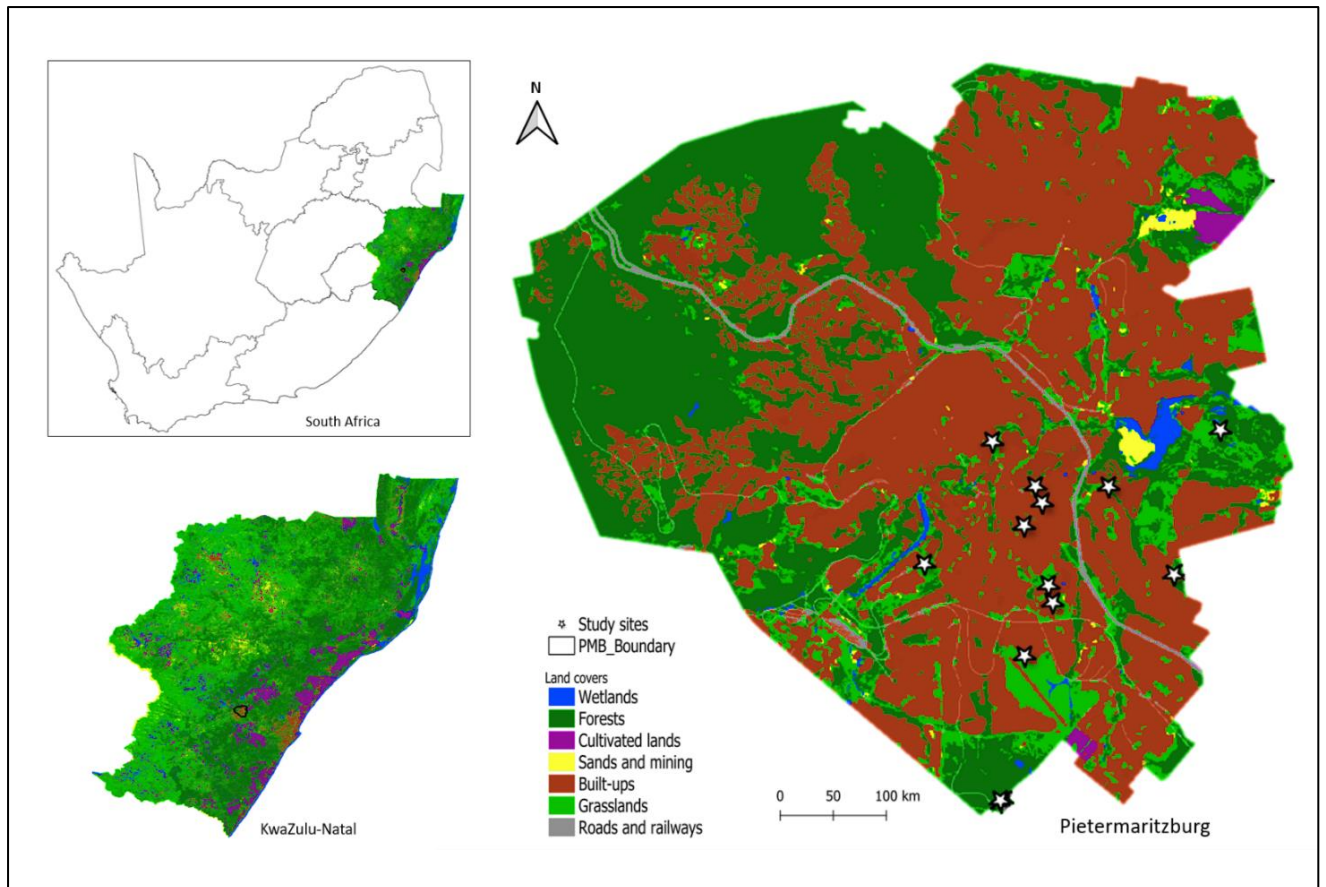
### **4.3.1 Study species**

Blacksmith Lapwings and Crowned Lapwings are ground-nesting birds native to southern Africa with localized distribution in most arid regions (Hockey et al. 2005). They are common in urban areas around South Africa (Phoswa unpublished data; Chapter 3). Both species prefer to nest in short grasslands of about 2-3 cm in height (Ward 1989a). Generally, Blacksmith Lapwings inhabit moist areas and near places with plenty of water, such as dams, lakes and rivers. Crowned Lapwings prefer short, grazed or unburnt grasslands rather than near water bodies. Blacksmith Lapwings and Crowned Lapwings have precocial chicks that remain with the parents until fledging while parents defend their respective territories (Turpie and Ryan 2005; Turpie et al. 2005), but chicks can feed by themselves shortly after hatching (Ward 1989a). Lapwing chicks have excellent camouflage capabilities to avoid predation. These species nest on the ground, potentially more vulnerable to human-modified environments and

processes associated with these environments, such as human disturbance activities and predation by domestic pets.

#### **4.3.2 Study area**

The study was conducted in different sites in Pietermaritzburg (29°37'S, 30°23'E), the second largest city in KwaZulu-Natal Province, South Africa, with an estimated population of over 540 000 (Stats SA, 2011; Figure 4.1). The city of Pietermaritzburg (Msunduzi Local Municipality) comprises various types of urban buildings, such as residential areas, informal settlements, and commercial and industrial properties. The natural landscape has changed because of urban sprawl and infrastructure construction, creating a mosaic landscape of urban infrastructure such as buildings, roads, agricultural fields and natural /managed green spaces (e.g., parks, domestic gardens, sports fields and playgrounds). Ecological diversity is also enhanced by the availability of wetlands, such as rivers, dams and streams across the city's landscape. Based on our historical data and citizen science feedback, we identified locations with Crowned Lapwings and Blacksmith Lapwings present in the mosaic urban landscape (Figure 4.1). These locations also had open grasslands, natural/managed green spaces and wetlands such as rivers, marshes, dams, etc. The area of these sites varied, as did the amount of nearby built infrastructure. So, in this study, we report on the presence and abundance of lapwings and not the density of lapwings at each site.



**Figure 4.1:** Site locations (n = 12) with Blacksmith and Crowned Lapwing sightings in Pietermaritzburg, KwaZulu-Natal, South Africa. Note: Only eight of the study sites were consistently used sites and observed throughout the study period (April 2022 - September 2023).

**Table 4.1:** Location and description of the Blacksmith Lapwing and Crowned Lapwing study sites (n = 8) in the mosaic urban landscape of Pietermaritzburg, KwaZulu-Natal Province, South Africa, that were consistently used in the present study with their habitat types.

<b>Sites</b>	<b>Coordinates</b>	<b>Habitat type</b>	<b>Grass height (cm)</b>
Darvill Bird Sanctuary	29°36'04"S 30°26'06"E	Open grasslands with dams and marshes	1-3
Scottsville Racecourse	29°36'38"S 30°24'02"E	Open grasslands with a dam	3-4
Maritzburg Golf Club	29°36'47"S 30°24'49"E	Open grasslands with dams and rivers	2-3
Scottsville Primary School	29°36'55"S 30°24'00"E	Open grasslands	3-4
Peter Booyesen Sports Fields	29°38'01"S 30°24'08"E	Open grasslands and green spaces	3-7
Oribi Airport	29°38'48"S 30°23'54"E	Open grasslands and green spaces	4-8
Intaba Ridge Eco-estate	29°40'47"S 30°23'49"E	Open grasslands, green spaces and dams.	3-6
Camps Drift	29°37'37"S 30°22'15"E	Grassland patches, green spaces and river	2-9

### 4.3.3 Data collection

To collect information about the habitat, use, behaviour and nesting ecology of Crowned and Blacksmith Lapwings, we conducted monthly surveys at the different sites identified in the mosaic urban landscape of Pietermaritzburg. The surveys took place between April 2022 and September 2023, usually in the early mornings (3 - 4 h after sunrise) because we found lapwings were active during that time. We observed and counted Blacksmith Lapwings and Crowned Lapwings present in each site during ~150 field surveys. Sites were visited three times a month, and each site was observed with an area search conducted for 30 min. using

binoculars (Bushnell, 10 x 25), observing any presence of lapwings and counting the number of individuals present per species at each site. The species were observed at a distance without disturbing the lapwings while ensuring no repetition of the already counted individuals. We approached the individuals when we noticed they were likely nesting. These included Darvill Bird Sanctuary, Intaba Ridge Eco-estate, Peter Booyesen Sports Fields, Oribi Airport, Scottsville Racecourse, Maritzburg Golf Course, and Scottville Primary School, Camps drift (Figure 4.1, Table 4.1). Additional sites (Figure 4.1) had inconsistent lapwing presence during our surveys and appeared only for a few months (UKZN Main campus, Hayfields, Ashburton, and Merchiston Preparatory School). During our surveys, we also observed whether any predators were present, but no nocturnal predation observations were done during the data collection. We recorded lapwing behaviour (flying, feeding, breeding, or nesting) during area search and recorded whether the visited site had the presence of water sources or not. Lastly, we recorded the grass height using a 30 cm ruler for each site. As these lapwing species were sometimes observed in the morning in fog or mist, which sometimes caused difficulties in observing these species because of reduced visibility, we delayed observations by 90 min. No data collection was conducted on rainy days.

During the breeding season (June 2022 - October 2022; June 2023 - September 2023), we located incubating lapwings (singles or pairs) by searching by vehicle or on foot around each site using binoculars. We located more nests with assistance from the field labourers present at most sites. We marked each nest site found using twigs placed 2 - 3 m away from the nest to be easily recognised during further nest visits. Visiting nests does not affect their survival. We counted the eggs in each nest from a distance of 3 m or more and tracked the success of each nest by checking each nest after 4 days to identify if the eggs had hatched or not. We avoided disturbing adult incubating birds.

Around hatching dates, we visited nests every 2 days. If the nest became empty and chick/chicks were seen around with the pair of adults, we assumed it was a successful nest if the incubation period had passed. If no eggshell fragments were found in the lining of the nests and no chick was seen around or near the nest, or if the nest disappeared before the estimated hatching dates, we assumed nest failure. Sometimes, signs/evidence of predation were visible. We also identified nests that were lost because of agricultural/anthropogenic activities such as machinery use and mowing of grass; eggs were crushed or damaged. The juveniles can fly when their feathers are half-grown. This occurs after 20-24 days after hatching. We calculated hatching and reproductive success as follows (Ward, 1989a):

- **Hatching success** = (Eggs hatched / Eggs laid) \* 100
- **Reproductive (breeding) success** = (Survived to flying / Eggs laid) \* 100

#### 4.3.4 Data analyses

We recorded the data collected from our survey in Microsoft© Excel and used the IBM SPSS Statistics (version 29) (SPSS Inc, Chicago, USA) for further analyses. Firstly, we used the Shapiro-Wilk tests for normality. Tests for normality showed that the abundance of both species was not normally distributed (Blacksmith Lapwings:  $W = 0.86$ ,  $df = 18$ ,  $p < 0.05$ ; Crowned Lapwings:  $W = 0.674$ ,  $df = 18$ ,  $p < 0.05$ ).

The abundance of Blacksmith Lapwings and Crowned Lapwings at the different sites was evaluated using the one-way analysis of variance (ANOVA), and the descriptive data were presented as a mean  $\pm$  standard deviation. Non-parametric Kruskal-Wallis tests were used to assess differences in the sightings or occurrence of Blacksmith Lapwings and Crowned Lapwings in the different study sites. We used an analysis of variance (Two-way ANOVA) to investigate the impact of the breeding season and species (Blacksmith Lapwings and Crowned Lapwings) on abundance and determine whether there was an interaction between the species

and breeding season. We recorded breeding data for our nest observation analyses to determine hatching and reproductive (breeding) success in percentages (%).

#### **4.4 Results**

The presence of Crowned Lapwings and Blacksmith Lapwings was relatively consistent at Darvill Bird Sanctuary, Scottsville Racecourse, Maritzburg Golf Club, Scottsville Primary School, Peter Booysen Sports Fields, Oribi Airport, Intaba Ridge Eco-estate, and Camps Drift, respectively (Figure 4.1, Table 4.1). Additional sites (Figure 4.1) had inconsistent lapwing presence during our surveys. The lapwings were only seen once or twice in that area, thus showing their inconsistent presence at these particular sites. We found Blacksmith Lapwings were common in sites with water, while Crowned Lapwings were seldom associated with water. Both species were found in short grassland habitats (Table 4.1). Measures such as grass height influenced the habitat selection of these bird species. In mown grasslands (about 2 - 4 cm), Crowned Lapwings gathered in flocks and became territorial, but we observed that they tended to move locality if the grass height became taller than 6 cm (Table 4.1).

##### **4.4.1 Site use, abundance and behaviour**

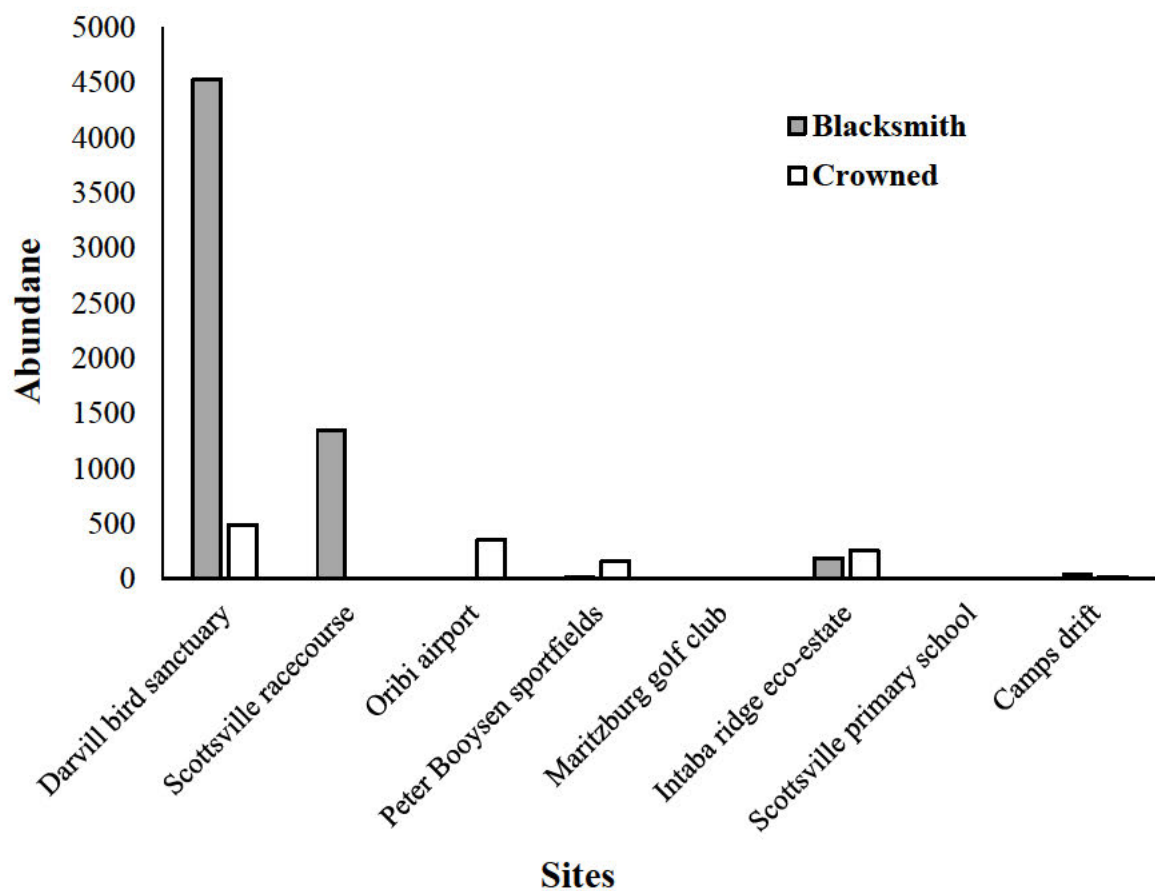
From our surveys (two breeding seasons and two non-breeding seasons) at eight sites, a total of 7410 lapwings were recorded. We recorded a total of 6120 Blacksmith Lapwings and 1290 Crowned Lapwings. We detected the maximum number of lapwings at Darvill Bird Sanctuary, with mean  $\pm$  standard deviation (mean  $\pm$  SD) for Blacksmith Lapwings of  $251.5 \pm 271.14$  and  $27.3 \pm 86.76$  for Crowned Lapwings), with no detection of either lapwing at Maritzburg Golf Club ( $0.0 \pm 0.00$ ) (Table 4.2). The abundance of the lapwings differed significantly across sites ( $F = 11.840$ ,  $df = 7$ ,  $p < 0.001$ ). Blacksmith Lapwings were present at 6/8 sites over the study period but not at the Oribi Airport and Maritzburg Golf Club sites. Crowned Lapwings were

also present at 6/8 sites but not present at Scottsville Primary School and the Maritzburg Golf Club (Figure 4.2). The occurrence of Blacksmith Lapwings and Crowned Lapwings varied significantly among sites (Kruskal-Wallis test,  $H = 4.571$ ,  $df = 1$ ,  $p = 0.033$ , Table 4.2).

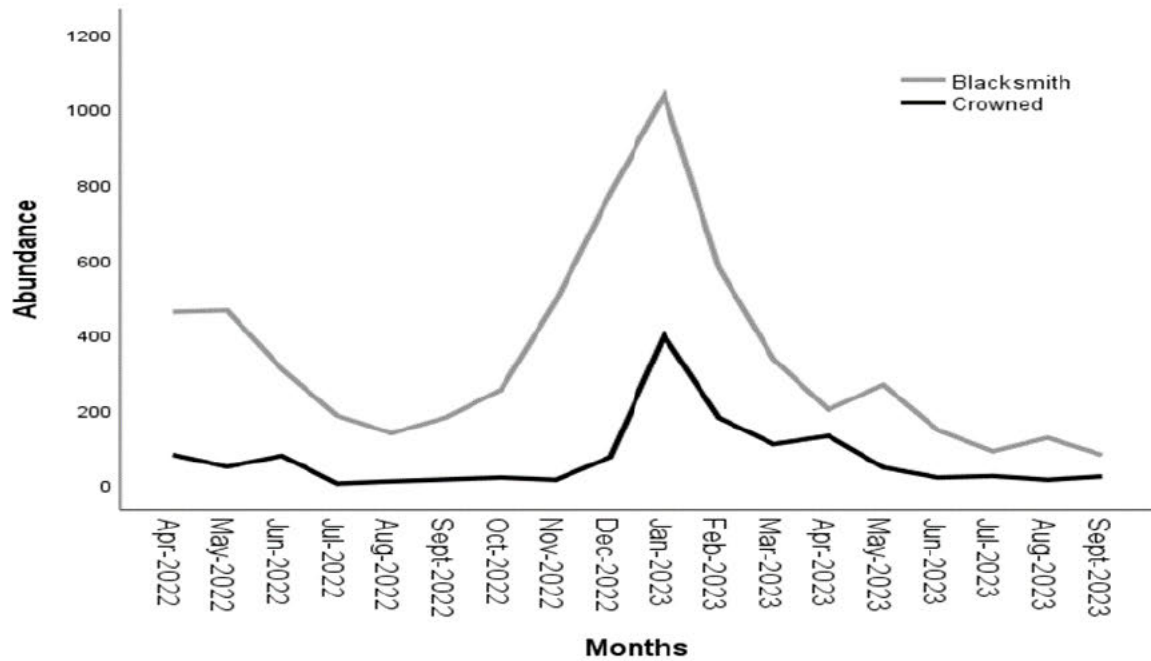
Seasons significantly affected the composition of the lapwing community, and there was an interaction effect between season and lapwing species ( $F = 6.332$ ,  $df = 1$ ,  $p = 0.017$ ). The number of individuals observed during the breeding season (June 2022 - October 2022; Jun 2023-September 2023) was lower (Mean  $\pm$  SD;  $95.3 \pm 91.49$ ) during the non-breeding season (April, May, November, December 2022- January 2023-May 2023) (Mean  $\pm$  SD;  $36.3 \pm 280.96$ ) (Figure 4.3; Figure 4.4). Blacksmith Lapwings were detected as the species with maximum abundance in all sites (Mean  $\pm$  SD;  $340.0 \pm 257.14$ ) compared with Crowned Lapwings (Mean  $\pm$  SD;  $71.7 \pm 94.48$ ). There was a seasonal fluctuation in the abundance of the species in different sites (Figure 4.3 - Figure 4.5). Blacksmith Lapwings and Crowned Lapwings spent most of their time foraging (Figure 4.6). Their feeding behaviour differed between winter and summer; they started feeding early, around 06h00 in summer and around 06h30 in winter, but their feeding period depended on ambient temperature.

**Table 4.2:** Recorded mean number of Blacksmith Lapwings and Crowned Lapwings per study site from April 2022 - September 2023.

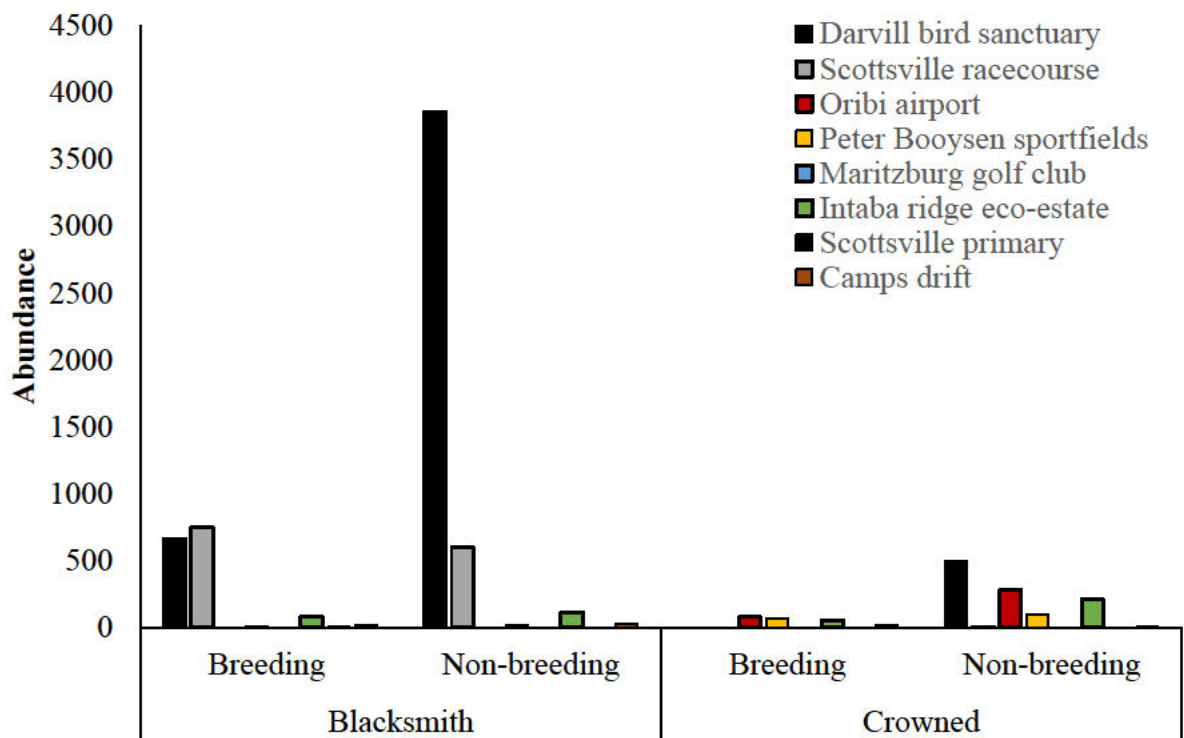
Sites	Blacksmith Lapwings	Crowned Lapwings
	Mean $\pm$ standard deviation	Mean $\pm$ standard deviation
Darvill Bird Sanctuary	251.5 $\pm$ 271.14	27.3 $\pm$ 86.76
Scottsville Racecourse	74.8 $\pm$ 31.89	0.3 $\pm$ 0.97
Maritzburg Golf Club	0.00 $\pm$ 0.00	0.0 $\pm$ 0.00
Scottsville Primary School	0.1 $\pm$ 0.47	0.0 $\pm$ 0.00
Peter Booyesen Sports Fields	0.9 $\pm$ 1.61	9.1 $\pm$ 11.97
Oribi Airport	0.0 $\pm$ 0.00	8.3 $\pm$ 28.59
Intaba Ridge Eco-estate	11.9 $\pm$ 10.99	16.3 $\pm$ 20.76
Camps Drift	5.2 $\pm$ 3.53	2.1 $\pm$ 3.53



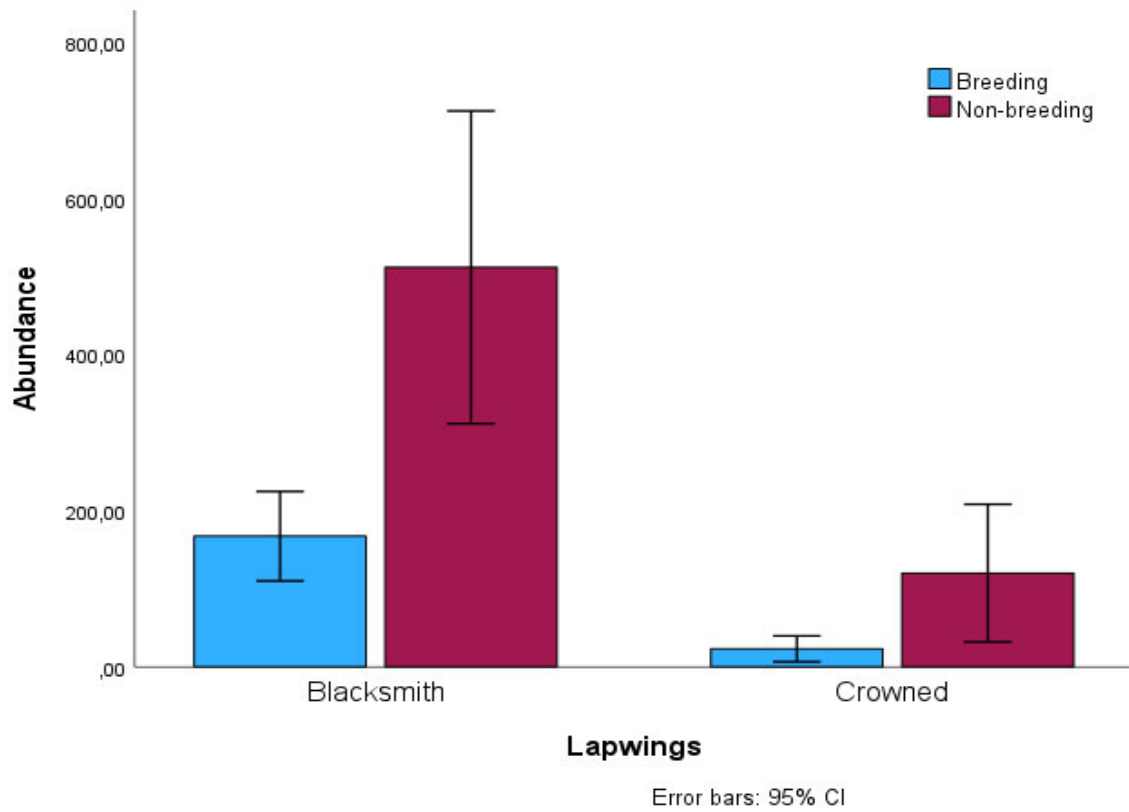
**Figure 4.2:** Blacksmith Lapwing and Crowned Lapwing total abundance at eight selected sites in Pietermaritzburg from April 2022 - September 2023.



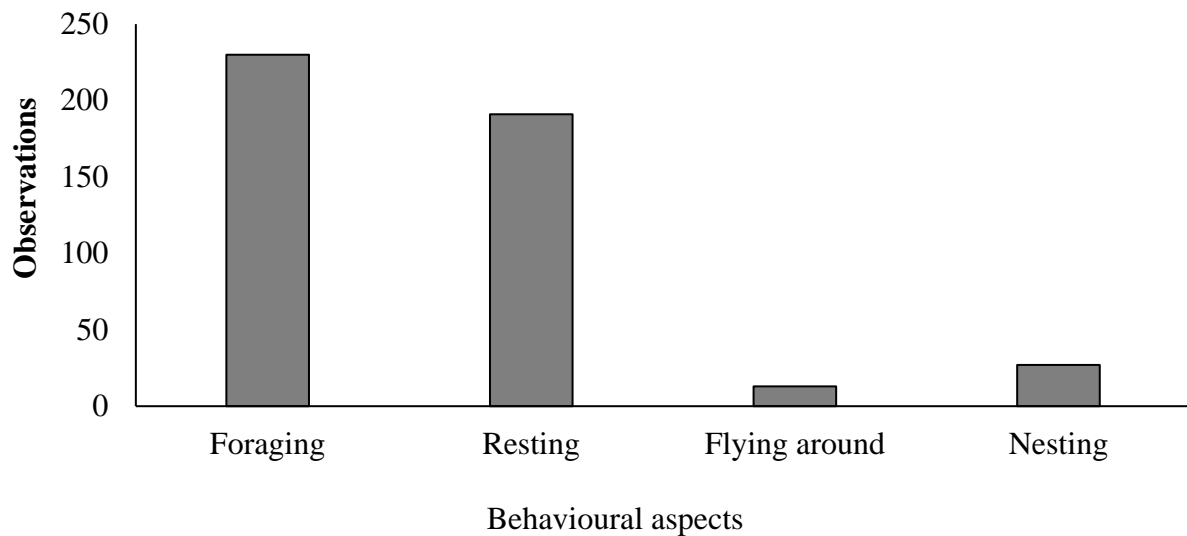
**Figure 4.3:** Monthly abundance of Blacksmith Lapwings and Crowned Lapwings in the urban mosaic landscape of Pietermaritzburg.



**Figure 4.4:** Seasonal fluctuations of abundance in different sites in the urban mosaic landscape of Pietermaritzburg.



**Figure 4.5:** Mean ( $\pm$  95% CI) abundance of Blacksmith Lapwings and Crowned Lapwings in the mosaic urban landscape in breeding and non-breeding seasons (April 2022 - September 2023) in Pietermaritzburg, South Africa.



**Figure 4.6:** Observed behavioural aspects in Blacksmith and Crowned Lapwings in the urban mosaic landscape of Pietermaritzburg.

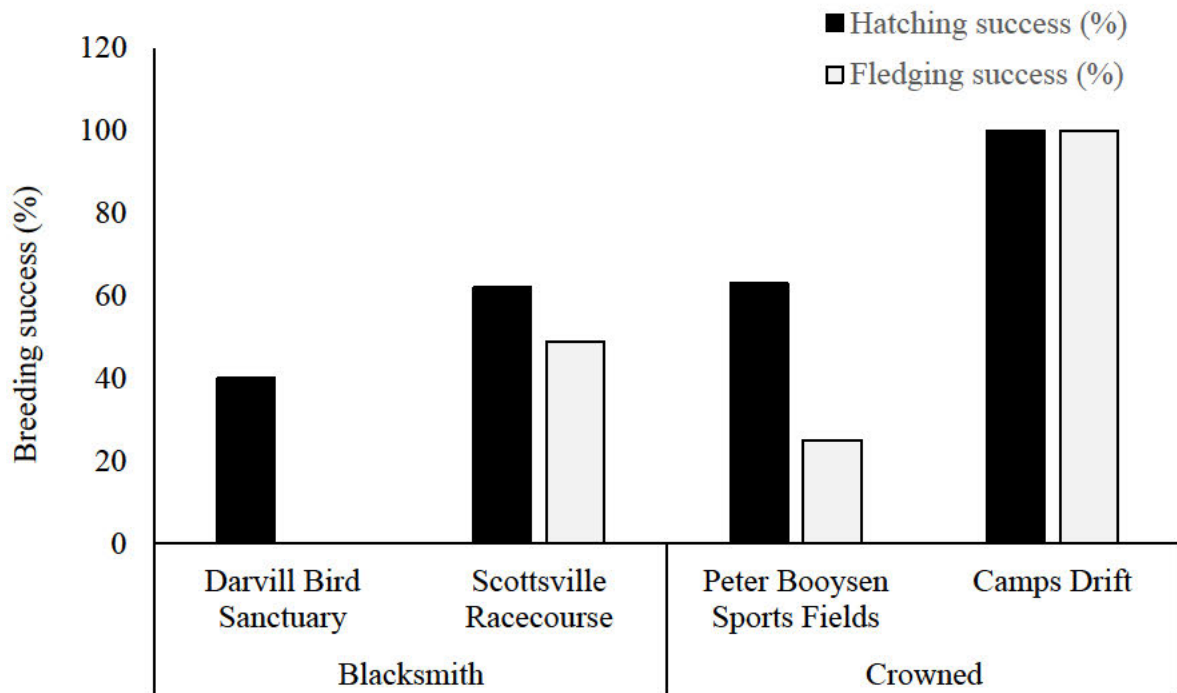
#### 4.4.2 Nests observations

Blacksmith Lapwing and Crowned Lapwing nests were observed in only four study sites. Most nesting pairs nested in short grasslands within the study sites with 2 – 3 cm grass height. A total of 52 eggs were laid in 17 nests for Blacksmith Lapwings, and 13 eggs hatched successfully, giving a hatching success of 60% (Table 4.3). For Crowned Lapwings, a total of 12 eggs were laid in four nests, and nine eggs were successfully hatched, giving a 75% hatching success (Table 4.3). The species preferred to nest in agricultural fields, open, managed green spaces, and sports fields. The most successful nests were observed in open grasslands (Scottsville Racecourse (n = 14) for Blacksmith Lapwings; Camps Drift (n = 1) and Peter Booysen Sports Fields (n = 2) for Crowned Lapwings) (Figure 4.7). Human disturbances disrupt nesting sites, leading to abandonment or direct destruction of nests. Nest failure was observed for both species in different nesting sites. Blacksmith Lapwings (n = 2), Crowned Lapwings (n = 1) nests lost; and Blacksmith Lapwings (n = 5) nests lost with unknown causes of failure.

The reproductive (breeding) success of Blacksmith Lapwings and Crowned Lapwings are summarised in Table 4.3. Eight nests were observed in 2022, while 13 nests were observed in 2023. The reproductive success was higher in 2023 than in 2022. Overall reproductive success was low, which raises concerns about ground-nesting birds nesting in urban mosaic landscapes.

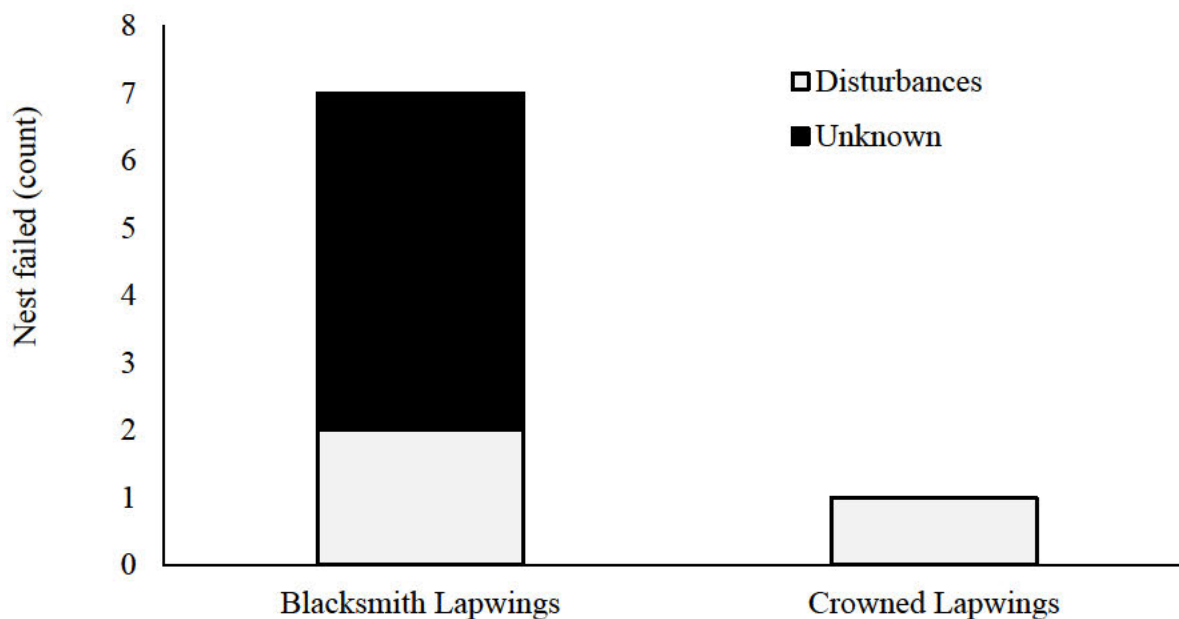
**Table 4.3:** Hatching and breeding success of Blacksmith Lapwings and Crowned Lapwings nesting in an urban mosaic landscape.

<b>Breeding season</b>	<b>Lapwing species</b>	<b>Nests observed</b>	<b>Eggs laid</b>	<b>Eggs hatched</b>	<b>Hatching success (%)</b>	<b>Survived to flying</b>	<b>Reproductive (breeding) success (%)</b>
2022	Blacksmith	6	18	13	72.2	9	50
	Crowned	2	5	2	40	2	40
2023	Blacksmith	11	34	18	53	14	41
	Crowned	2	7	7	100	4	57
Total	Blacksmith	17	52	31	60	22	42
	Crowned	4	12	9	75	6	50



**Figure 4.7:** Hatching success (%) and fledging success (%) of Blacksmith Lapwings and Crowned Lapwings in different sites in Pietermaritzburg during the study period in 2022 and 2023.

We found that the Crowned Lapwing nest loss was caused by human activities on the sports fields, where lawnmowers crushed the eggs (pers. obs.; Figure 4.7). Blacksmith Lapwings eggs were lost because of the use of machinery in one of the agricultural sites (Darvill), and machines crushed eggs (pers. obs.; Figure 4.7). We found vehicle tyre tracks in one of the nests. Most Blacksmith Lapwing nests were unsuccessful, and many eggs were lost without us knowing the cause (Figure 4.7).



**Figure 4.8:** Causes of nest failures in Blacksmith Lapwing and Crowned Lapwing nests during the study period.

## 4.5 Discussion

### 4.5.1 Abundance, habitat use and behaviour

A cumulative total of 7410 lapwings were observed during the investigation in the mosaic urban landscape of Pietermaritzburg. Blacksmith Lapwings ( $n = 6120$  individuals) were the most abundant species compared with Crowned Lapwings ( $n = 1290$  individuals). Short grassland areas with wetlands (such as rivers, lakes, etc.) and open fields were typically home to Blacksmith Lapwings. Crowned Lapwings, on the other hand, were rarely found near water and were typically found on short grasslands in residential areas like airports, sports fields and private residences.

These lapwings often congregate in flocks in the morning during the non-breeding season; however, this depends on how suitable the habitat is. Both species congregate in small territorial flocks during the breeding season, often in pairs. Study sites have open grasslands, with the availability of resources for species thriving in open grasslands. We found that

Blacksmith Lapwings abundance was higher at Darvill Bird Sanctuary during the non-breeding season, but they were abundant in Scottsville racecourse during the breeding season. Crowned Lapwings were common at Darvill Bird Sanctuary, Oribi Airport and Intaba Eco-estate during the non-breeding season, and they were abundant at Oribi Airport and Peter Booyesen Sports Fields, although breeding pairs were only found and observed at Camps Drift and Peter Booyesen Sports Fields during the breeding season. Both these species co-occur in some sites such as Darvill Bird Sanctuary and Intaba Ridge Eco-estate, but Blacksmith Lapwings were mostly found closer to water sources, while Crowned Lapwings were found distant to any water source in these sites. Some sites were the exclusive domains of Blacksmith Lapwings while some were the exclusive domains of Crowned Lapwings; thus, the abundance was greater for Blacksmith Lapwings at Darvill, the Scottsville Racecourse, and Camps Drift because those sites had relatively more wetlands, but Crowned Lapwings were more abundant at Oribi Airport because this site had less to no water availability and contained dry/burnt low grass vegetation. Some sites are ideal for feeding, while others are appropriate for breeding and provide good nesting grounds. Blacksmith Lapwings and Crowned Lapwings could associate with one another, as discovered feeding together at various sites in the mosaic urban landscape; hence, no competition was identified. Both species spend the majority of the time foraging by foot-trembling and pecking, searching for invertebrates (Cantlay et al. 2019).

No predation of the lapwings was detected during the study period because observations were conducted only during the day. However, based on assumptions, there are likely to be predators during the night, but no inferences can be made without evidence of predation events. According to our findings, Crowned and Blacksmith Lapwings adapt well to human-modified habitats, provided they have access to suitable habitats for feeding and breeding.

The abundance of Blacksmith Lapwings and Crowned Lapwings fluctuated, being lower during the breeding season (June - October) and increased during the non-breeding

season (November - May) when they congregated. The reason would be the dispersal of non-breeding/young birds away from the breeding grounds because breeding pairs become highly territorial; only breeding birds would be around those areas, which would explain why there are fewer birds during breeding seasons. The species move away from the breeding grounds if they are not breeding because the breeding pairs become highly territorial; only the breeding pair will remain in the breeding sites; thus, few individuals are observed in breeding sites during breeding seasons. Another reason may be local movement in winter (breeding season) to better breeding areas or to access better food resources because food availability tends to differ among seasons (Vickery et al. 2014; Riddiford et al. 2019). If predation risks and competition are higher, bird species move to avoid predators and find suitable spaces that are safer and reduce competition (Bonnet-Lebrun, Manica and Rodrigues, 2020; Kikuchi and Reinhold, 2021). Furthermore, we observed that at Darvill Bird Sanctuary, these lapwing species become scarce during the breeding season because of many disturbances caused by agricultural activities, such as machinery use and turf removal. During the non-breeding seasons, this site tended to have abundant Blacksmith Lapwings. This site is more open than other sites and may have a higher availability of food sources and more view of potential predators. Crowned Lapwings were abundant on sports fields but tended to be fewer during breeding seasons because only the breeding pairs remained in those sites during the breeding season. Their movement is also associated with the availability of resources and habitat suitability, and these species seem to thrive in a wide variety of conditions. However, they tend to disperse when they have limited resources and habitats that are unfavourable for them.

#### ***4.5.2 Nests observations***

The Blacksmith Lapwings and Crowned Lapwings observed in Pietermaritzburg bred from June to early October. The nests were found in only four sites: two sites for Blacksmith

Lapwings and two sites for Crowned lapwings. Nests were defended, and both parents incubated the clutches. Blacksmith Lapwings and Crowned Lapwings mostly laid 3 - 4 eggs per nesting attempt, and two eggs were also observed in a few nests. The egg-laying period was at its peak during late July, August and September for both species, with an incubation period of about 3 to 4 weeks (20 - 30 days). It is well known that females and males differ in terms of activities; most lapwing sexes show differences in behavioural aspects (Kis et al. 2000). Males are more aggressive and show intense defence behaviour when a predator approaches (Hegyí and Sasvari 1998; Liker and Székely 1999)

Hatching success for Crowned Lapwings was over 50%, which is lower compared with the observations by Ward (1989) and de Swardt (2010). The chicks that survived to the flying stage (fledging success) were few for both species, which lowered reproductive success. Blacksmith Lapwings laid 52 eggs for the 2022 and 2023 breeding periods, and only 22 survived to the fledging stage. Crowned Lapwings laid 12 eggs for the 2022 and 2023 breeding periods, but only six survived the fledging stage. Egg and chick loss are caused by different factors, such as human activities, predation, etc. Crowned Lapwings had fewer nests during the study period than Blacksmith Lapwings, despite thorough nest search in different sites during the breeding period; Crowned Lapwings nests were the most difficult to find. We only managed to observe four nests for 2022 and 2023, but we found reasonable nest numbers for Blacksmith Lapwings. Nesting success is generally influenced by the suitability of the sites (Golawski and Mroz 2019). Out of eight sites where these species occur, only two sites were suitable sites for Blacksmith Lapwings to breed, and two sites were suitable for Crowned Lapwings to breed.

Ground nesting birds are victims of predation, which limits factors associated with reproductive success. Predation is considered the main factor affecting the reproductive success of these species. During our study, we failed to assess the predators because of difficulties in assessing them. Josiah and Downs (2023) used camera traps to monitor the nests and assess

predation; this was impossible for our study because of the possible theft of camera traps and that most of our study sites are used by humans, and many activities are carried out daily. We assumed that most nests were predated, but we could not make inferences without clear evidence. Ward (1989a) observed that most Crowned Lapwing eggs and chicks were predated by Pied Crows (*Corvus albus*). Our study showed that the Crowned Lapwing nest loss was caused by human activities on the sports fields, where lawnmowers crushed the eggs. Blacksmith Lapwings eggs were lost because of the use of machinery in one of the agricultural sites, and machines crushed eggs. Most Blacksmith Lapwing nests were unsuccessful, and many eggs were lost without knowing the cause.

In conclusion, it is important to understand the species' habitat use, their behaviour, and breeding in urban mosaic landscapes for conservation purposes. It is human responsibility to mitigate any threats associated with the change in the environment because humans destroy many natural habitats to satisfy their own needs. There is a need to apply urban planning strategies that may be essential for species persistence by incorporating green spaces and avoiding disturbances during breeding seasons. As ground-nesting bird species in urban mosaic landscapes face predation risks, and their nest sites are destroyed by increased urban development or human activities, it is important to implement measures that can help mitigate predation risks to enhance species' reproductive success. The study highlighted how Blacksmith Lapwings and Crowned Lapwings persist and breed in urban areas. Recognising and addressing the challenges faced by the species in urban areas can help preserve these species amidst urban development. Blacksmith Lapwings and Crowned Lapwings persist in urban mosaic landscapes, and their behavioural plasticity is impressive. Still, the challenges surpass the positive adaptations of these species, as they are faced with a decline in their population in South Africa (Phoswa unpublished, Chapter 3).

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## CHAPTER 5

### General discussion, conclusions and recommendations

#### 5.1 Background

The complexities that come with the persistence of the species in urban areas represent a complex interaction between adaptability/flexibility, challenges, and the importance of conservation (McKinney, 2002; Donihue and Lambert, 2015; Birnie-Gauvin et al., 2016; Simkin et al., 2022; Ducatez et al., 2022). Some species persist with urbanisation by modifying their behaviours, especially enhancing nesting adaptations, to coexist with the developments associated with urban areas (Bressler et al., 2020; Reynolds et al., 2021). However, the species' ability to persist requires overcoming various challenges, including habitat loss, increased predation risks, and disturbances caused by human activities (McKinney, 2002; Ducatez et al., 2022). Urbanisation has become an increasing concern for the study of avian biology, especially various aspects such as life history, survival, breeding success, and individual health.

Blacksmith Lapwings and Crowned Lapwings are listed as the least concern in South Africa, according to the IUCN (IUCN, 2016; BirdLife International, 2022). They have a relatively large distribution range, and the populations appear to be increasing, which makes them less vulnerable (BirdLife International, 2022). The increase in their population numbers, especially in anthropogenically modified environments, including urban mosaic landscapes, suggests that these ground-nesting birds can persist in these landscapes. This study assessed different aspects of the ecology and behaviour of these two lapwing species in urban mosaic landscapes to understand how they persist and reproduce successfully in anthropogenically modified habitats. In summary, their behavioural plasticity likely facilitates their persistence in urban mosaic landscapes.

This study assessed the persistence of Crowned and Blacksmith Lapwings in a mosaic urban landscape, Pietermaritzburg, KwaZulu Natal, South Africa. The objectives were to (1) determine the distribution and range change across South Africa; (2) collate information about Crowned and Blacksmith Lapwing occurrence, persistence, habitat use, distribution, breeding, and behaviour in urban areas; and (3) determine the influence of human activities and different land uses on the nesting ecology of Crowned and Blacksmith Lapwings breeding in urban mosaic landscapes.

## **5.2 A systematic review of lapwing research in Africa to determine trends and evidence of their response to changes in terrestrial ecosystems.**

Humans have altered natural habitats to satisfy their needs, causing a decline in terrestrial ecosystems. Grasslands are considered one of the changing ecosystems because of intensive agriculture and anthropogenic land conversions (Bardgett et al., 2021). Grasslands cover about 26% of global landscapes, and land conversion causes a decline in grassland species worldwide. In southern Africa, few grasslands are intact and unthreatened (Chapter 2). The grassland species have declined in recent years because of land-use intensification and ongoing changes in agricultural practices that affect these species' reproductive and breeding success (Chapter 2). Lapwings (*Vanellus* spp.) are ground-nesting birds belonging to the family Charadriidae; they usually forage and breed in open grasslands and are associated with wetlands such as rivers, lakes, dams, etc. (Chapter 2). A noticeable global decline has been occurring (Chapter 2). There are 14 lapwing species found occurring/breeding in Africa (Chapter 2). According to IUCN, 12/14 lapwing species are of least concern, while 1/14 are critically endangered and 1/14 are near threatened (Chapter 2).

The study focused on past and present research on lapwings in Africa (Chapter 2). We were interested in whether there had been increased research with time and whether

anthropogenic effects on terrestrial landscapes in Africa affected lapwing species negatively. Understanding how lapwing species react and respond to their surroundings and changing habitats is key to the designation of conservation strategies. The study findings highlighted important gaps in studies about lapwings in association with human-modified habitats in Africa (Chapter 2). The results revealed that African lapwing publications did not continuously increase with time (Chapter 2). More studies were conducted in the early 2000s, while recent years lacked research (Chapter 2). The available studies highlighted various African lapwing species' behaviour, breeding, habitat selection, and diet (Chapter 2). These species can coexist and exhibit defensive behaviours to avoid predation; their diets are mainly invertebrates, such as insects, and they tend to migrate in unsuitable habitats. These adaptive behaviours and plasticity enhance their fitness to survive and reproduce in anthropogenically modified terrestrial landscapes (Chapter 2). Significant gaps were highlighted in our research, with increasingly fewer studies of lapwings in Africa despite continuing anthropogenic land use change (Chapter 2).

### **5.3 Range change and distribution across South Africa**

One of the national bird atlas projects in South Africa carried out by citizen scientists is the Southern African Bird Atlas Project 1 and 2 (SABAP1: 1987–1992, and SABAP2: 2007–present) (Chapter 3). These projects provide overviews of avian distribution across southern Africa. Spatial records in this database show changes in species distribution (range), and by comparing reporting rates (the proportion of checklists reporting a species, which is an index of relative abundance) between these projects to estimate population change (Chapter 3). We assessed Blacksmith (*Vanellus armatus*) and Crowned Lapwings (*V. coronatus*) presence and distribution range in southern Africa by comparing the presence and reporting rates between historical data (SABAP1) and present data (SABAP2) (Chapter 3). Both species' distribution

range and overall relative abundance declined (Chapter 3). The causes of these declines include anthropogenic land transformation and prolonged drought that occurs in some regions, which may have caused the shift of these species (Chapter 3).

#### **5.4 Occurrence and persistence of Blacksmith Lapwings and Crowned Lapwings and their reproductive success in urban mosaic landscapes**

The objective was to assess the abundance, habitat use, behaviour and nesting ecology of Blacksmith Lapwings and Crowned Lapwings in the urban mosaic landscapes of Pietermaritzburg (Chapter 4). The findings showed that the species can use the available resources in urban mosaic landscapes, and they forage and reproduce in open grasslands, agricultural fields, and natural and managed green spaces (Chapter 4). Blacksmith Lapwings and Crowned Lapwings showed variation in terms of the habitats they use (Chapter 4). Selected areas provide these species with suitable ground for nesting and potentially away from predators. Blacksmith Lapwings were mostly associated with grasslands with wetlands, such as rivers, dams, mudflats, etc., while Crowned Lapwings were seldom associated with water but were found in grassland patches and residential areas (Chapter 4). The abundance of these species was influenced by breeding season, where their abundance in the selected sites tended to be lower than in the non-breeding season (Chapter 4). Lapwings may disperse during breeding to find suitable nesting sites and return to forage after breeding is complete. A reasonable hatching success rate was found in the present study, while lower reproductive success was found (Chapter 4). Although their populations appear to be declining in South Africa, it is evident they can persist in mosaic urban landscapes where they show behavioural plasticity (Chapter 4).

## **5.5 Final conclusions and recommendations**

The findings of this thesis emphasise the essential need for conservation in urban planning. The importance of understanding ecosystem services and the ecological importance of each species in urban areas calls for integrated approaches that can help balance urban growth while preserving natural habitats for species persistence and nesting in these areas. The most important implementations are maintaining and creating green spaces, creating corridors for wildlife, and implementing environmentally sensitive urban designs suitable for wildlife.

Moreover, public awareness and human engagement in species conservation can create a space for initiatives promoting the coexistence of humans and wildlife (Larson et al., 2016; Mekonen, 2020). Understanding the value of biodiversity in urban areas and the implication of their persistence and preservation contributes to the relationship between urban development and nature as well as human wellbeing. The ability to monitor the populations is important to conservation biology because it provides important information about the status of the species, especially for threatened species. Increasingly, citizen scientists can contribute to this. The information and data gathered can provide long-term trends about species abundance and geographical distribution, which helps in tracking and understanding the different crises of global biodiversity. Bridging the gap between urban development and conservation practices is crucial in creating environments that can support the needs of humans as well as species persistence for a range of diverse wildlife populations that can withstand the challenges for survival in these mosaic urban landscapes.

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