THE IINGCUNGCU PROJECT: Restoring nectar feeding birds, building biodiversity leadership.

By

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Declaration

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Abstract

Plant-pollinator interactions are threatened by habitat fragmentation and little is being done to mitigate its varying impacts. Thus the *Iingcungcu* study put together three chapters 1) aiming to establish a methodology to establish ecological corridors linking two protected areas using high school gardens as stepping stones planted with nectar producing plants; 2) Have nectar-feeding birds returned to restored sites?; 3) Did the study manage to nurture future leaders for biodiversity?

The methodology included setting up a nectar producing and bird-pollinated plant species list for the Cape Floristic Region (CFR); criteria for establishment of ecological corridors and another for selection of suitable plants for planting at high schools; selection of suitable plants for planting within the study area. This chapter concludes with a communication and a media strategy used to communicate the study progress.

The results following bird observations suggest that planting suitable nectar producing plants can restore nectar feeding birds, thus restoring plant-pollinator networks. An upward trend in bird abundance was observed on the two species i.e. *Zosterops virens* (Cape white-eye) and *Cinnyris chalybeus* (Southern double-collard sunbird).

Furthermore, the results following interaction with grade 10 learners showed an increasing trend over time in the experimental group especially in their responses to one of the grouped questions that tested the knowledge variable. This concludes that there was a significant statistical interaction between the two variables Period (time) and Treatment.

I found that learners are always eager to engage in new projects to learn new things and that their attitudes can change over time towards biodiversity when engaged in environmental education projects.

Restorative efforts on a landscape scale, especially in urban ecosystems, can be best achieved when ecologists begin working together with social scientists. Biodiversity will continue its perilous path if it does not consider humanity its biggest partner in perpetual existence.

Opsomming

Plant-bestuiwer interaksies word bedreig deur habitat fragmentasie en min word gedoen om die verskeidenheid gevolge te versag. Gevolglik stel die *Iingcungcu* studie drie hoofstukke saam gestel 1) poog om 'n metodologie daar te stel om ekologiese korridors tussen twee beskermde gebiede te vestig met Hoërskool tuine beplant met nektar-produserende plante, as ‘n voël-vriendelike korridor; 2) het nektar etende voëls teruggekeer na areas wat gerestoureer is?; 3) het die studie dit reggekry om toekomstige leiers vir biodiversiteit te kweek?

Die metodologie sluit in die opstel van ‘n nektar-produserende en voëlbestuifde plantspesies lys vir die Kaapse Floristiese Streek (KFS); kriteria vir die vestiging van ekologiese korridors en 'n ander vir seleksie van geskikte plante vir aanplanting by hoërskole; seleksie van geskikte plante vir aanplanting binne die studie area. Hierdie hoofstuk sluit af met 'n kommunikasie en 'n media strategie wat gebruik was om die studie se vordering te kommunikeer.

Die resultate van die voël waarnemings dui daarop dat indien geskikte nektar produserende plante geplant word, nektar etende voëls terugkeer en die bestuiwings web dus herstel kan word. 'n Opwaartse tendens in voël getalle in twee spesies naamlik, *Zosterops virens* (Kaapse glasogie) en *Cinnyris chalybeus* (Klein-rooibandsuikerbekkie), is waargeneem.

Verder het die resultate van die interaksie met graad 10 leerders, met verloop van tyd, 'n toenemende tendens getoon in die eksperimentele groep, veral in hul reaksies op die vrae wat kennis getoets het. Dit dui daarop aan dat daar 'n beduidende statistiese betekenisvolle interaksie tussen die twee veranderlikes periode (tyd) en behandeling.

Ek het gevind dat leerders altyd gretig is om betrokke te raak by nuwe projekte en om nuwe dinge te leer. Leerders se houding teenoor biodiversiteit kan verander oor tyd indien hulle blootgestel word aan omgewings onderrig.

Ekologiese restorasie pogings op ‘n landskap skaal, veral in stedelike ekosisteme, kan die beste bereik word wanneer ekoloë begin saamwerk met sosiale wetenskaplikes. Biodiversiteit sal voortgaan op sy gevaarlike afdraande pad solank.

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Further acknowledgements are available in chapters 2 to 4 of this study.

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1. Chapter 1: A general introduction to the *Iingcungcu* project in relation to urban ecology and the effects of urbanisation on sunbirds and sugarbirds

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1. General introduction

1.1. Background

Iingcungcu is an isiXhosa name referring to Sunbirds and Sugarbirds with long beaks and largely feed on nectar (Skead, 1967). These birds pollinate over 350 species of plants in the Fynbos Biome (Rebelo, 1987). Pollination has typically been studied from an evolutionary perspective, to answer questions about floral adaptation and plant speciation. This has led to the application of ecological thinking to pollination biology lagging behind (Pauw, 2013; Sargent and Ackerly, 2008). As a result, it is currently difficult to answer basic ecological questions about the role of mutualism in structuring plant communities (Pauw, 2013).

Further, the current global decline in pollinators highlights the need to answer the basic ecological question of whether mutualisms are important for the maintenance of diverse plant communities (Aguilar et al., 2006; Aizen et al., 2016; Potts et al., 2010). Although many species-level studies support the ecological importance of mutualism, evidence for community-level impacts of mutualists is lacking and the role of pollination, relative to other mutualistic interactions (such as predation and competition), has long been debated in the theoretical literature (Pauw, 2013; Price et al., 2008). One view, the “keystone mutualist hypothesis”, predicts that the human-caused loss of mutualisms, especially pollinators, will trigger a cascade of linked extinctions throughout the community (Anderson et al., 2011; Bascompte et al., 1980; Lennartsson, 2002; Memmott et al., 2007; Pauw and Bond, 2011; Pauw and Hawkins, 2011; Soulé and Wilcox, 1980). Intriguingly, pollination is often considered to be of little ecological importance largely because, in the absence of their primary pollinator, many plant species often compensate by self-pollinating or switching to other pollinators (Bond, 1994; Ghazoul, 2005; Knight et al., 2005). Furthermore, it is argued that even if seed sets decline due to pollinator loss, recruitment in some plant species may not decline because an excess of seeds capable to survive for long extended periods is normally produced (Bond, 1994), or because the species can recruit vegetatively (Pauw and Bond, 2011). However, Geerts and Pauw (2012) argue that *Nectarinia famosa* (Malachite sunbirds) as the sole pollinator for a group

of deep-flowered plant species within the Cape Floristic Region (CFR) are arguably ecologically irreplaceable pollinators. In real terms, this may mean that species relying on them for pollination may also suffer an irreversible turn should this sunbird species become locally extinct (Aizen et al., 2012). The above point seems to suggest that mutualistic interactions remain crucial in shaping ecosystem functioning and services, which fosters biodiversity stability (Cagnolo et al., 2009; Memmott et al., 2007; Menz et al., 2011; Phillips et al., 2015; Zhang et al., 2011).

Earlier work has shown that habitat fragmentation, urbanization, road traffic and honeybee farming reduce the abundance of nectar-feeding birds (Geerts and Pauw, 2010; Geerts and Pauw, 2011; Kremen et al., 2002; Pauw and Louw, 2012). This is largely caused by the loss of native vegetation leading to the remainder becoming small and isolated remnants of natural vegetation (Andrieu et al., 2009; Ramalho et al., 2014). Recent research revealed substantial evidence on the significance of restoration of species interactions, particularly plant-pollinator interactions (Hanna et al., 2013). Nevertheless, some authors suggest otherwise. For example, Urbanska et al. (1997) argue that even if plant species are added to a restoration plan, there is no guarantee that pollinators will return. While this argument might be true, is it not worth testing what really happens when nectar producing plants are planted, particularly in corridors that are strategically linked to areas known to have high prevalence of pollinators (Urbanska et al., 1997). Would this pollinator guild of birds still stay away, despite the restorative efforts?

In Cape Town where every square metre counts, i.e. where there is a high level of plant species richness and endemism (Helme and Trinder-Smith, 2006; Rebelo et al., 2011), the importance of managing anthropogenic factors, which are detrimental to plant-pollinator interactions can no longer be ignored (Pauw, 2007). As such, there must be concerted efforts towards pro-active ecological restoration (Devoto et al., 2012; Menz et al., 2011).

This project will focus largely on connecting conservation areas within the Cape Flats as scientific evidence reveals that habitat fragmentation can disturb pollinator communities in various ways (Andrieu et al., 2009; Cagnolo et al., 2009; Hostetler and McIntyre, 2001; Kolb, 2008; Niemelä, 1999). Urbanska et al. (1997) highlight the importance of considering appropriate pollinators when restoration work is

undertaken, as distances travelled from one point to another could dictate whether pollinators do visit such restored sites (Amorim et al., 2013).

In this study, we have established small gardens with nectar producing plants across the selected landscape, where plant-pollinator interactions may potentially be restored (Brudvig et al., 2015; Zhang et al., 2011). We recognise that restoration requires time as well as both economic and human resources (Menz et al., 2011). Thus, opportunities like the *Iingcungcu* project could bring about convergence by involving society into the environmental affairs. Restoration could take place while involving society to ensure continuous restorative efforts. This is arguably one of the recommended ways to conduct restoration especially when done in urban areas (Adams et al., 2016; Alberti et al., 2003; Collins et al., 2000; Husté et al., 2006). The benefits of working with the society may present an opportunity to interest them into environmental matters and possibly transform them into responsible leaders for biodiversity (Dennis et al., 2016; Stevens, 2014). Essentially this is a pilot study, which would be later used to motivate a larger scale project in the greater Cape Town areas. The ideas of this study are nevertheless transferable to other urban areas in the country and even abroad. Ultimately the aim is to see this study taken up and owned by local governments as a way of bringing about a convergence in the ecological and the sociological aspects of Cities (Felson and Pickett, 2005; Luck et al., 2013; Pickett et al., 2001). We believe that this will help recreate suitable habitats embedded in unsuitable environments and restore the four species of obligate nectar feeding birds in the Cape, as the main and critical pollinators of about 350 plant species (Andrieu et al., 2009; Rebelo, 1987).

There is no doubt that green spaces in cities are essential not only for the provision of ecosystem services, but to positively contribute towards human quality of life and wellbeing (Belaire et al., 2014; Beumer and Martens, 2015; Dickinson et al., 2010; Goddard et al., 2010; Morrison et al., 2016; Stevens, 2014).

1.2. Study aims

The study focuses on the interaction between nectar-feeding birds (the iconic Sunbirds and Sugarbirds) and bird-pollinated plants to answer the ecological question of whether corridors can be established to facilitate the movement of specialist nectar feeding birds across a landscape where they have been commonly known to occur (Pauw and Louw, 2012). Simultaneously, we hope to test whether exposure to a restoration project of this nature influences school learners' attitudes to biodiversity.

I hypothesised that there would be an increase in bird abundance where nectar producing plants are added; and that there would be a difference (before vs. after) in the responses to questionnaires from learners who participated in the study, in particular indicating an increased interest in natural sciences as a career choice, as well as a change in knowledge, attitudes and awareness.

1.3. Chapter Summary

Firstly, I investigated various methods suitable for the establishment of ecological corridors (stepping-stones). Using relevant literature, I put together a list of nectar producing plants for the Cape Floristic Region (CFR). Selected plant species suitable for planting according to the various vegetation types found in the study area. I identified schools suitably located in the proximity of one another and then planted nectar plants in school gardens measuring 10 m X 20 m = 200 m^2. I concluded the chapter with the information on plant survival as well as discussing the communication and media coverage (Chapter 2).

Secondly, I conducted bird surveys within four high schools (planted) and four primary schools (not planted) as well as the Table Mountain National Park (protected area) and the Rondevlei section of False Bay Nature Reserve (protected area) before and after planting (2013, before-planting; 2014-2016, after-planting). The surveys were done to test for changes in bird abundance (Chapter 3).

Thirdly, I worked with grade 10 high school teachers who helped to identify two grade 10 classes. The leaners were introduced to the *lingcungcu* project and involved them in various interactions including, but not limited to planting of nectar

plants, weeding, and introduced them to biodiversity worksheets. The leaners were encouraged to complete a questionnaire individually before and after interaction to determine whether those who participated in the project would show a slight shift in attitude towards natural sciences (Chapter 4).

Lastly, I conclude with a brief summary of the thesis in (Chapter 5) where I highlight the importance of ecological restoration to promote ecosystem functioning. This chapter also makes some recommendations for possible future studies that may add value to both the social and ecological fields.

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2. Chapter 2: How to restore a nectar feeding bird migration corridor by establishing nectar-rich stepping-stones

2.1. Abstract

In this chapter I describe how we selected a corridor for pollinator restoration, selected schools at which to establish pollinator friendly gardens, chose plants for restoration, planted gardens, and marketed the project. We provide a list of bird-pollinated plant species of the Cape Floristic Region (CFR), a list of species useful for restoration (along with their establishment success), a list of nurseries, and a breakdown of costs (both of plants and labour).

2.2. Introduction

This study was pursued despite earlier unenthusiastic sentiments around studying urban ecosystems as they were considered inferior to natural ecosystems due to their being usually associated with heavy disturbances (Niemelä, 1999). However this view has since shifted following the recent urban planning positive outlook towards urban ecosystems research and the concerted effort to integrate ecosystems into the urban development (Alfsen-Norodom, 2004; Marco et al., 2010; Niemelä, 1999). Moreover, ecologists have become increasingly aware and concerned about the effects of anthropogenic activities on urban natural ecosystems (Niemelä, 1999; Steffan-Dewenter and Tscharntke, 1999). According to Doody et al. (2010), in urban areas, ecosystems and/or ecological restoration is a challenge, which affects both the social and the ecological systems. Thus they argue that ecological restoration is not a role for ecologists only, but a program which sees conservation moving beyond natural areas such as protected areas into people's daily lives, thus leading to the personalisation of nature and building community support for the conservation and restoration of ecological processes (Doody et al., 2010). Perhaps in doing this, the importance of understanding the overall meaning of biodiversity loss, which is believed to be less understood by many people, may begin to grow (Sol et al., 2014). This is actually critical because without fully understanding the real causes and perhaps the cascading effects of biodiversity loss, efforts geared towards ecological restoration on degraded environments especially plant-pollinator connections may be in vain (Anderson et

al., 2011; Husté et al., 2006; Menz et al., 2011; Sekercioglu, 2011; Wiens and Hobbs, 2015).

According to Goddard et al. (2010); Niemelä (1999), fragmented, isolated and smaller habitat patches, characterise many cities in the world. Even though not much evidence for extinction exists, research suggests that many specialist plant species go extinct as many bird assemblages especially nectar guilds in this case alter their movement behaviour, which has a negative impact on species relying on them for pollination (Anderson et al., 2011; Lennartsson, 2002; Lomov et al., 2010; Neuschulz et al., 2013; Sekercioglu, 2011). To mitigate current trends and perhaps future loses, there is a need to create deliberated plant-pollinator networks (Menz et al., 2011), which can work to support restored ecosystems (Gill et al., 2006; Lerman and Warren, 2011). Research also indicates that in order for smaller remnants to be viable and continue to support plant and animal populations, they need to be expanded into the surrounding urban matrix (Doody et al., 2010; Kremen and M'Gonigle, 2015; M'Gonigle et al., 2015; Smith et al., 2008; West et al., 2016). To achieve these connections, they recommend the planting of native species within surrounding urban areas for various reasons (Doody et al., 2010; French et al., 2005; Husté et al., 2006).

The *lingcungcu* study supports the principle of planting native species as it focuses on planting specific native nectar producing plant species in smaller school gardens to restore plant-pollinator mutualism. The public school gardens will be used as stepping-stones to connect two important areas such the Table Mountain National Park (Muizenberg and Silvermine Mountains) with the False Bay Nature Reserve (Rondelvlei). The selected school gardens are public and owned by government. In order to work in this environment especially within schools, a relationship with the school heads and life sciences teachers had to be established before establishing any garden to form part of the stepping-stones series.

Worth noting is that, whether it is private (domestic and business) or public (government offices, school and/or hospital grounds) gardens, the value of gardens in general, have been recognised as one of the ways in which biodiversity could be enhanced, especially within cities (Alfsen-Norodom, 2004;

Goddard et al., 2010; Husté et al., 2006; Lomov et al., 2010; Marco et al., 2010; Morandin and Kremen, 2013). Evidence also reveals that these gardens or green spaces cover over 40% of cities' or rural surface spaces in certain areas (Belaire et al., 2014; Beumer and Martens, 2015; Folke et al., 1997; Goddard et al., 2010). This is an interesting finding because in Cape Town, particularly the Cape Flats areas where this study is executed, there are many school grounds standing unused even after sports fields have been established, where possible. The availability of these open and unused grounds was an opportunity waiting to be explored in this study as spaces to connect smaller reserves with large protected areas was a prerequisite. In some instances, open green spaces are left overgrown with unwanted and fast growing invasive species, which leads to all varieties of challenges often leading to the open spaces ending up as concrete to prevent the persistence of such challenges.

2.2.1. Study aims

The aims of this methodological chapter are to serve as a guide to the restoration of nectar feeding birds in urban environments. Specifically, my objectives were five-fold:

(1) To put together a list of bird pollinated species for the Cape Floristic Region (CFR);
(2) To identify, source and plant selected plant species on allocated spaces of equal sizes on each high school grounds guided by the criteria for the selection of plants i.e. bright coloured, tubular and nectar producing;
(3) To identify and establish an ecological corridor (stepping-stones) linking the Muizenberg-Silvermine Mountain ranges in the Table Mountain National Park with the False Bay Nature Reserve's Rondevlei section;
(4) To determine the establishment success of these indigenous gardens and the availability of the nectar resource;
(5) To determine the cost of establishing the indigenous gardens as well as the communication necessary to reach a wider community.

2.3. Methods and Materials

2.3.1. Study Area

The study was done within the City of Cape Town, in particular the Cape Peninsula. The City is located within the southwest most portion of the Cape Floristic Region (CFR), which is part of the Mediterranean Biome in the Western Cape, South Africa (Holmes et al., 2008; Rebelo et al., 2011; Underwood et al., 2009). The City extends all the way from Silverstream Beach and in the northwest to Kogel Bay in the southeast, totalling an area of 2460 km^2 (Rebelo et al., 2011). The Cape Flats Dune Strandveld largely dominates the City's western and southern coastal edges, whereas the Cape Flats Sand Fynbos and Renosterveld cover inlands and low shale-granite hills, respectively (Mucina and Rutherford, 2006; Rebelo et al., 2011). In the centre where the lingcungcu study took place, lies the Cape Flats Sand Fynbos, which is significantly threatened by growing anthropogenic factors, such as urbanisation which is major contributor to habitat fragmentation (Fahrig, 2003; McKinney, 2006; Pauw and Louw, 2012; Rebelo et al., 2011; Stout, 2014).

Essentially, this was a pilot study where two sites were identified, but only one of them was selected as a study site due various ecological and social reasons. The areas initially considered included the Muizenberg/Rondevlei corridor and the Sun Valley corridor, which links the northern and the southern portions of the Table Mountain National Park. For an ecological reasons however, the corridor needed to have closer proximity to the areas where the sunbirds are known to occur; whereas for the social reason, the corridor needed to be located within an area where eight schools including four high schools (planted) and four primary schools (not-planted) were available.

2.3.2. The ecological role of corridors

Selecting a viable biological corridor required that important questions regarding the ecological role of corridors were answered:

- Do corridors really work?
- Can corridors effectively support the ecological restoration efforts by ecologists?

- How can the effectiveness of corridors be measured?

Therefore, the study did not attempt to directly answer the above questions of corridors, but discussed them as a general concern and using them to guide the study. Interestingly, despite the debate on the significance of corridors to effectively maintain biological diversity (Townsend and Levey, 2005; West et al., 2016), various literature argue that they nevertheless remain fairly significant (especially in bird populations) at connecting isolated populations and promoting ecological processes (Beier and Noss, 1998; Pérez-Hernández et al., 2015; Rosenberg et al., 1997; Townsend and Levey, 2005). Beier and Noss (1998); Rosenberg et al. (1997) further highlight that ecological corridors are fundamental and can benefit biological diversity on a local and regional scale and contribute towards reducing extinction rates of species. Rosenberg et al. (1997) define a corridor as "a linear landscape element that provides for movement among habitats patches, but not necessarily reproduction." Whereas the definition focuses only on the one aspect of corridor significance, our study focused on using nectar producing plants planted at high school gardens (Beumer and Martens, 2015; French et al., 2005; Marco et al., 2010) to reconnect broken migration routes for the guilds of pollinators to actively act as stepping-stones (Pérez-Hernández et al., 2015) across an urban landscape that currently lack nectar resources for nectar feeding birds.

2.3.3. Important factors considered when selecting a corridor

Ensuring that the selected corridor fulfils its ecological role of linking fragmented landscapes (Pérez-Hernández et al., 2015; Townsend and Levey, 2005), it is critical that the following aspects are covered.

- The existence of natural habitats at either end of the corridor was one of the critical factors that determined which of the two identified corridors would be suitable for this study (Townsend and Levey, 2005), i.e. where the targeted pollinator guilds occur naturally and where the birds' migration route may lead.
- Availability of reasonably large open grounds, which could be used for the establishment of small indigenous gardens planted with nectar resources for birds.

- Infrastructure such as water resources to maintain the nectar producing plants for birds once established needed to be available and reliable.
- Willingness from all the selected management authorities to participate in the study was a major factor to be considered and resolved prior to the study taking place.
- The selected sites needed to be part of some environmental education programme, planning to and/or willing to embark on one in the near future.
- Where schools were a target (like in our case), the study needed to easily link or be adaptable to the school's curriculum to increase the level of participation by both learners and educators.
- The area needed to be reasonably safe to allow a continuation of the study without interruptions through acts of criminal nature including intimidation of the research team and vandalism of critical research materials and infrastructure.
- The average distances between areas where nectar resources for the pollinator guilds are known to occur need to be reasonable as research indicates that certain guilds may be affected by distances between foraging areas (Neuschulz et al., 2013; Pauw and Louw, 2012).

Though not exhaustive, the above list represents the minimum criteria used in this study when selecting a corridor to connect broken migration route for birds, in order to create stepping-stones across urban areas that lack nectar resources.

Furthermore, assuming a hypothetical direct flight pattern of the pollinators, a total flight distance between the stepping stones was determined (Table 2.1; Map 2.1). The flight distance was an interesting find as Pauw and Louw (2012) found that some pollinator guilds did not prefer flying distances greater than a kilometre from their natural environments into the urbanised environments. Their results indicated that species mostly affected were the *Nectarinia famosa* (Malachite sunbirds) (Pauw and Louw, 2012). Interestingly, Moore et al. (2008) also had similar findings revealing that some birds were reluctant to cross waters and fragmented forest patches. Of concern was that this particular pollinator i.e. *Nectarinia famosa* (Malachite sunbird), has a longer bill than that of the *Cinnyris chalybeus* (Southern double-collared sunbird) and that reduction in their numbers, could mean a reduction in pollinator visitations to the long-tubed flowering species

like the *Brunsvigia orientalis* (similar to *Brunsvigia litoralis*), which could end up suffering lower seed set (Geerts and Pauw, 2012), due to the lack of and/or reduced plant-animal interactions (Kaiser-Bunbury et al., 2009; Kaiser-Bunbury et al., 2010a; Kaiser-Bunbury et al., 2010b; Pauw and Louw, 2012).

2.3.4. Criteria used to select nectar producing and bird pollinated plant species

In order to fulfil the objectives of the study, each plant species was carefully selected due to their characteristics (Geerts and Pauw, 2009; Krömer et al., 2008; Menz et al., 2011; Van der Pijl, 1961).

- The plants had to conform to the bird-pollination syndrome i.e. be brightly coloured (especially reddish colours), scentless, tubular with sturdy stems, nectar volumes per flower measuring >3 microlitres, and nectar concentration of 10-25% sucrose (Franke et al., 1998; Krömer et al., 2008).
- Be able to flower for extended periods during the flowering season and be able to retain flowers for long; i.e. flowering for three months and more (Menz et al., 2011).
- To be hardy and able to withstand harsh conditions without artificial irrigation for longer periods of time to ensure establishment through the first summer with occasional deep watering (Menz et al., 2011).
- Plant species to be locally native to the Cape Flats Sand Fynbos (CFSF) and Cape Flats Dune Strandveld (CFDS) (Mucina and Rutherford, 2006), and produced or propagated from locally sourced material to avoid introduction of foreign genotypes.
- Native South African species that are not typical of the abovementioned vegetation types were also considered for the boosting of nectar production.
- Highly poisonous plant species avoided.
- Plants with prickles or thorns made up less than <5% of the total planted species.

The *Erica (verticillata* and *mammosa), Pelorgonium fulgidum, Leucospermum conocarpodendron* and *Mimetes fimbriifolius* species were the only ones that struggled to survive during the project phase whereas all other species managed to survive the harsh drought conditions. Although some of these struggled to survive, it is by no means an indication that the species are not ideal for

restoration projects. However, being slow growing, we suspect that their struggle may be linked to the timing, i.e. perhaps the species needed more time for development before they could be planted in the gardens. It is worth noting that all plants were propagated in 2013, which was seven months before planting in 2014. The *Erica spp.* however, may require more nurturing in the first few seasons following their planting, if considered for restoration projects.

2.3.5. Propagation of nectar producing plant species

Four nurseries with various special skills and interests were contracted to propagate plants seven months before the planting season. The nurseries were given a list of all species occurring in the Cape Flats Sand Fynbos and Cape Flats Dune Strandveld vegetation types from a species list compiled as part of the study. Without hesitation, two nurseries confirmed which species they could comfortably propagate and using this feedback, the species were accordingly divided between them. The fully grown species like the *Erica verticillata*, *Protea repens* and *Protea cynaroides* were sourced from Arnelia Farms, whereas all other species were sourced from the Cape of Good Hope, Cape Flats Plants nurseries as well as the City of Cape Town's restoration facility. Initially, the assumption was that any plant could be easily propagated, but the lack of due consideration for the types of species, the seasons during which they should be cut and the required rooting process, meant that not all plants species on the list could be propagated. In other instances even species, which could be easily produced, could not be produced due to not having enough lead-time to allow for a significant growth and development to guarantee a sustained growth especially during the summer season soon after planting. Many species were thus planted young and small (though propagated from cuttings), which meant that only the fast growing nectar producing shrubs, bulbs and succulents survived.

2.3.6. The design and planting of nectar producing plant species

Each school had its own design of the garden according to the structure of the school grounds. However, each garden was established and designed to be part of the school. In other words; whereas a garden would normally be established out of the learners' sight to avoid trampling etc., these gardens needed to be right where the leaners played sports, played during class intervals and closer to the

parking areas for everyone to see. The aim was to create a connection between the gardens, teachers and the learners (Dickinson et al., 2010; Lorenz, 2016). Bird pollinated and nectar producing plant species were planted at all identified school grounds in a demarcated area size of 200 m^2 (10 m x 20 m). Compost was used in each hole where plants were planted. To ensure higher survival rate, the depth of each hole was determined by the root structure of each plant. The plants were planted during the wet winter months in April and May 2014 to increase their chances of survival during the winter rains and hopefully reduce unnecessary usage of water through artificial irrigation. According to Geerts et al. (2012), birds are more conspicuous in open vegetation. To increase visibility of birds, large shrubs like *Lycium ferrocisimum* and *Salvia africana-lutea* were planted in the centre and low growing shrubs and geophytes were planted around the edges.

2.3.7. The labour component and training opportunities during the planting process

The planting process involved a huge labour component, which was provided for by the City of Cape Town's Expanded Public Works Programme (EPWP) contractors who were already employed on other City projects. By including them on this project, benefitted them as they received extra skills such as basic gardening tips, landscaping, plant species identification, and understanding of planting seasons. While the contractors were randomly selected, many of them voluntarily advanced their interest to do something different. Moreover, what made the labour critical was because most sites had tenacious *Pennisetum clandestinum* (Kikuyu grass) growing, while others had previously dumped concrete materials, which needed to be removed before any plants could be put in the ground.

2.3.8. Number of plant species planted and the survival rate

A total of 3700 individual plants (about 900 per school) from a list of 23 species from 11 families were planted at the four different high schools (Table 2.2). Species authors, flowering times and distribution ranges were obtained from various authors (Johnson, 1996; Manning et al., 2002; Manning, 2007; Manning and Goldblatt, 2012; Pauw, 1998; Robelo, 1987; Trinder-Smith, 2006; Wester and Claßen-Bockhoff, 2006) (Appendix 2.1). More than >98% of plants species

planted in the school gardens were sourced from local material and were from the Cape Flats Sand Fynbos and the Cape Flats Dune Strandveld vegetation types (Mucina and Rutherford, 2006). All species except for the *Erica (verticillata* and *mammosa), Pelorgonium fulgidum, Leucospermum conocarpodendron* and *Mimetes fimbriifolius* survived.

2.3.9. Total cost of the school gardens establishment process

The true cost of the garden establishments including only the labour component for the preparation and the planting process, landscaping advice (i.e. location of the gardens), the hiring of a five-ton truck and a half-ton light duty vehicle (LDV) with 100 kilometres per day for the transportation of various materials was about R58526.00 (Table 2.3). The table tabulates the basic guideline cost that is necessary when establishing small ecological gardens.

2.3.10. Communication and media coverage

A FaceBook Community Page was created in 2013 to communicate the exciting moments during the project phase. As such, various key moments like when learners participated in the planting process, when the Proteas first flowered during the 2014 bird observation and when birds were seen and counted in 2015 and 2016, were shared. A number of people expressed their interest to be kept abreast with the accomplishments the project would have achieved by liking and even following the page. To date the page has over 385 likes and 383 followers, respectively (Figs. 2.1-2.6). Although the facebook page appears to have reached a wider community within its sphere by having one of its posts been seen by over 780 people in less than three days, it is worth noting that it can be time consuming and requires fulltime attention to manage it.

Considering that this neither is a free FaceBook page, i.e. none of the number of likes nor is the number of people who saw what was being posted onto the page was boosted in any way. These numbers grew organically; as such it was not possible at the time to draw suitable data for proper anaylsis to reflect the demographics of the people engaging the page. Further, no target audience had been set; as the focus at the time was merely keep the public informed of where the project was. Going forward, it may be an excellent idea to set a target

audience in order to monitor the interest created among such community groups, especially school leaners.

With regards to media, the project received much publicity through various media including radio broadcasting by the Classic FM and RSG FM in 2014; publicised on Cape Town's local newspaper (Cape Argus (16 June 2014_p15); it was also published on four magazines i.e. Promerops No. 303_p14, Veld and Flora Vol. 102_p22, The Big Issue (25 July 2014_p7) and City of Cape Town's Contact magazine_61 (July/August 2014_p18). A 19 minute Stepping Stones Video – Through Fragmented Environments available at https://vimeo.com/98544377 highlighting the essence of the project and produced by CareTakers in 2014 was filmed.

2.3.11. Lessons from school gardens establishment

When a study like this is anticipated, the relationship with nurseries must to be established at least two years before planting take place to allow for the propagation of all sensitive and slow growing species. Once the planting is completed, all plants must receive constant deep watering to enhance roots development in the new environment. All schools must be informed when and how to prune the plants to prevent pruning at the wrong time of the year, thus reducing the flowering potential of such plants in the next season. The number of large shrubs must be reduced to low numbers as they tend to take over and prevent other plants from flourishing. To increase water percolation, the school grounds must be carefully tilled once a month. The area with geophytes must be clearly marked to avoid unnecessary watering as this may cause them to die during their dormant period.

2.4. Conclusion

In this chapter we have put together a list of bird pollinated plant species for the Cape Floristic Region (CFR). A species list specifically for the Cape Peninsula highlighting the Cape Flats Sand Fynbos and the Cape Flats Dune Strandveld was also put together. An ecological corridor aiming at restoring a migratory route for sunbirds and sugarbirds connecting the Table Mountain National Park's Muizenberg and Silvermine mountains with the False Bay Nature Reserve's Rondevlei section was established. A study done in Southern Costa Rica found that not only are ecological corridors vital for the restoration of pollination rates, but can reduce pollination failures in plants found trapped in fragmented landscapes (Kormann et al., 2016; Townsend and Levey, 2005).

In support of the findings in the study done in Costa Rica, we have managed to establish an ecological corridor, although it was not without challenges. We found that while the schools had an interest in the project, some gardens did not receive as much attention as in other schools where dedicated groundsmen were available. The lack of this resource meant that weeding was often accompanied with the removal of important planted material due to lack of consisted knowledge of plants species. Perhaps investing in water infrastructure such as boreholes and watertanks may be beneficial to projects like these so that they can continue to be used during water stressed seasons. Cape Town received too little rain since 2014 and this was not great to support plants during their critical stage of development where deep watering was necessary.

Furthermore, the following basic criteria were determined 1) criteria for selecting an ecological corridor; and 2) criteria for the selection of plants, especially where such plants would be at the reach of school leaners. The criteria for plant selection was made simple in order to encourage many schools and/or organisations to plant nectar producing plants that may be easily accessible from local nurseries. We hope that the recommended species list will inspire local plant producers to produce such pants for continued use by local schools and communities at large. The planting process was accomplished and with this, the number of plants planted per school as well as their survival rate was determined.

The indigenous gardens establishment cost was determined as a basic guideline. A communication and media network was also established.

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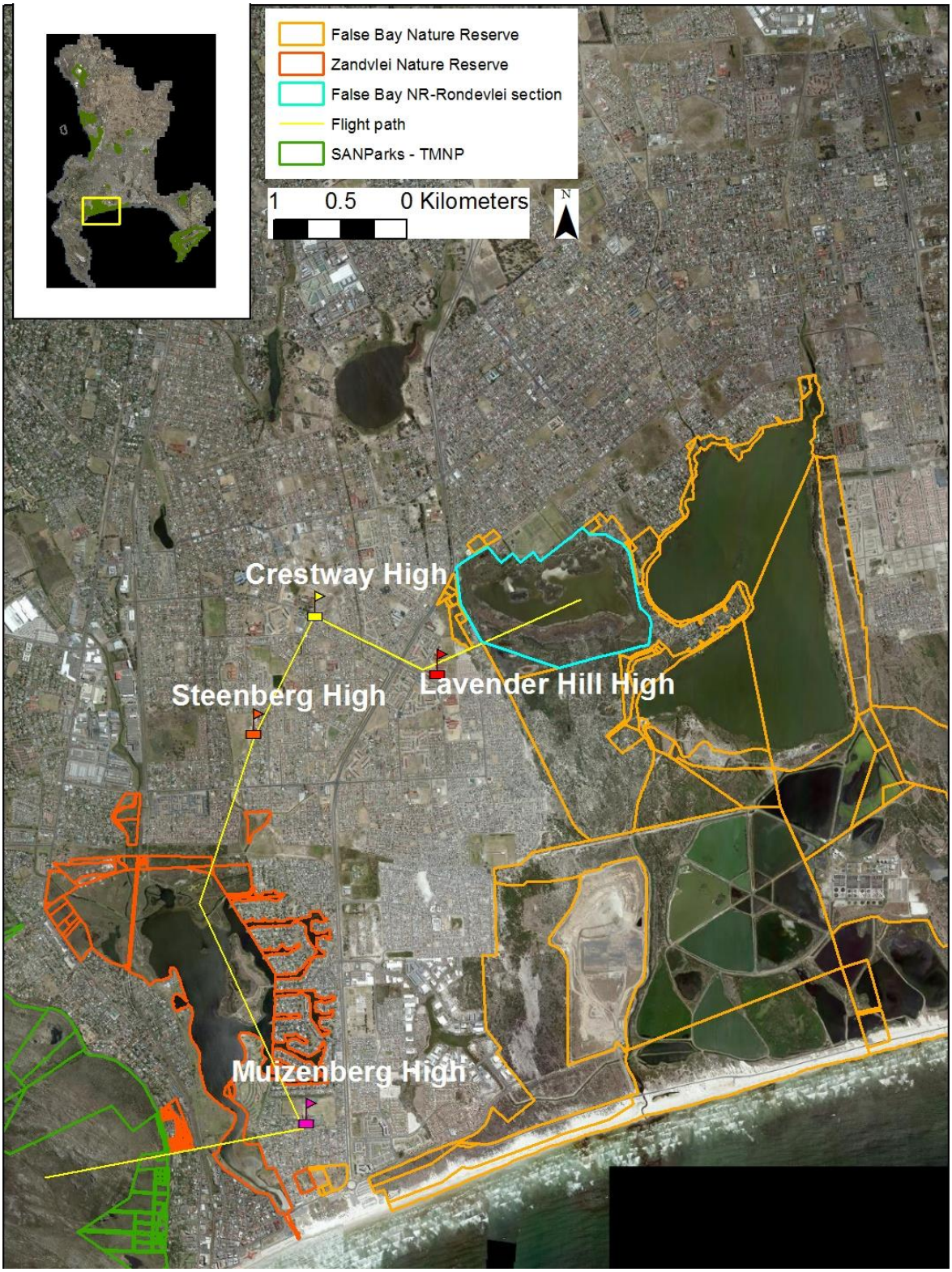
Map



Map 2.1 Study Site showing the established corridor trajectory across a series of stepping-stones (small indigenous gardens planted with nectar producing plants at selected high schools) from Table Mountain National Park (TMNP) to Rondevlei (Andre Rossouw: City of Cape Town). Conservation areas are outlined in colour.

Figures

Fig. 2.1 FaceBook Page created in 2013.

Fig. 2.2 Leaners participating in the planting activity at high schools.

Fig. 2.3 One of the first flowers following the planting activity in 2014.

Fig. 2.4 Plants in their second growth season in 2015.

Fig. 2.5 Southern Double Collared Sunbird observed at the school garden in 2016.

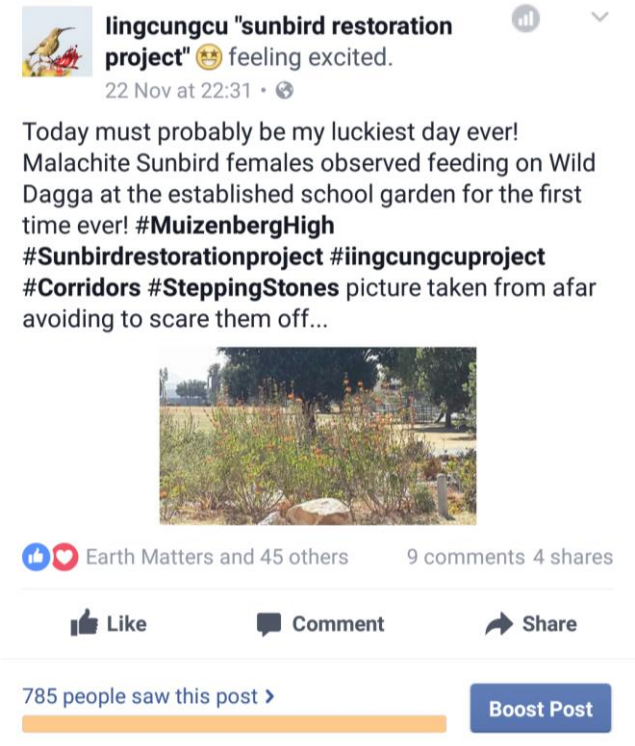


Fig. 2.6 Malachite Sunbirds observed at the school garden drawing so much attention in 2016.

Tables

Table 2.1 A hypothetical flight path of pollinators distancing 8235 metres between stepping stones (Map 2.1).

Distances between stepping stones	
Segment measured	**Distance (m)**
Table Mountain National Park - Muizenberg High School	1424
Muizenberg High School - Zandvlei Estuary	2651
Zandvlei Estuary - Steenberg High School	1184
Steenberg High School - Crestway High School	1050
Crestway High School - Lavender Hill High School	1210
Lavender Hill High School - Rondevlei Nature Reserve	716
Total flight distance: between stepping stones	**8235 (Ave.1372,5)**

Table 2.2 List of 23 species from 11 families were planted at the four different high schools. Species authors, flowering times and distribution ranges were obtained from various authors (Manning, 2007; Manning and Goldblatt, 2012; Manning et al., 2002; Trinder-Smith, 2006).

Family	**Genus**	**Species**	**Author(s)**	**Flowering**
LAMIACEAE	*Leonotis*	*leonurus*	(L.) R.Br.	Nov.-Jul.
	Leonotis	*ocymifolia*	(Burm.f.) Iwarsson	Mar.-May.
	Salvia	*africana-lutea*	L.	Jun.-Dec.
	Salvia	*lanceolata*	Lam.	Sep.-Jun.
ERICACEAE	*Erica*	*verticillata*	P.J.Bergius	Jan.-May.
	Erica	*mammosa*	L.	Nov.-Mar.
GERANIACEAE	*Pelorgonium*	*fulgidum*	(L.) L'Hér.	Jun.-Nov.
PROTEACEAE	*Protea*	*repens*	(L.) L.	Jan.-Dec.
	Protea	*cynaroides*	(L.) L.	Jan.-Dec.
	Protea	*burchellii*	Stapf	Jun.-Aug.

	Leucospermum	*conocarpodendron*	(L.) H.Buek	Aug.-Dec.
	Mimetes	*fimbriifolius*	Salisb. Ex Knight	Jul.-Dec.
IRIDACEAE	*Chasmanthe*	*floribunda*	(Salisb.) N.E.Br.	Jul.-Sep.
	Chasmanthe	*aethiopica*	(L.) N.E.Br.	Apr.-Jul.
	Watsonia	*meriana*	(L.) Mill.	Sep.-Nov.
	Watsonia	*tabularis*	J.W.Mathews & L.Bolus	Nov.-Dec.
CRASSULACEAE	*Cotyledon*	*orbiculata*	L.	Sep.-Dec.
ASPHODELACEAE	*Aloe*	*arborescens*	Mill.	May-Jun.
	Aloe	*commixta*	A.Berger	Aug.-Set.
STILBACEAE	*Halleria*	*lucida*	L.	Jul.-Feb.
SOLANACEAE	*Lycium*	*ferrocissimum*	Miers	Jul.-Nov.
AMARYLLIDACEAE	*Haemanthus*	*coccineus*	L.	Jan.-Apr.
HYACINTHACEAE	*Lachenalia*	*rubida*	Jacq.	Mar.-July.

Table 2.3 Total cost of school gardens establishments at the four selected high schools.

Item	Cost/day or /hour	Quantity	Day(s)/hrs	Cost (R)
Labourer	R85	10	4	3400.00
Landscape Architect	R800	1	1	800.00
Five-ton Truck	R800	1	2	1600.00
Half-ton LDV	R272	1	2	544.00
Code 10 driver	R80/hour	2	32 hours	2560.00
Plant species	Various prices	3700	-	49622.00
			Total cost	**58526.00**

3. Chapter 3: Have nectar-feeding birds returned to restored sites?

3.1. Abstract

Sunbirds and sugarbirds are important pollinators in the Fynbos Biome pollinating over 350 plant species. We test the effectiveness of planting small gardens with nectar-producing plants in restoring plant-pollinator interactions on the Cape Flats. We worked with eight schools including four high schools (planted/experimental) and four primary schools (non-planted/control). Each of the four high schools gardens measuring 10 m X 20 m = 200 m^2 were planted. We conducted bird observations before and after planting. In 2013, before planting birds were sampled during summer; in 2014-2016 sampling was in spring and summer. Surveys were conducted at two spatial scales, gardens and entire grounds. For gardens, two variables were collected for each bird species: the total number of individuals seen (Sum); and the maximum number of individuals seen at one time (Max). For the nectar-feeding *Zosterops virens* (Cape white-eye) we detected significant differences in the number of individuals observed at control and experimental schools both before and after planting of nectar resources, with higher numbers at planted schools. For *Cinnyris chalybeus* (Southern double-collard sunbird) we could not detect a difference in the abundance of birds observed at control and planted schools before planting. This trend remained the same i.e. the results show no significance even after planting although there were higher numbers at planted schools. After planting, *Nectarinia famosa* (Malachite sunbird) were observed in the school gardens, but not at the control schools. Overall, our results suggest that restoring sites and planting them with nectar-producing plants can restore nectar feeding birds and plant-pollinator interactions.

3.2. Introduction

Chapter two focused on the methodological aspects of restoring nectar-feeding birds through planting nectar plants on selected sites from different high schools grounds. This chapter focuses on testing the effectiveness of the methods through bird observations i.e. have nectar-feeding birds returned following the planting of nectar producing plants? The City of Cape Town is in the heart of the Cape Floristic Region (CFR) (Rebelo et al., 2011) where approximately 4% of plants are dependent on birds for pollination (Burkle et al., 2013; Geerts et al., 2012; Geerts and Pauw, 2009a; Kaiser-Bunbury et al., 2009; Kaiser-Bunbury et al., 2010; Rodger et al., 2004). Thus, the loss of birds could severely affect plant communities (Hopwood, 2008).

Despite this challenge, few studies have been done with a specific focus on creating links through open spaces planted with indigenous plants to restore the movement of pollinators into fragmented and small protected areas from large natural habitats (Pauw and Louw, 2012). Consequently, the continued narrow approach to restoration ecology especially plant-pollinator interactions, could lead to permanent losses of biodiversity on a local and global scale (Dixon, 2009; Sargent and Ackerly, 2008; Wilcock and Neiland, 2002). More so because specialist pollinators are often the first causalities when ecosystems become degraded (Dallimer et al., 2012; Dixon, 2009). Some pollinating birds, in particular, are known to be reluctant to cross highly urbanised environments (Neuschulz et al., 2013; Pauw and Louw, 2012). The recognition of plant-pollinator mutualism as a major component of restorative efforts is clearly defined and discussed in Menz et al. (2011). In their study, which concurs with Sargent and Ackerly (2008), they highlight the value of structuring restorative efforts including choosing specific species of plants with the right characteristics when conducting plant-pollinator restoration (Menz et al., 2011).

The *Iingcungcu* study is not attempting to restore specific habitats to pristine state, but to test methods, which may be used when attempting to re-establish broken migratory routes to sites where populations of pollinator guilds used to occur using open spaces at high schools planted with nectar producing plant species of various kinds. This work is similar to the work done by Graham and Page (2012) in

Southeast Asia where they have used artificial bird perching platforms to encourage forest birds to leave the forest with the aim to increase chances of seed dispersal and seedling recruitment into seriously disturbed areas. In their study, they argued that forest birds struggled to move across the landscape, thus reducing the potential for seed dispersal and lowering chances for forests regeneration due to the destruction of forest habitats (Graham and Page, 2012). Similarly, in Leinebergland near Göttingen, Germany, a study found that isolation from natural habitats can severely affect bee species richness and abundance (Steffan-Dewenter and Tscharntke, 1999). In the highly urbanised cities such as the United Kingdom, United States of America (USA), Tucson and Arizona with available open spaces in urban areas than nature reserves, residential yards were planted with native plants and this restored birds (Lerman and Warren, 2011). Other examples include Pennsylvania in the USA where suburban residential yards planted with native plants reported higher abundance of birds compared to gardens planted with exotic plants (Lerman and Warren, 2011). Though not exhaustive, these are some examples of efforts aiming at reconnecting fragmented landscapes.

Accordingly, we can therefore no longer ignore the significance of using artificial methods to connect broken links through the re-establishment of natural links of whatever kind including green ecological corridors of pollinator-friendly plant species (Dixon, 2009; Graham and Page, 2012; Kormann et al., 2016). Thus, the *Iingcungcu* study established small indigenous gardens planted with nectar producing plants at selected high school grounds to establish a migratory route to connect smaller protected areas within the Cape Flats with other protected areas. The emphasis of this study will thus not be placed on full ecosystem restoration in each indigenous garden (Forup and Memmott, 2005) as this would require consideration of various factors like soil condition including organic matter or soil aeration, nutrient level, hydrology and landscape levels (Pouyat et al., 2008). Rather, a set of desired plants suitable for the local soil types and conditions (vegetation types) were planted (Forup and Memmott, 2005; Mucina and Rutherford, 2006).

3.2.1. Aims of the study

I hypothesised that planting nectar producing, bird pollinated plants in small gardens on various high school grounds will restore nectar-feeding birds. To test this hypothesis, I aimed to: confirm the presence of nectar resources for birds in the planted gardens by conducting nectar measurements; measure bird abundance by conducting observations before and after planting; compare bird abundance between high schools (planted) and primary schools (non-planted).

3.3. Methods and materials

3.3.1. Study area

The study was done within the City of Cape Town, in particular the Cape Peninsula. The City is located within the southwest most portion of the Cape Floristic Region (CFR), in the Mediterranean Biome in the Western Cape, South Africa (Holmes et al., 2008; Rebelo et al., 2011; Underwood et al., 2009). The City extends all the way from Silverstream Beach in the northwest to Kogel Bay in the southeast, totalling an area of 2460 km^2 (Rebelo et al., 2011). The Cape Flats Dune Strandveld largely dominates the City's western and southern coastal edges, whereas the Cape Flats Sand Fynbos and Renosterveld cover inlands and low shale-granite hills, respectively (Mucina and Rutherford, 2006; Rebelo et al., 2011). In the centre where the Iingcungcu study took place, lies the Cape Flats Sand Fynbos, which is significantly threatened by growing anthropogenic factors, such as urbanisation which is a major contributor to habitat fragmentation (Anderson and Elmqvist, 2012; Fahrig, 2003; McKinney, 2006; Pauw and Louw, 2012; Rebelo et al., 2011; Stout, 2014).

3.3.2. Participating schools and site selection for the establishment of small school gardens

A corridor from Table Mountain National Park (TMNP) linking the Rondevlei section of the False Bay Nature Reserve was selected. Essentially sugarbirds and sunbirds are known to occur in the mountains of TMNP, whereas the same could not be said for Rondevlei as their numbers are very low and are in certain instances absent. A source (where birds are known to occur) and destination (where birds are meant to go) was established. Eight schools including four high schools (treatment) and four

primary schools (control) with open grounds were selected. Only the high schools were planted with nectar producing plants in small gardens measuring 10 m X 20 m, equalling 200 m^2.

Eight schools including four primary and four high schools were selected based on their proximity from one another and the trajectory from areas where they are known to occur to where their numbers have seen declines over the years. Whereas the primary schools include Levana, Steenberg, Prince George and Muizenberg Junior, high schools include Lavender Hill, Crestway, Steenberg and Muizenberg. To measure the effects our methods, the small indigenous gardens were only planted at all the four high schools and nothing planted at primary schools and as such used as control (Figs. 3.1-3.4). The control (primary schools) needed to have no nectar plant resources planted in order to determine whether planting of such resources can have an effect in sunbirds and sugarbirds returning to restored sites. Further, the gardens were planted as part of the study aimed at involving grade 10 learners who have life science as a subject.

3.3.3. Measuring nectar volume and sugar concentration

To confirm the presence of nectar in the planted gardens, we measured nectar volumes and concentrations in one focal species, *Salvia africana-lutea*, which had successfully established across all gardens. Five different flowers from one plant were measured at each school. Nectar volume was determined using microcapillary tubes with a capacity of up to 5µl and nectar concentration was measured and determined with a refractometer with a 0-50% range (Davis et al., 2015; Geerts and Pauw, 2009; Johnson, 1996; Krömer et al., 2008; Liu et al., 2016; Morrant et al., 2008). Nectar concentration, was measured at midday as nectar concentration is known to increase during this time due various factors including water evaporation from the nectar and/or evaporation elsewhere within the plant (Cruden, 1997; Krömer et al., 2008).

3.3.4. Bird surveys

To test the effect of the gardens on bird abundance, before and after counts were done from both the high schools (planted gardens with nectar resources for birds) and the primary schools (not planted). All birds including nectar-feeding and facultative nectar-feeding birds were counted during the bird observations, which were conducted at a range of ±4 metres from the study area and plots (Geerts et al., 2012). The duration of all counts was 20 minutes of observation conduced in the morning, when the pollinators are known to be most active (Cruden, 1997; Geerts et al., 2012) and new flowers are open (Cruden, 1997). Apart from doing counts within the plots at schools, counts were also done throughout the entire school grounds for 10 minutes duration to determine the kinds of birds found in the area. Similarly to the counts at school gardens, before and after counts were done at Table Mountain National Park (Muizenberg and Silvermine mountains) and False Bay Nature Reserve (western and eastern sections of Rondevlei). Each area had two plots where counts were done from a range of ±4 metres. The duration of all counts was 20 minutes. In the period 2013-2016 counts were conducted once per month at each school for the months of July-December. Since not all school could be visited on the same day, observations spanned over three consecutive days in these month. The before/after bird observations were conducted both at primary and high schools as well as source and destination. The before planting were conducted in 2013 between September and December whereas the after planting bird observations conducted over three years in 2014, 2015 and 2016 between July and December.

Only birds seen and perched anywhere within the study areas and plots were recorded. No birds were recorded by sound only. All bird observations were captured on datasheets (one for schools and for the national park and the nature reserve) (Appendices 3.1 and 3.2 and Table S3.1). In 2013, before planting birds were surveyed during summer; in 2014-2016 sampling was in spring and summer (Table 3.1). Surveys at schools were conducted at two spatial scales, gardens and entire grounds. For gardens, two variables were collected for each bird species: the total number of individuals seen (Sum); and the maximum number of individuals seen at one time (Max).

3.3.5. Statistical analysis

The survey data per bird species are count data with low numbers (0-6) and many zeros. The replication for treatment (Control/Planted) is four schools, with substantial pseudo-replication within schools, i.e. multiple surveys at the same schools (Barry and Welsh, 2002; Guisan et al., 2002; Kuhnert et al., 2005; Martin et al., 2005; Podlich et al., 2002; Welsh et al., 1996). We focus on *Cinnyris chalybeus* (Southern double-collared sunbird) and *Zosterops virens* (Cape white-eye) because these were the only relatively abundant bird species that include nectar as an important component of their diet (Chittenden, 2007).

The two dependent variables (Sum, Max) were highly correlated with Max setting the lower limit for Sum (Figs. S3.1 and S3.2). The two variables convey essentially the same information, so Max (henceforth referred to as “Number of birds”) was chosen as the response variable because it does not include multiple sightings of the same returning individual and thus is more likely to reflect abundance.

Because the survey periods before and after planting do not match (Summer only vs. Spring and Summer) we analysed the before (2013) and after (2014-2016) data separately, with Treatment (control, planted) as the fixed factor in a Generalized Linear Mixed-Effects Model (GLMM, R-function “glmer”, Library “lme4”). To account for pseudo-replication we included School (8 levels) as a random factor (on both intercept and slope). A Poisson error distribution was used. The data for *Cinnyris chalybeus* (Southern double-collared sunbird) was zero inflated relative to a Poisson distribution, hence we fitted zero-inflated Poisson GLMMs, using the package glmmADMB (Barry and Welsh, 2002; Bolker et al., 2009; Finney, 1980; Guisan et al., 2002; Kuhnert et al., 2005; Martin et al., 2005; Nicholls, 1989; Podlich et al., 2002; Welsh et al., 1996; Wood, 2005).

3.4. Results

We were able to confirm the presence of nectar in at least one species, *Salvia africana-lutea* that occurred in all of the gardens (Table 3.2).

For *Cinnyris chalybeus* (Southern double-collared sunbird) there was not a significant difference in the maximum number of birds seen at the control and experimental schools before planting (Fig. 3.5). Although higher values were seen at planted schools after planting, still there was no significant difference before and after planting (Fig. 3.6, Table 3.3). The absolute value of the increase at planted schools is small (Figs. 3.6 and 3.9).

For *Zosterops virens* (Cape white-eyes) there were significant differences in the maximum number of individuals seen at the control and experimental schools both before and after planting (Figs. 3.7, 3.8 and 3.9), with higher numbers at planted schools (Table 3.3).

Malachite sunbirds (two individuals) were observed on one occasion in the final year of the study in one of the well-established gardens. Nectar-feeding birds in general are well represented in the gardens relative to their abundance on the school grounds (Fig. 3.10). Nectar-feeding birds were abundant at False Bay Nature Reserve (Rondevlei) and Table Mountain National Park (Muizenberg), two conservation areas which we hoped to linked via the “stepping stones” provided by the school gardens (Fig. 3.11).

3.5. Discussion

The statistical analysis using GLMMs and zero-inflated GLMMs with Poisson error distributions (Martin et al., 2005) provide support for the idea that nectar feeding birds can be restored using ecological corridors. Although there was no significance (P = 0.608; Table 3.3) in the numbers of the *Cinnyris chalybeus* (Southern double-collared sunbird) before planting in 2013, the 2014-2016 results still show no significant result (P = 0.092; Table 3.3) with higher abundance at the planted gardens. Further, for *Zosterops virens* (Cape white-eyes) there was a pre-existing significant difference (P = 0.006; Table 3.3) in the numbers at control and planted schools, with higher numbers at the schools that were selected for planting, and this difference persisted after planting. The later result highlights the need for conducting thorough “before” surveys during restoration projects.

With these results, we can assume that the diet of *Cinnyris chalybeus* (Southern double-collared sunbird) and *Zosterops virens* (Cape white-eyes) may have contributed to the sharp, but relatively steady increases in the bird numbers. The *Zosterops virens* (Cape white-eyes) are known to include nectar, fruit and insects compared to only nectar and insects preferred by the *Cinnyris chalybeus* (Southern double-collared sunbird) (Chittenden, 2007; Jackson and Nicolson, 1998; Kopij, 2004; Witteveen and Brown, 2014). The results also show distinct differences in bird abundance and species richness between the school gardens where planting took place and the entire school grounds (Figs. 3.10).

This result is similar to the study done in Phoenix, Arizona where it was found that residential yards planted with native plants increased urban birds diversity (Lerman and Warren, 2011). In Aiken, South Carolina, USA where experimental patches and corridors were created to increase pollen flow in fragmented landscape, experimental corridors were reported to have significantly increased butterfly movement and increased pollen flow between source and connected patches (Berggren et al., 2002; Haddad, 1999; Haddad and Tewksbury, 2005; Öckinger and Smith, 2008; Tewksbury et al., 2002; Townsend and Levey, 2005). Our study is one of the few that explored the use of open grounds especially school grounds as stepping-stones to create a connection and links with other protected areas.

Although birds are one of the pollinators that are easily displaced due to habitat fragmentation (González-Varo et al., 2009), our results suggest that plant-pollinator interactions can be restorable and also support the significance of linking such restoration efforts to other protected areas to enhance chances of success (Hadley and Betts, 2012; Brudvig et al., 2015; Schmid et al., 2016). The results also suggest that urban environments play a critical role in connecting remnants of natural ecosystems (White et al., 2005; Graham and Page, 2012; Rouget et al., 2006).

In Cape Town where every remnant of natural ecosystem matters (Rebelo et al., 2011; Anderson and Elmqvist, 2012), the results provide motivation for setting aside connective patterns of green natural spaces to act as green ecological corridors to perpetuate bird migration in urban environments. Green urban spaces are considered essential in maintaining urban biodiversity and ecosystem services as well as good quality of life in many ways (Jasmani et al., 2016). This study contributes to the literature on ecological corridors in urban environments especially focusing on the restoration of plant-pollinator interactions. The results obtained following four years of bird surveys both before and after planting suggest that pollinators can return to restored sites especially when the preferred types of plants are restored (Menz et al., 2011).

3.6. Conclusion

Sunbirds and sugarbirds can return to restored areas especially when planted with nectar-producing plants. Future projects may benefit from planting larger gardens, with a higher density of plants. Although the study managed to attract a few of the bird pollinators, we recommend that the study be done over a long period of time to allow for the plants to fully develop and produce large enough flowers to be able to attract other nectar feeding birds.

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Figures

Fig. 3.1 Flowering *Protea cynaroides* in the first planting season 2014, school gardens. (Photo: Bongani Mnisi).

Fig. 3.2 Planting of various nectar producing plants at school gardens including *Cotyledon, Salvia, Protea* and *Leonotis spp.* (Photo: George Davis).

Fig. 3.3 Watering of school gardens to promote establishment in the first season of planting. (Photo: Bongani Mnisi).

Fig. 3.4 Learners participated in the planting of nectar plants at their respective school gardens. (Photo: Anton Pauw).

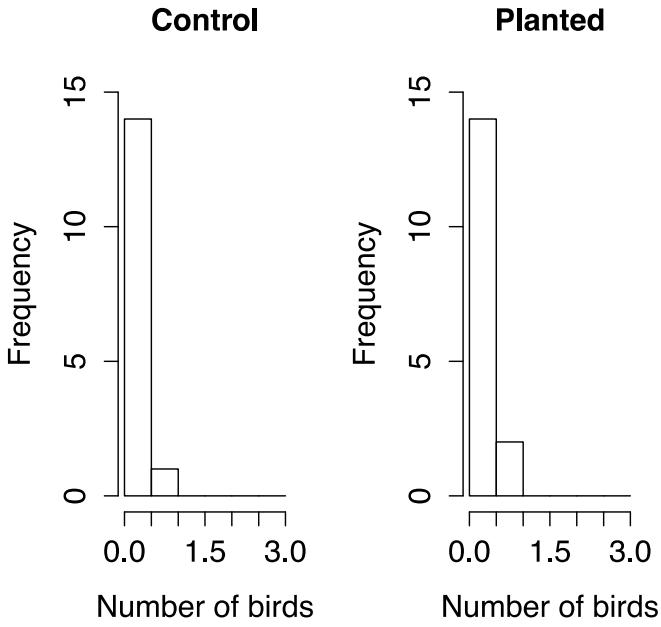

Fig. 3.5 Histograms of the number of *Cinnyris chalybeus* (Southern double-collared sunbirds) seen before planting (year = 2013). Control N = 15; Planted N = 16 observation periods.

Fig. 3.6 Histograms of the number of *Cinnyris chalybeus* (Southern double-collared sunbirds) seen after planting (year = 2014-16). Control N = 72; Planted N = 72 observation periods; *P* = 0.092.

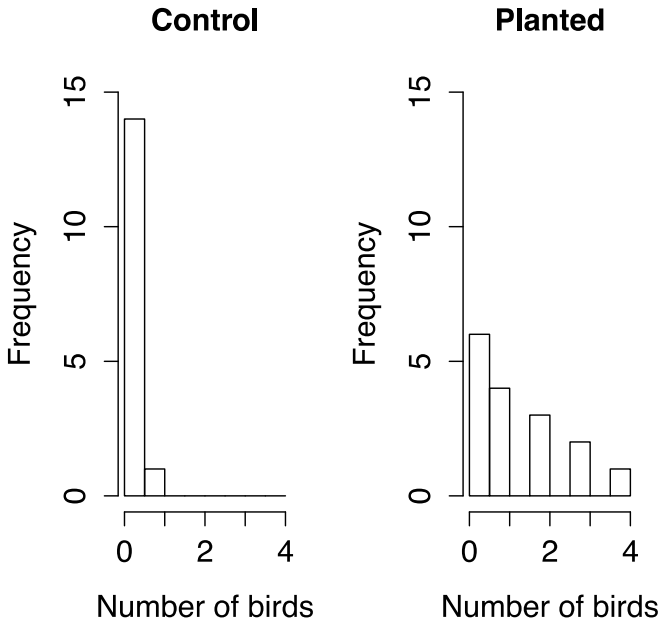

Fig. 3.7 Histograms of the number of *Zosterops virens* (Cape white-eyes) seen before planting (year = 2013). Control N = 15; Planted N = 16 observation periods.

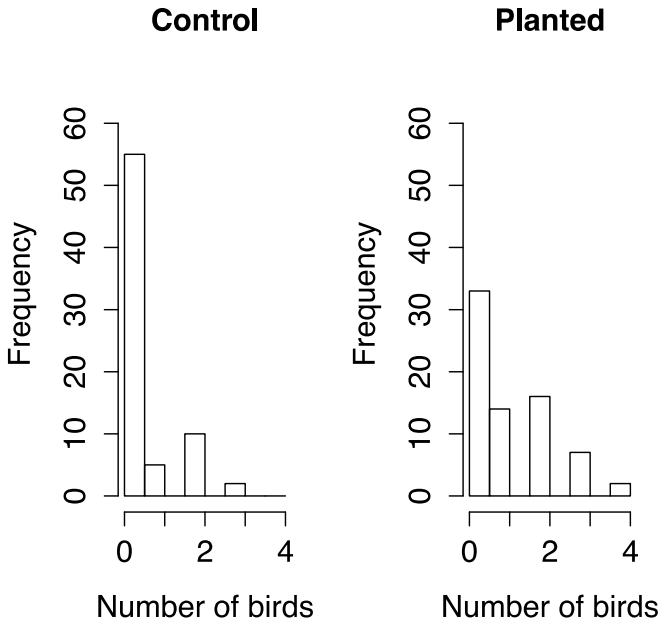

Fig. 3.8 Histograms of the number of *Zosterops virens* (Cape white-eyes) seen after planting (year = 2014-16). Control N = 72; Planted N = 72 observation periods; *P* = 0.006.

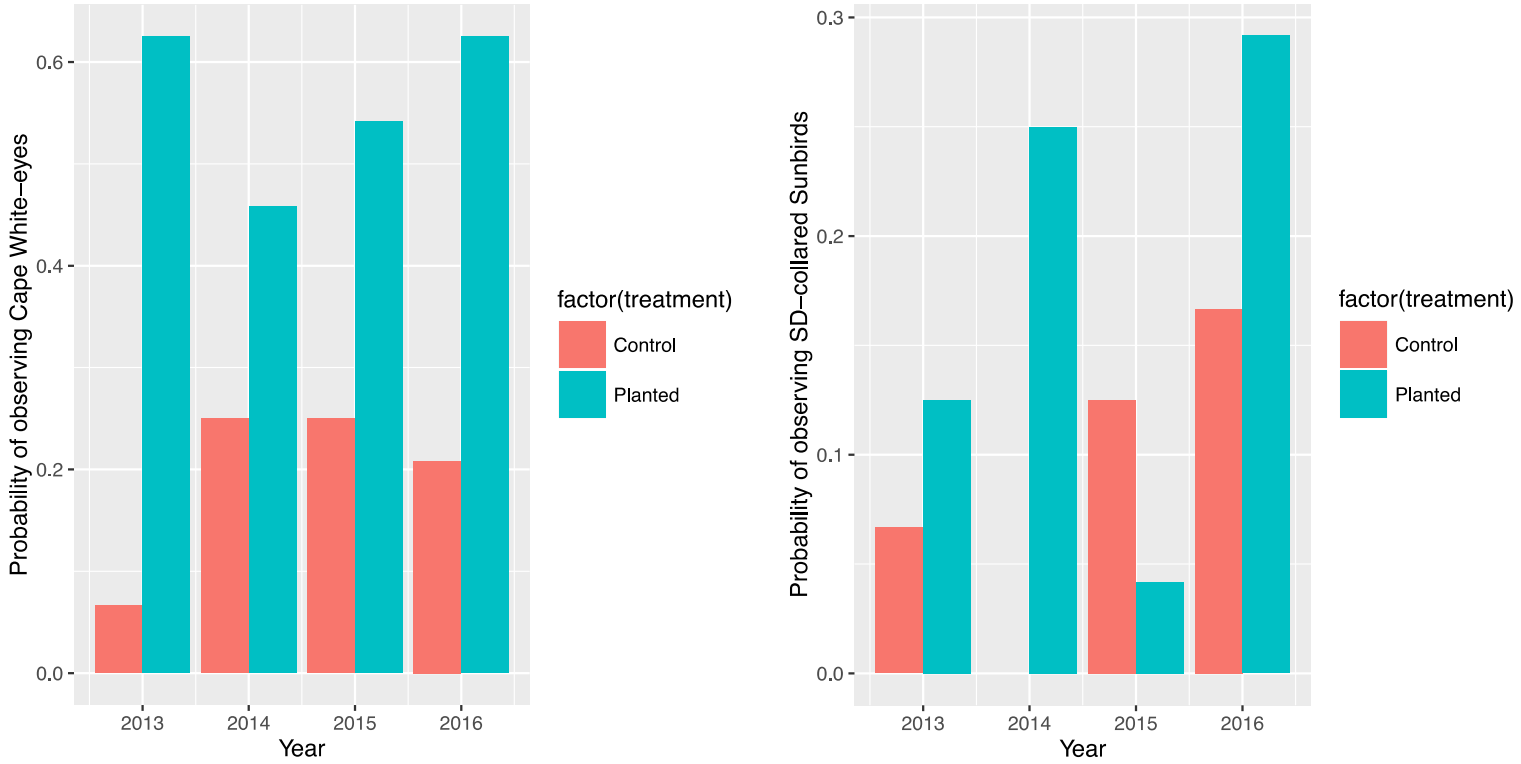

Fig. 3.9 Trends over time in the probability of seeing *Zosterops virens* (Cape white-eyes) (left panel) and *Cinnyris chalybeus* (Southern double-collared sunbird) (right panel) during a 20 minute survey. The number of surveys conducted per year are listed in Table 3.1. The number of individuals observed during the survey is not taken into account, simply whether or not the species was observed. Gardens were planted in 2014.

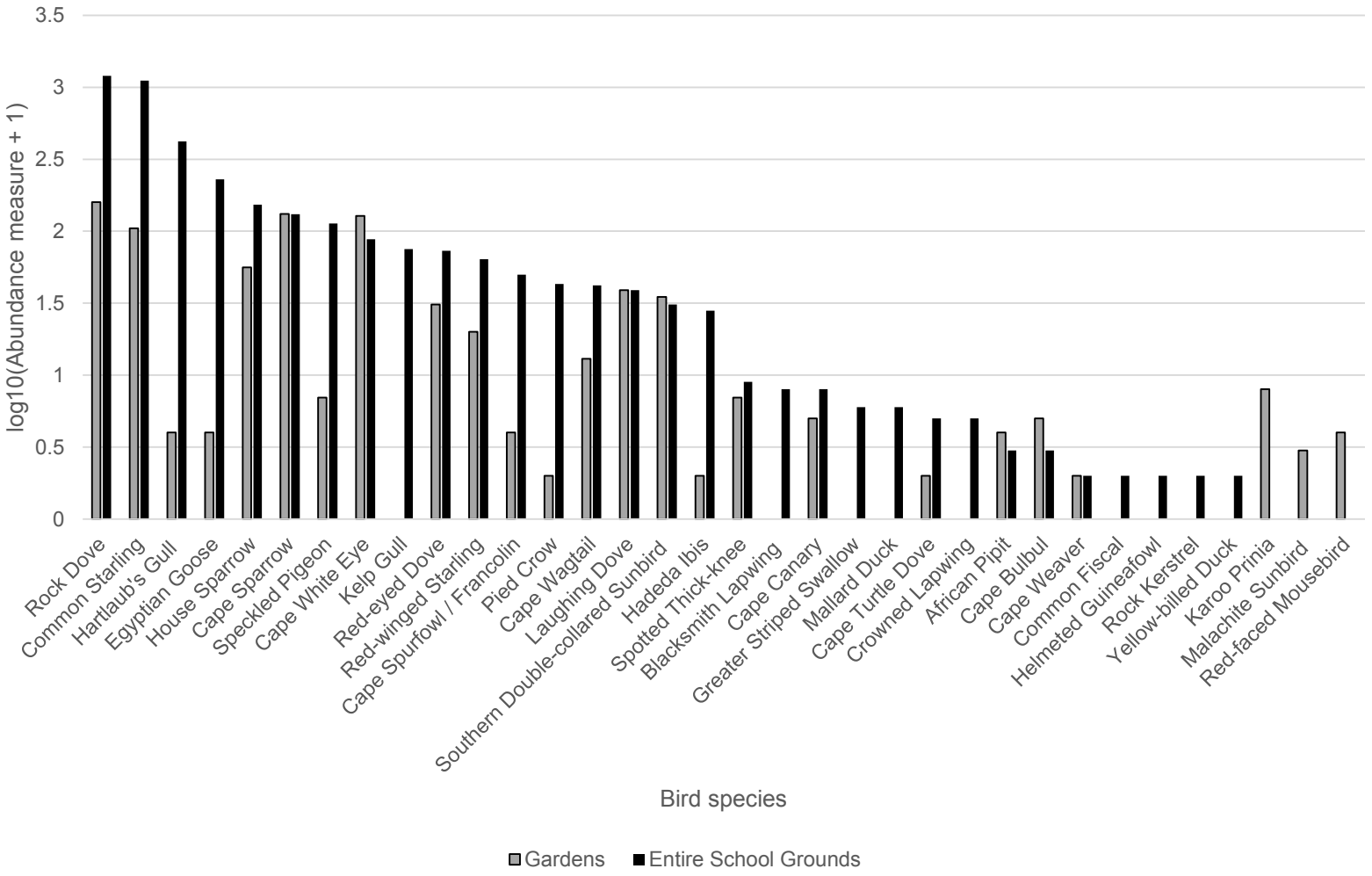

Fig. 3.10 Rank-abundance curves for the bird communities of the entire school grounds and in the planted gardens.

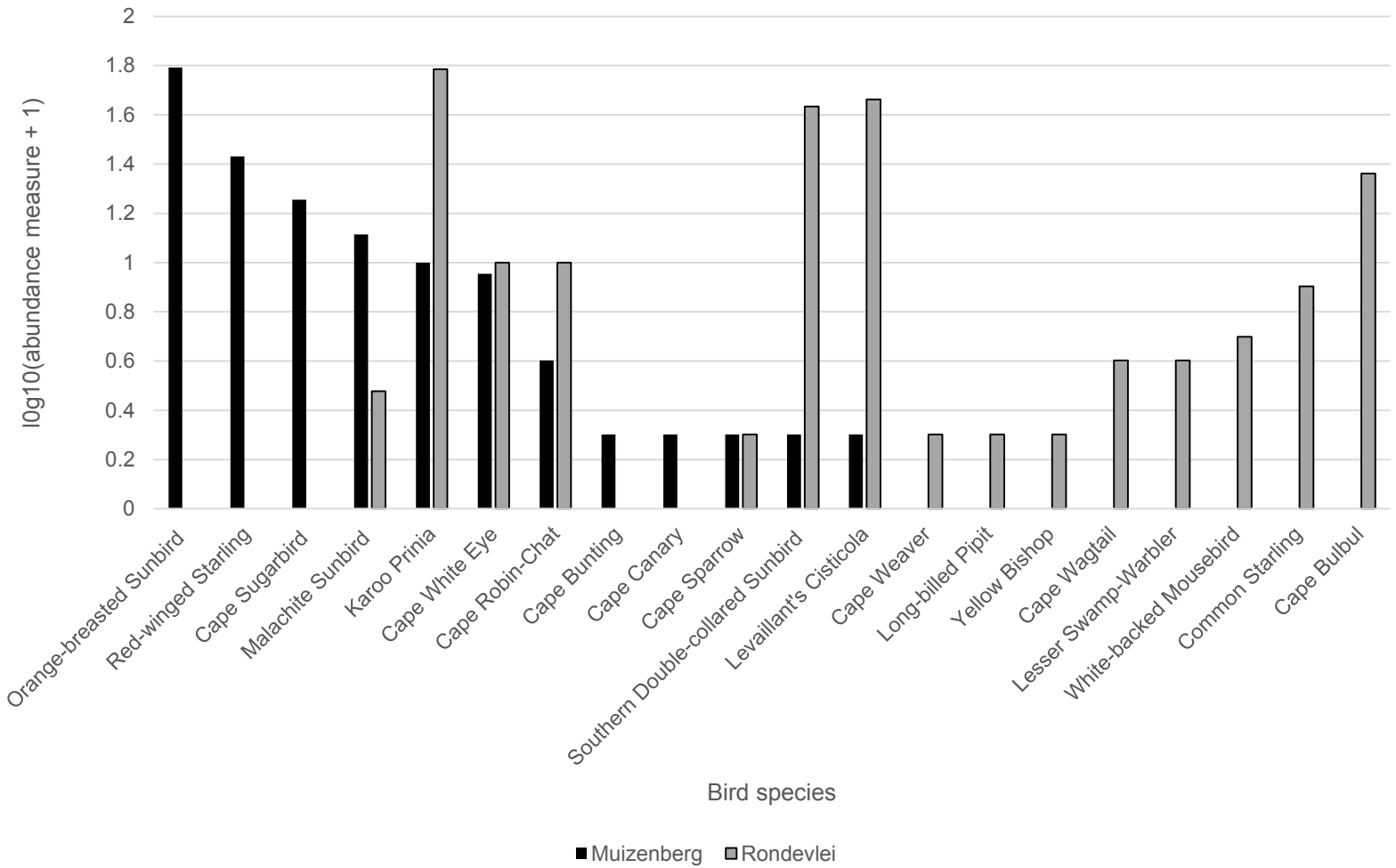

Fig. 3.11 Rank-abundance curves for the bird communities of two natural areas near the schools. Rondevlei is an urban conservation area, and Muizenberg is part of the extensive Table Mountain National Park.

Tables

Table 3.1 Before and after planting bird sampling to determine bird abundance

Before planting (Sept.-Dec.) 2013	After planting (Jul.-Dec.) 2014-2016
2013 (Sept-Dec): 8 schools * 4 months = 32; - 1 missing observation Total = 31	2014 (July-Dec): 8 schools * 6 months = 48 2015 (July-Dec): 8 schools * 6 months = 48 2016 (July-Dec): 8 schools * 6 months = 48 Total = 144
Total: 175 (20 minute surveys)	

Table 3.2 Nectar volume and sugar concentration variation in *Salvia africana-lutea*

Measurement of nectar production and concentration on *Salvia africana-lutea*

School	Plant Species	Ave. Nectar Volume (µl)						Nectar Concentration (%)					
Muizenberg High School	*Salvia africana-lutea*	5	5	5	5	5	**5**	8	8	8	7	9	**8**
Steenberg High School	*Salvia africana-lutea*	5	5	5	4.8	5	**4.96**	10	12	17	13	11	**12.6**
Crestway High School	*Salvia africana-lutea*	5	4	5	5	5	**4.8**	15	11	9	10	12	**11.4**
Lavender Hill High School	*Salvia africana-lutea*	5	5	5	5	5	**5**	13	11	8	10	10	**10.4**
							4,94						**10,6**

Table 3.3 Effect of treatment (control, planted) on the number of birds analysed using separate GLMMs with Poisson error distributions. Underlined variables are in the intercept.

Species	Period	N (surveys)	Variable	Estimate	Std. Error	z value	Pr(>|z|)
Cinnyris chalybeus	Before	31	Treatment Planted	0.629	1.225	0.51	0.608
Cinnyris chalybeus	After	144	Treatment Planted	1.044	0.620	1.69	0.092
Zosterops virens	Before	31	Treatment Planted	2.932	1.057	2.78	0.006
Zosterops virens	After	144	Treatment Planted	0.898	0.402	2.23	0.026

Supplementary figures

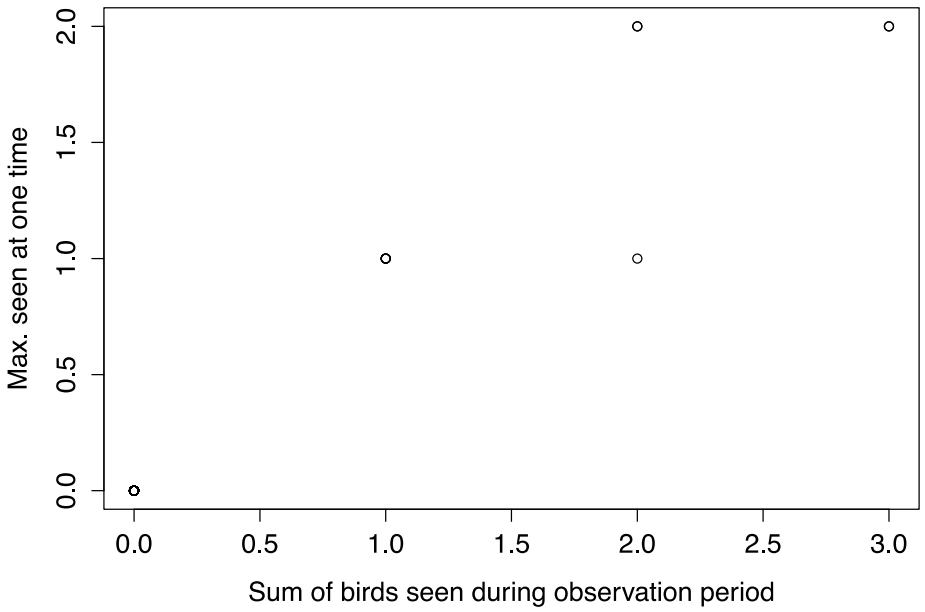

Fig. S3.1 Two dependent variables (Sum, Max) for *Cinnyris chalybeus* (Southern double-collared sunbird) indicating a slight increasing trend over the bird survey period. These variables were highly correlated with Max setting the lower limit for Sum.

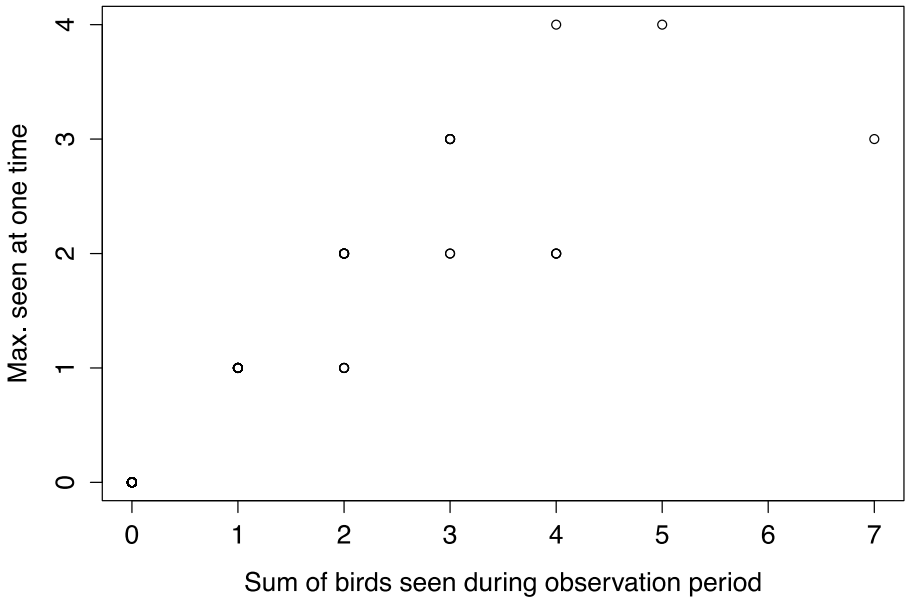

Fig. S3.2 Two dependent variables (Sum, Max) for *Zosterops virens* (Cape white-eye) indicating a persistent increasing trend over the bird survey period. These variables were highly correlated with Max setting the lower limit for Sum.

Supplementary tables

Table S3.1 Summary of bird abundance over four years of bird survey showing an increasing trend in all the selected species for analysis as well as the first record of *Nectarinia famosa* (Malachite sunbird) observed in 2016 bird survey.

	Bird surveys Before-After				
	2013	2014	2015	2016	Grand Total
Zosterops virens (Cape white-eye)					
Control	1	12	9	10	32
Levana Primary	0	0	2	3	5
Muizenberg Primary	0	2	1	0	3
Prince George Primary	1	3	4	3	11
Steenberg Primary	0	7	2	4	13
Planted	20	20	26	29	95
Crestway High	5	3	6	8	22
LavenderHill High	1	2	4	4	11
Muizenberg High	5	1	6	3	15
Steenberg High	9	14	10	14	47
Nectarinia famosa (Malachite sunbird)					
Control	0	0	0	0	0
Levana Primary	0	0	0	0	0
Muizenberg Primary	0	0	0	0	0
Prince George Primary	0	0	0	0	0
Steenberg Primary	0	0	0	0	0
Planted	0	0	0	2	2
Crestway High	0	0	0	0	0
LavenderHill High	0	0	0	0	0
Muizenberg High	0	0	0	2	2
Steenberg High	0	0	0	0	0
Cinnyris chalybeus (Southern double-collared sunbird)					
Control	1	0	3	6	10
Levana Primary	0	0	0	2	2
Muizenberg Primary	0	0	0	0	0
Prince George Primary	1	0	3	4	8
Steenberg Primary	0	0	0	0	0
Planted	2	11	2	9	24
Crestway High	1	2	2	1	6
LavenderHill High	0	6	0	3	9
Muizenberg High	0	2	0	3	5
Steenberg High	1	1	0	2	4
Grand Total	**24**	**43**	**40**	**56**	**163**

4. Chapter 4: Did the study manage to nurture future leaders for biodiversity?

4.1. Abstract

This study is about testing whether involving school learners in biodiversity related projects can inspire a shift in their knowledge of biodiversity, attitudes, awareness and sense of place as well as encouraging them to consider careers in natural sciences and becoming leaders for biodiversity. The results suggest that either time involved in the project or being involved in the project can have significant outcomes, thus supporting our initial assumption.

4.2. Introduction

Chapter two detailed the methodology to determine effectiveness of ecological corridors (stepping-stones) by establishing small gardens at selected high schools planted with nectar producing plants to restore a guild of bird pollinators. Chapter three tested whether the pollinator guilds have returned to restored sites by using a series of bird observations. In this chapter, we worked with grade 10 leaners and teachers from four high schools. The leaners were introduced to the lingcungcu project with an effort to attempt inspiring them to consider natural sciences related studies and hopefully leading to careers in the various fields of natural sciences.

The assumption in the world today is that various experts believe they are doing well in their respective fields i.e. natural and social sciences. For this reason, this chapter will attempt to bring together these two fields in order to promote a space where collaborative approaches become a reality, instead of the one-sided approach, which is often accompanied with some form of criticism. However, has it ever been imagined what kind of environment would the world of the future be without a deliberate and preconceived collaborations between both the natural and social sciences (Alberti et al., 2003; Collins et al., 2000; Moslemi et al., 2009; Molsher and Townsend, 2016)? Ehrlich and Ehrlich (2013) call for such collaborations, even though their focus is more on establishing ways to avoid a global civilisation collapse. Furthermore, if “youth are the future leaders of tomorrow” (Peteru, 2008), how can these collaborative approaches become true to what they stand for if they do not involve the youth (Bennett and Heafner, 2004; Lethoko, 2014; Peteru, 2008)?

Young people are the only hope in shaping the conservation future of the Cape Floristic Region and that of the world (Johnson et al., 2007; Lethoko, 2014). In 2003, the Outcomes-Based Education recognised the importance of introducing natural sciences learning for young people to understand the environmental and global issues (Stevens, 2014; Van der Horst and McDonald, 2003). Despite this call, there seems to be a delayed approach in including environmental education as a critical element of teaching at schools, although it is not without attempts (Bennett and Heafner, 2004). It is also revealed that the delayed implementation of environmental education as a way of teaching is not without trying, but often due to poor training where teachers often do not have enough or appropriate skills (Bennett and Heafner, 2004). With this in mind, projects like Iingcungcu become critical in catalysing the enthusiasm of teachers to see the reality and the value of environmental education (Scott and Oulton, 1998). One of the significant elements of environmental education is that pupils get to learn in the outdoors and experience textbook contents hands-on, something that many of them may nevertheless experience in their lifetime (O'Donoghue and Russo, 2004). While the outdoor learning experience is important, it is reasonable to indicate that it is not the main focus of the study, but rather to involve grade 10 leaners and test the effectiveness of such engagements. As such, the above points are highlighted mainly to give a rational for the study.

Today we face a range of environmental challenges (Cilliers and Siebert, 2012; Ehrlich and Ehrlich, 2013; Hsu, 2004). As such, it is vital that biodiversity and conservation inspire and attract young people. These challenges present a good opportunity for the society to get involved and contribute towards the protection of nature (Collins et al., 2000; Dennis et al., 2016; Marco et al., 2010). Many cities are known to have high abundance of critical habitats and vegetation types (Holmes et al., 2008; Marco et al., 2010; Myers et al., 2000; Sanderson and Huron, 2011), yet because urbanisation and cities are intertwined, the results are nevertheless detrimental to the environment especially where cities' development planning does not take cognizance of the need to plan for the protection of ecological functioning and ecosystem services (Collins et al., 2000; Devoto et al., 2012; Marco et al., 2010).

If anthropogenic factors are ranked highest in the destruction of the natural environment (Aronson et al., 2014; Beumer and Martens, 2015; Cagnolo et al., 2009; Collins et al., 2000; Mammides et al., 2015; Stout, 2014), it is no question why people especially youth should be engaged at a very young age (Dennis et al., 2016; Grange, 2004). Ehrlich and Ehrlich (2013) maintain that the earth's biodiversity needs to take the centre stage for scientific research and for the society through appropriate environmental education (Mitchell et al., 2015; Scott and Oulton, 1998). It is further argued that scientists can no longer fight this fight alone, but the rest of the society must get involved if we are to survive the plight of habitat destruction (Baron et al., 2002; Ehrlich and Ehrlich, 2013; Hsu, 2004; Lethoko, 2014). Moslemi et al. (2009) highlight that skills and expertise to tackle the complexity of contemporary environmental problems is growing and that reliance on graduate training is not filling the gaps, but working together could. If conservation efforts are required to move beyond protected areas into people's daily lives leading to the personalisation of nature and building community support for the conservation and restoration of ecological processes, it should involve them (Doody et al., 2010).

A study done in Abu Dhabi working with high school leaners, concluded that leaners' future studies and job aspirations can be inspired by their subject choices like science taken in high school (Badri et al., 2016). Yueh et al. (2014) did a study in Taiwan using questionnaires to test students' attitudes towards enrolling in agriculture as well as working in agriculture. Various studies found that introducing primary and high school leaners to environmental education activities can inspire a change in attitudes and knowledge in the natural environment and leads to them taking careers along the same lines (Badri et al., 2016; Bradley et al., 1999; Hutchinson et al., 2015; Kloser, 2013; Rahm et al., 2005). Environmental education such like education in general that is aimed at changing human behaviour, need to be properly directed in order to move beyond just awareness, into ownership and empowerment on environmental issues leading towards enthusiastic citizenry (Badri et al., 2016; Spencer, 2007).

The *lingcungcu* project study included practical engagement of pupils from selected high schools focusing on the restoration of the iconic sunbirds and sugarbirds. Leaners were involved in the planting process of bird pollinated plants as part of

school gardens establishment. Awareness was created among the teachers and leaners to bring about an understanding that although there are only four species of obligate nectar feeding birds in the Cape Floristic Region (CFR), they played an important role as pollinators of over 350 plant species (Rebelo, 1987). The study further exposed the leaners to earlier work published in various literature, which revealed that habitat fragmentation, urbanization, road networks, alien plant invasion and honeybee farming activities reduces the abundance of nectar-feeding birds (Aguilar et al., 2006; Aguirre and Dirzo, 2008; Aguirre et al., 2011; Gaertner et al., 2011; Garibaldi et al., 2013; Geerts and Pauw, 2007; Geerts and Pauw, 2009; Geerts and Pauw, 2010; Geerts and Pauw, 2011; Kremen et al., 2002; Mammides et al., 2015; Pauw and Louw, 2012; Ramalho et al., 2014; Tylianakis, 2013; Wardell et al., 1998).

4.2.1. Aims of the study

The aims of the study were to work closely with grade 10 pupils and nurture their interest in biodiversity and natural sciences in order to inspire them into becoming future leaders for biodiversity. I hypothesised that leaners who participated in the Iingcungcu project would respond better to the project based questionnaires than leaners that had little or no interaction. To respond to the hypothesis, we asked the following questions:

- Did their participation in the planting (practical garden interaction), measuring of nectar volume, weeding the garden, completion of worksheets and the viewing of the Stepping-Stones video as part of project interaction enhance the leaners' general knowledge about what the Iingcungcu project is about?
- Is there a significance difference in attitudes to nature between the leaners' responses that participated in the Iingcungcu project, compared to those who did not?
- Did the leaner interaction adjust their awareness about the importance of environmental related activities?
- How did leaners' career choices shift following their participation in the project?
- Comparing the before and after engagement responses, can we assume that the study inspired them towards becoming leaders for biodiversity?

4.3. Methods and study area

4.3.1. Study area

The study was done within the City of Cape Town, in particular the Cape Peninsula. The City is located within the southwest most portion of the Cape Floristic Region (CFR), which is an affiliate of the Mediterranean Biome in the Western Cape, South Africa (Holmes et al., 2008; Rebelo et al., 2011; Underwood et al., 2009). The City extends all the way from Silverstream Beach in the northwest to Kogel Bay in the southeast, totalling an area of 2460 km^2 (Rebelo et al., 2011). The Cape Flats Dune Strandveld largely dominates the City's western and southern coastal edges, whereas the Cape Flats Sand Fynbos and Renosterveld cover inlands and low shale-granite hills (Mucina and Rutherford, 2006; Rebelo et al., 2011). All of these vegetation types are significantly threatened by growing anthropogenic factors (Fahrig, 2003; McKinney, 2006; Pauw and Louw, 2012; Rebelo et al., 2011; Stout,

2014). The high school leaners that participated in the study came from various areas including, but not limited to Lavender-Hill, Steenberg, Muizenberg, Retreat, Seawinds and Vrygrond. Some of the communities here live below the poverty line and are exposed to various kinds of perils including early school dropout, drug abuse, gangsterism and early pregnancies (Bickford-Smith, 2009; Treasury, 2011; Wegner et al., 2008; Ziervogel et al., 1997).

4.3.2. Permission and research ethics clearance

Following the permissions granted to conduct research by the various school heads from all the participating high schools and the Western Cape Education Department, ethical clearance was also submitted and approved by the Stellenbosch University's Research Ethics Committee (Appendix 4.1 and 4.2). The ethics approval was necessary in order to ensure that the rights and dignity of all participants would be secured (Tauginienė, 2016; Horn, 2016). In addition, the respondents could indicate on the questionnaire whether they agreed to the use of the data that they provided.

4.3.3. Leaner engagement approach

We decided to work with grade 10 leaners as their teaching program includes chapters covering critical issues on biospheres, ecosystems, biodiversity and humans in their curriculum (Van der Horst and McDonald, 2003). As such, all school heads and teachers from the different schools easily accepted the study, as it did not bring with it anything that deviated from the schools' curriculum, but was complimentary. The study was easily integrated into the grade 10 leaners' lessons. The four high schools that participated in the study include Lavender-Hill ($18^0$29'21.664" -$34^0$4'4.019"), Crestway ($18^0$28'42.350" -$34^0$3'47.380"), Steenberg ($18^0$28'40.604" -$34^0$4'18.621") and Muizenberg ($18^0$28'40.682" -$34^0$5'51.425") that were strategically identified and selected within the Cape Flats.

Two grade 10 classes from each school were selected with the assistance from the grade 10 teachers. One randomly allocated class was involved as a Control Class (CC), whereas the other was involved as an Experimental Class (EC). The leaners were required to complete a questionnaire designed to test and measure different variables, which included knowledge, attitudes, and sense of attachment, career

choice and leadership (Appendix 4.4). The two grade 10 classes from each school consisted of leaners that had Life Sciences as a subject.

Leaners were required to complete a questionnaire before and after they were formally involved in the project. The leaners were involved in practical planting of bird pollinated plants at their respective schools gardens (Figs. 4.1-4.4), they completed worksheets (Appendix 4.3), they watched the Stepping Stones Video (Through Fragmented Environments https://vimeo.com/98544377) and used microcapillary tubes and refractometer to measure nectar volume and sugar concentration found in nectar producing plants growing at their school gardens (Fig. 4.5).

4.3.4. Questionnaires analysis

The questionnaire had 25 questions. Questions 1 and 2 asked Sex and Age; 3 a general question on whether they had a bird friendly garden or not; 24 whether their answers should be used for the research or not and 25 asking their respective Grades (10A-F etc.). This left 20 questions available for analysis (Table 4.1). The responses to the questions included multiple choice (list of either 2 or 5 possible answers), yes/no, Likert scale 1-7 (1 strongly disagree and 7 strongly agree) and were also required to list up to 4 possible answers. Most of these responses were converted to either yes/no or correct/incorrect for statistical analysis. Wherein a question would have expected a leaner to respond using Likert scale 1-7 response variables, the values 1-3 would be categorised (incorrect), whereas values 4-7 would be categorised (correct). These would be further simplified by using (1 = incorrect) and (2 = correct). Similary to the response variables yes/no where (1 = yes) and (2 = no).

4.3.5. Statistical analysis

We conducted multivariate analyses in the response to several questions, simultaneously (Baggaley, 1981; Conley, 1973). We grouped questions in the following sets: knowledge, attitude, awareness and leadership and analysed each group separately. Only the one question testing career choice preference was individually analysed. Thus we asked whether experimental and control groups differed in their overall response to these questions before and after the project. Similarity among learners' responses was calculated with Bray-Curtis Similarity and visualised as a nonmetric multidimensional (NMDS) scaling plot (R package, Vegan; function, metaMDS). We tested for a significant effect of treatment (control/experimental) and period (before/after) as well as their interaction using a permutational multivariate analysis of variance (R package, Vegan; function, adonis). Randomisation was restricted within schools, i.e. students were "swapped" among experimental and control groups only within the same school.

In addition to multivariate analyses, univariate analyses were conducted on individual questions that best represent each set of questions: knowledge, attitude, awareness, leadership career choice were conducted. Similarly to the multivariate analyses, we asked whether experimental and control groups differed in their overall response to these questions before and after the project. We compared the treatment and control groups with a Binomial Generalized Linear Mixed-Effects Model with a logit link function for correct/incorrect or yes/no answers and with a Poisson Generalized Linear Mixed-Effects Model with a log link function for the Likert scale 1-7 and ranges 0-5 responses. "School" was included as a random factor in these analyses (R-package, lme4; function, glmer).

4.4. Results

Four hundred questionnaires were received with only 69 (17.25%) learners electing for their responses not to be used. In the multivariate analyses the set of questions that tested knowledge was the only set that showed significant effects. Here treatment and period, as well as interaction with learners were significant factors (Table 4.2). The NMDS plot shows that the experimental learner group in the period after the interaction is differentiated from all other groups of learners, especially because of their response to question 14 (Fig. 4.6). The sets of questions that tested attitude, awareness and leadership showed no significant effects (Tables 4.3-4.5). The NMDS plots show that the experimental learner group in the period after the interaction is not clearly differentiated from all other groups of learners (Figs. 4.7-4.9).

From the 20 questions analysed, we present five, one from each set of questions that tested knowledge, attitude, awareness, leadership and career choice that best represent the grouped questions. We selected question 14 (knowledge), 17 (attitude), 5 (awareness), 8 (leadership) and 20 for (career choice). The questions that tested knowledge and leadership showed significant interaction effects. The experimental class (EC) did significantly better in question 14 (knowledge type question) after the learner interaction, with no changes in the control class (CC) (Fig. 4.10). Treatment, but not period, and the interaction between treatment and period were significant factors (Table 4.6). Learners from the EC did talk significantly more about the Iingcungcu project (Table 4.7; Fig. 4.11). Both EC and CC learners were able to name significantly more schools (that are part of the Iingcungcu project) after the learner interaction (Fig. 4.12), but the interaction between treatment and period was not significant (Table 4.8). There was no significant effect of the learner interaction on the career choice of learners (Table 4.9; Fig. 4.13) or on learner attitude towards littering (Table 4.10; Fig. 4.14).

4.5. Discussion

School gardening projects in the United Sates, after school and community projects in Canada and outdoor activities in the United States have similarly been used to inspire youth and transform their attitudes towards nature (Blair, 2009; Draper and Freedman, 2010; Ernst and Theimer, 2011; Rahm et al., 2005). Other findings in the study done in Abu Dhabi, though not entirely the same as in the *Iingcungcu* study, found that attitudes of learners who attended a science class had an increased inclination towards science (Badri et al., 2016). While it is clear that the methods and focus of the study done in Abu Dhabi, differ from ours, we draw inspiration that learners can have a positive shift in attitude and even have an inclination towards a new subject when encouradged towards it. Interestingly, the study also highlights that it is not enough to simply make the subjects attractive, but there needs to be concrete and measurable objectives for what is intended in order for the transformation to be seen (Badri et al., 2016).

The multivariate and univariate analysis conducted in this study enable us to test and measure the effectiveness of the project interactions on the various sets of grouped questions. When we tested each set of the grouped questions we showed that the time factor (before and after) as well as the interaction (treatment) had significant effects especially in one of the knowledge questions. The result showed significant effects for interaction on one of grouped questions testing attitude, which suggest that learners' attitudes who engage in environmental education programmes are more likely to change.

Though with other grouped questions the results showed no significance for treatment, improvement in the experimental group of learners was reported especially for improved inclination towards studying natural sciences, improved awareness and potential leadership over time. Lorenz (2016) reports on the role of Citizen Science in improving knowledge and sense of place among youth especially those involved in various environmental programmes. The results suggest that the value of environmental education in schools as part of the curriculum and society can have positive effects in many aspects including knowledge, change in attitudes towards and awareness nature and can inspire responsible leadership (Bennett and Heafner, 2004; Bradley et al., 1999; Grange, 2004; Hutchinson et al., 2015; Hsu, 2004; Kloser, 2013; Mitchell et al., 2015; Moslemi et al., 2009; O'Donoghue and

Russo, 2004; Scott and Oulton, 1998; Stevens, 2014; Tal and Morag, 2013; Toomey and Domroese, 2013; Yueh et al., 2014).

The learning here is that while significant and no significant results were seen following the engagement with learners, it is important to appreaciate that some shift might have occurred in the learners considering that most of them got to experience planting of indigenous gardens for the very first time in their lives. We hope that their participation in the study will continue to have a long lasting impact in their studies and their connections with biodiversity.

4.6. Conclusion

Although there appears to be many studies done in this subject, not many of them focus entirely on determining the various aspects i.e. knowledge, attitude, awareness, career and leadership as covered in our study. However, we observed the main thread being environmental education, which suggest the continuous need to explore the subject even further. Some literature also refers to the linkages with the school curriculum to improve learning abilities and building interest in specific subjects like science and mathematics, as such we see this as a worthy avenue for further exploration.

The study's limitations were that it was limited to the same school where it became difficult to have clear results. For example, though we worked with one class and compared it to another class within the same school, the teacher was nevertheless the same and both groups were invariably exposed to the garden on their school grounds with the result that both the experiment and the control group showed an increasing trend over time in their answers to questions, i.e. there was not a significant interaction between period (before/after) and treatment (control/experiment), but only a significant effect of period as both groups (control and experiment) increased in their knowledge and awareness over time. While this wider-than-expected effect of the project is pleasing, we do recommend that should similar studies be attempted elsewhere, the control group should at least be from a different school, despite the added variance that this will introduce.

4.7. Acknowledgments

I thank the Western Cape Education Department and the following high schools Muizenberg, Crestway, Steenberg and Lavender-Hill high schools for allowing me to conduct my research. I thank Elzette Klue and Andiswa Ngcai from City of Cape Town for assisting with learner interaction. I'm also very grateful for the support and guidance I've received from Prof. Anton Pauw and Dr Sjirk Geerts without whom this study would have been very difficult to successfully complete.

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Figures

Fig. 4.1 Planting of nectar plants at Lavender-Hill High School (Photo: Anton Pauw).

Fig. 4.2 Planting of nectar plants at Steenberg High School (Photo: Anton. Pauw).

Fig. 4.3 Leaners participating testing of nectar and completing worksheets (Photo: Bongani Mnisi).

Fig. 4.4 Learners involved in weeding their own school garden (Photo: Anton Pauw).

Fig. 4.5 Learners measuring nectar using micro-capillaries at their own school garden (Photo: Andiswa Ngcai).

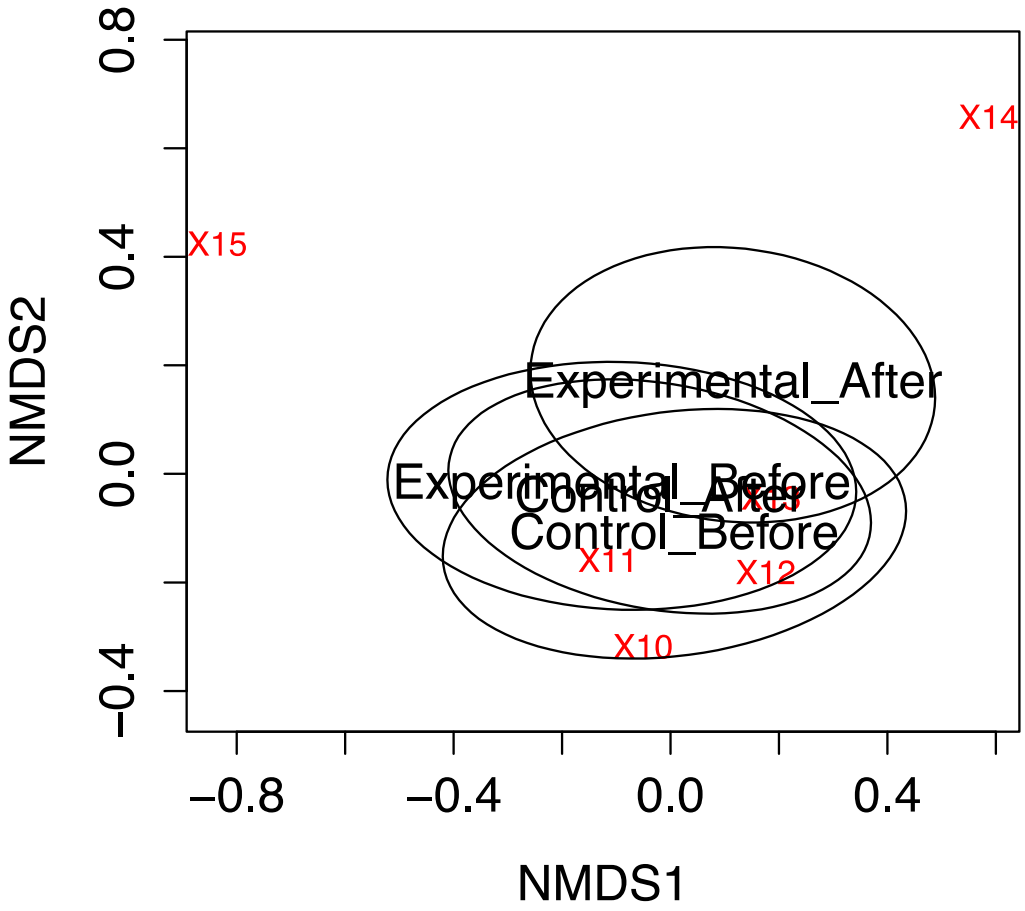

Fig. 4.6 Nonmetric multidimensional scaling analysis of the six questions that reflect knowledge of the interaction between plants and birds and their conservation.

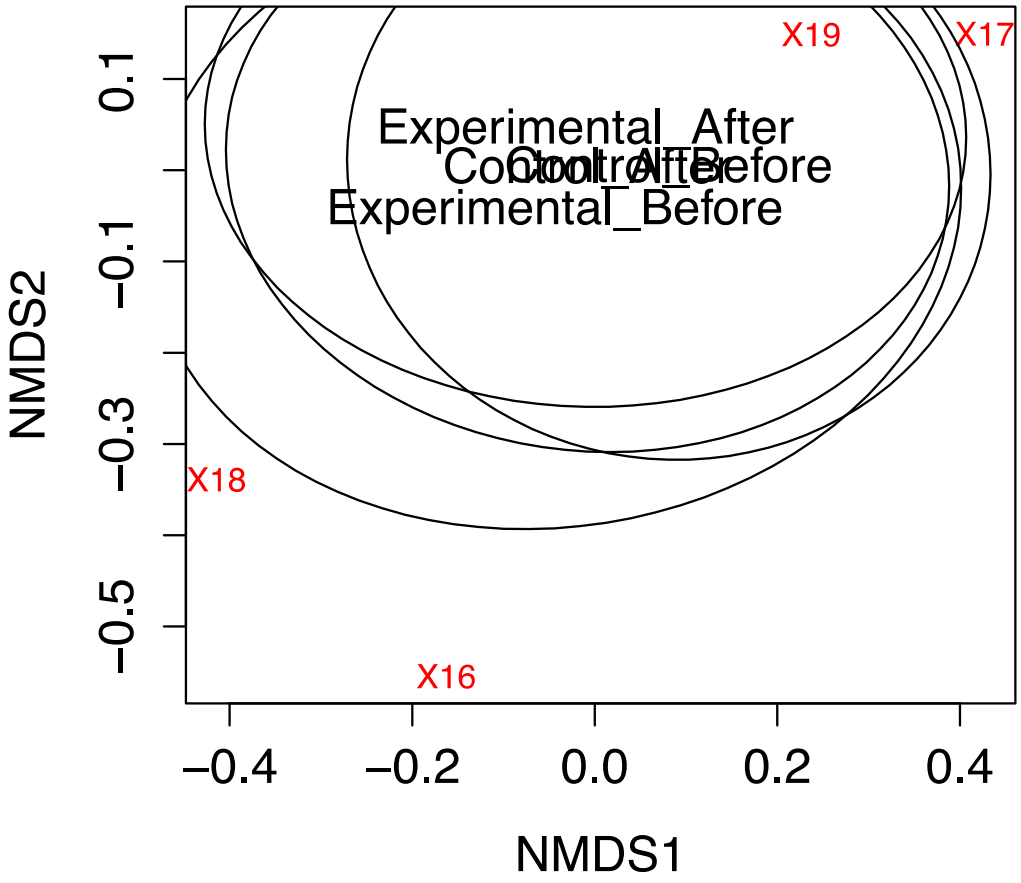

Fig. 4.7 Nonmetric multidimensional scaling analysis of the four questions that reflect attitude towards issues relating to the protection of nature, littering and vandalism in their environment.

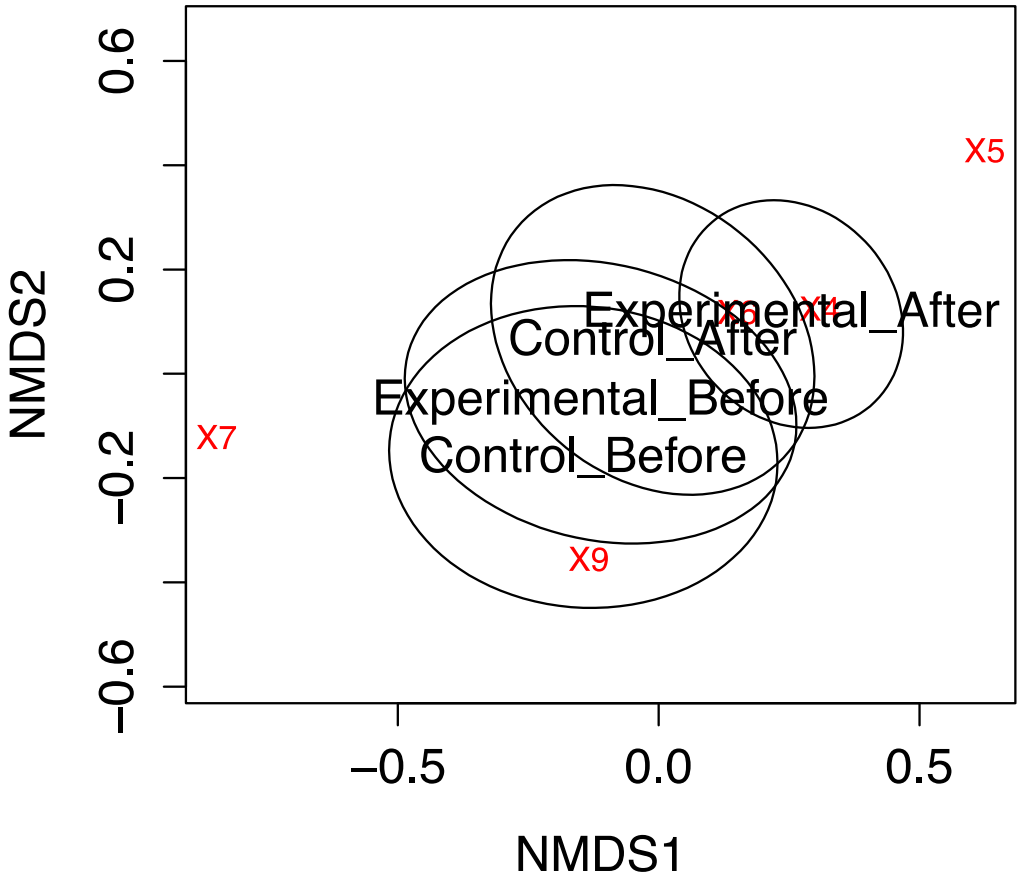

Fig. 4.8 Nonmetric multidimensional scaling analysis of the five questions that reflect their awareness of the lingcungcu project.

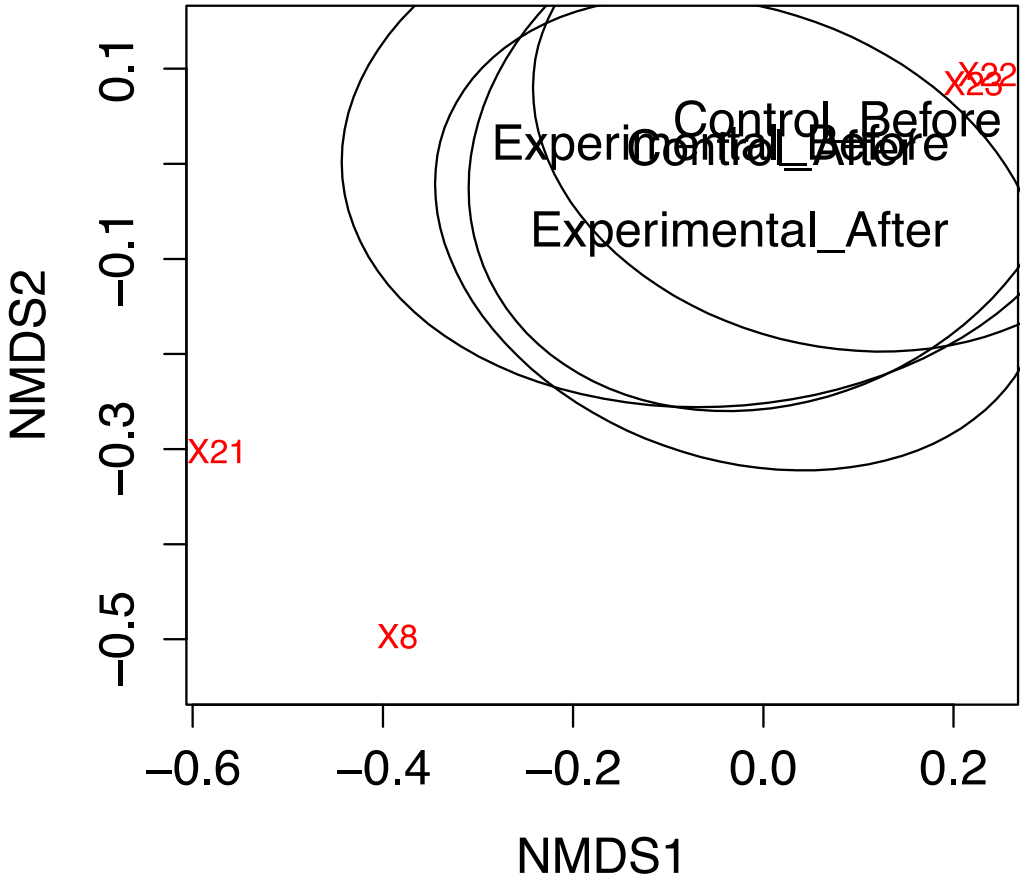

Fig. 4.9 Nonmetric multidimensional scaling analysis of the four questions that reflect leadership of the interaction between family, friends and participation in various projects.

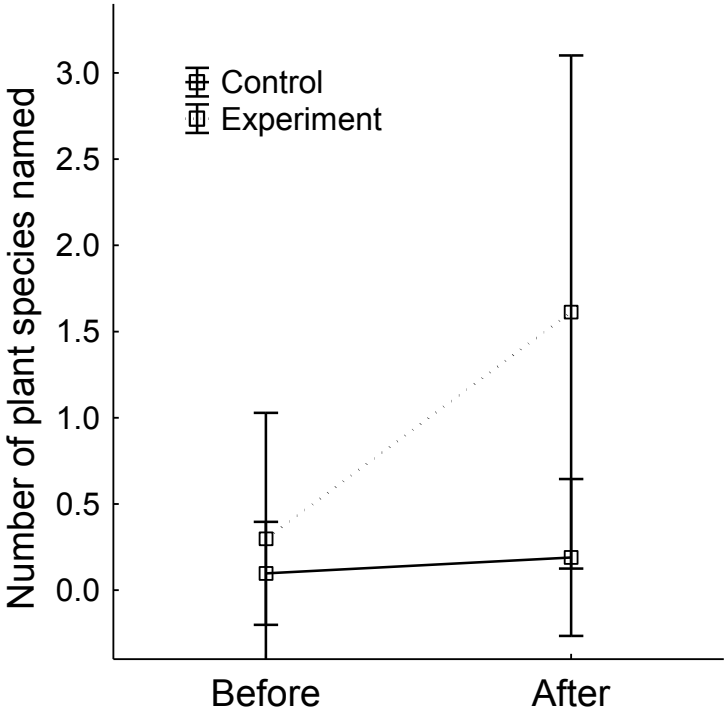

Fig. 4.10 Learners in the experimental classes could name significantly more plants after than before the learner interaction. There was no significant difference in the control classes. Error bars depict SD of means.

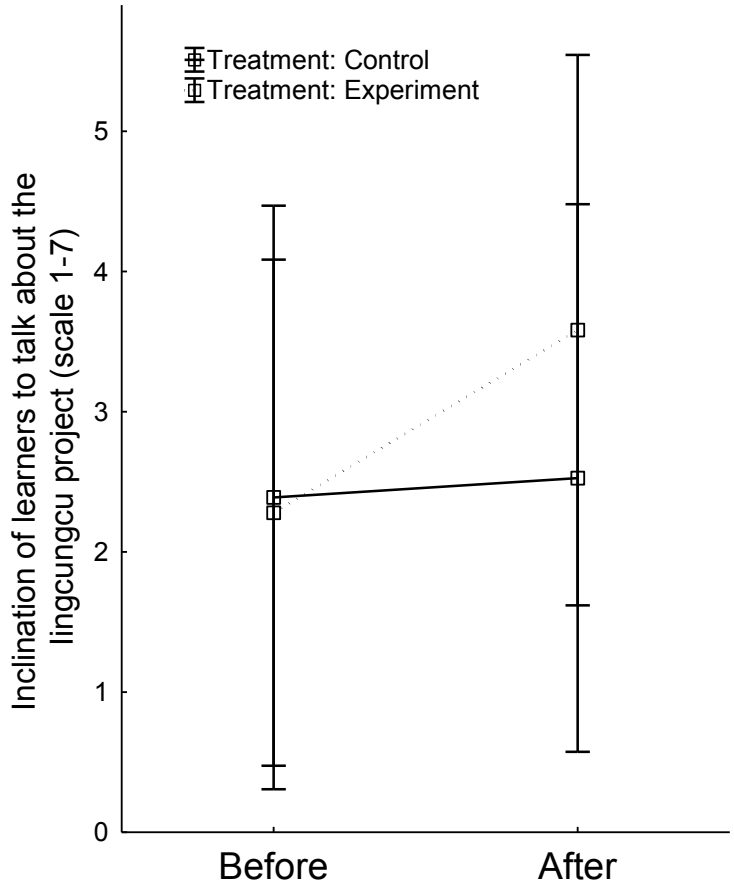

Fig. 4.11 Inclination of learners to talk about the lingcungcu project was significantly higher after the learner interaction with a significant interaction between period (before/after) and treatment (experiment/control). Error bars depict SD of means.

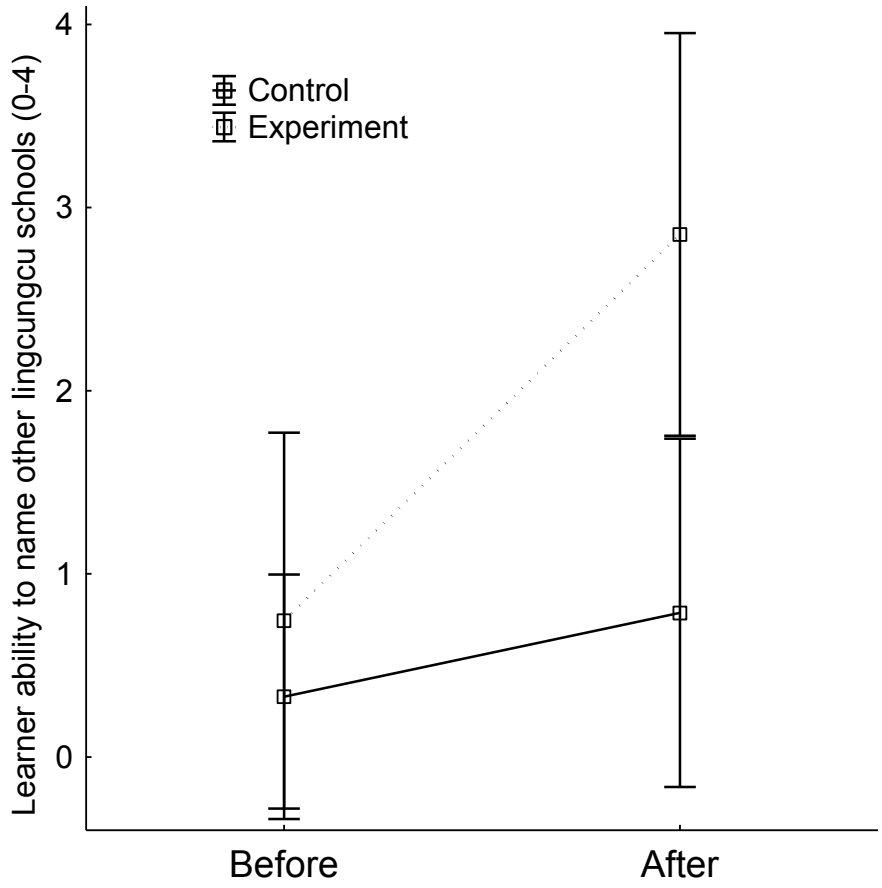

Fig. 4.12 The ability of learners to name the other schools that are part of the lingcungcu project. Error bars depict SD of means.

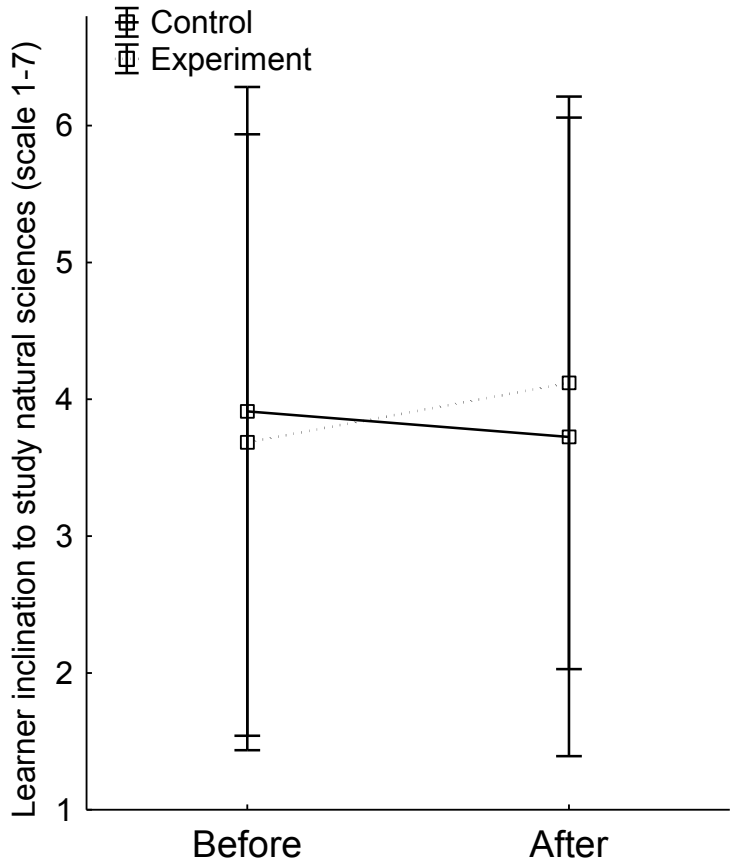

Fig. 4.13 Learners in the experimental classes were not more inclined to select natural sciences as a potential career after the learner interaction or in comparison with the control classes. Error bars depict SD of means.

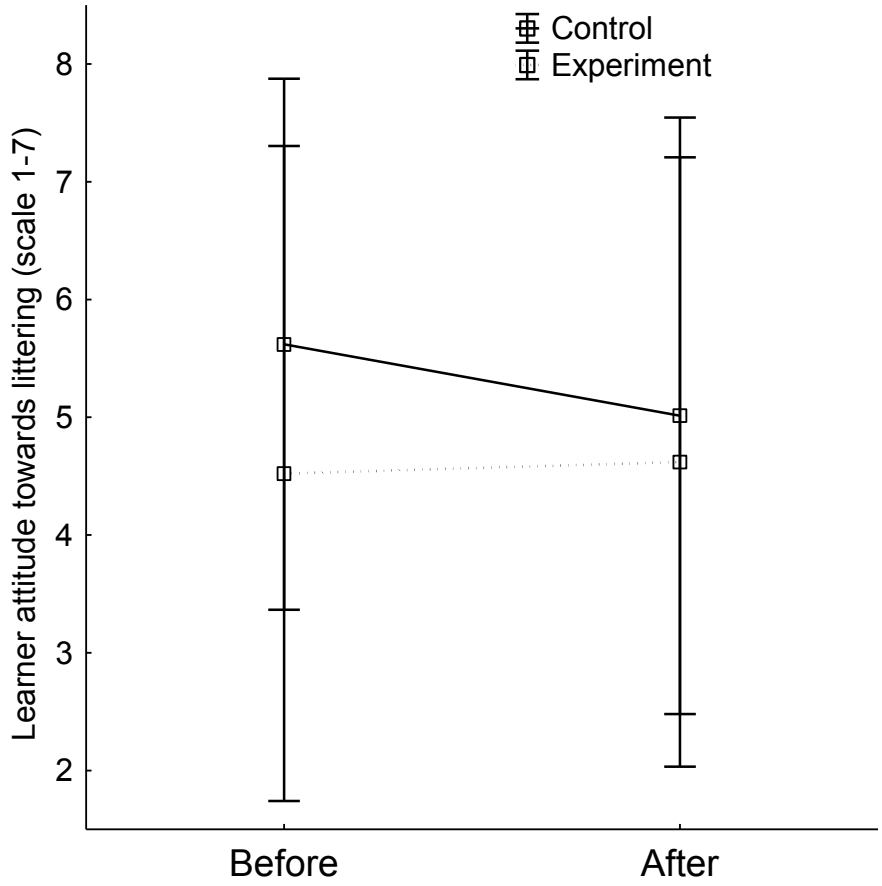

Fig. 4.14 There was no significant effect of the learner interaction on learners' attitude towards littering. Error bars depict SD of means.

Tables

Table 4.1 Sets of questions used in the survey to test whether experimental and control groups differed in their overall response before and after treatment.

Knowledge (10, 11, 12, 13, 14 and 15)	
Question 10	What season is the right time to plant a bird friendly garden?
Question 11	What does a Sunbird Sugarbird feed on?
Question 12	Which kind of flowers in your opinion attracts sugarbirds and sunbirds?
Question 13	Planting more nectar rich plants in my garden can attract more birds.
Question 14	Using common or scientific names; name as many plants currently growing in your school garden.
Question 15	Pigeons are good pollinators.
Attitude (16, 17, 18 and 19)	
Question 16	Protecting nature is not cool.
Question 17	Littering at my school is not cool.
Question 18	People make too much of a big deal of littering in my opinion.
Question 19	Vandalizing my school garden is not cool.
Career choice (20)	
Question 20	I would like to study natural sciences, nature conservation or horticulture after leaving high school.
Awareness and sense of place (4, 5, 6, 7 and 9)	
Question 4	Are you aware of the *IINGCUNGCU* PROJECT running at your school?
Question 5	Name other schools, which are part of the *IINGCUNGCU* PROJECT.
Question 6	Does your school encourage leaners to plant a bird friendly garden at home?
Question 7	Do you have a bird friendly garden at home?
Question 9	I take notice of birds around me.
Leadership (8, 21, 22 and 23)	
Question 8	I talk to my family and friends about the *IINGCUNGCU* PROJECT.
Question 21	I participate in community clean-up projects after school.
Question 22	Involvement in group projects encourages me to take on responsibility.
Question 23	Being involved in natural sciences projects makes me feel good about myself.

Table 4.2 Results of the permutational multivariate analysis of variance of the effect of treatment and period, as well as their interaction, on learners' knowledge regarding birds, plants and their conservation.

	Df	SumsOfSqs	MeanSqs	F.Model	R2	Pr(>F)
Treatment	1	0.3688	0.36883	5.3517	0.02144	0.004
Period	1	0.3959	0.39587	5.7441	0.02301	0.004
Treatment*period	1	0.3837	0.38371	5.5676	0.02230	0.002
Residuals	233	16.0580	0.06892		0.93326	

Table 4.3 Results of the permutational multivariate analysis of variance of the effect of treatment and period, as well as their interaction, on learners' change in attitude regarding protection of nature, littering and vandalism.

	DF	SumsOfSqs	MeanSqs	F.Model	R2	Pr(>F)
Treatment	1	0.0455	0.045473	0.60008	0.00255	0.578
Period	1	0.0291	0.029087	0.38385	0.00163	0.716
Treatment*Period	1	0.0921	0.092097	1.21534	0.00517	0.332
Residuals	233	17.6565	0.075779		0.99065	

Table 4.4 Results of the permutational multivariate analysis of variance of the effect of treatment and period, as well as their interaction, on learners' awareness regarding the lingcungcu project and surroundings.

	DF	SumsOfSqs	MeanSqs	F.Model	R2	Pr(>F)
Treatment	1	0.0455	0.045473	0.60008	0.00255	0.591
Period	1	0.0291	0.029087	0.38385	0.00163	0.689
Treatment*Period	1	0.0921	0.092097	1.21534	0.00517	0.333
Residuals	233	17.6565	0.075779		0.99065	

Table 4.5 Results of the permutational multivariate analysis of variance of the effect of treatment and period, as well as their interaction, on learners' leadership.

	DF	SumsOfSqs	MeanSqs	F.Model	R2	Pr(>F)
Treatment	1	0.0455	0.045473	0.60008	0.00255	0.602
Period	1	0.0291	0.029087	0.38385	0.00163	0.694
Treatment*Period	1	0.0921	0.092097	1.21534	0.00517	0.329
Residuals	233	17.6565	0.075779		0.99065	

Table 4.6 Effect of treatment (control or experimental classes), period (before and after the learner interaction) and the interaction of treatment and period on learner ability to name plants in the school gardens (Question 14).

	Estimate	Std. Error	Z value	*P*
(Intercept)	-1.872	0.3855	-4.857	<0.01
Period	-0.6798	0.4358	-1.560	0.119
Treatment	2.2587	0.2754	8.200	<0.01
Treatment*Period	-0.9202	0.4834	-1.903	0.05

Table 4.7 Effect of treatment (control or experimental classes), period (before and after the learner interaction) and the interaction of treatment and period, on whether learners talk about the lingcungcu project (question 8).

	Estimate	Std. Error	Z value	*P*
(Intercept)	0.9070	0.0981	9.245	<0.01
Period	-0.0724	0.1078	-0.672	0.502
Treatment	0.3661	0.0993	3.687	<0.01
Treatment*Period	-0.3880	0.1472	-2.636	<0.01

Table 4.8 Effect of treatment (control or experimental classes), period (before and after the learner interaction) and the interaction of treatment and period, on whether learners could name other schools that are part of the lingcungcu project (question 5).

	Estimate	Std. Error	Z value	*P*
(Intercept)	-0.2445	0.2045	-1.196	0.232
Period	-0.8782	0.2295	-3.826	<0.01
Treatment	1.2144	0.1456	8.338	<0.01
Treatment*Period	-0.4251	0.2678	-1.587	0.112

Table 4.9 Effect of treatment (control or experimental classes), period (before and after the learner interaction) and the interaction of treatment and period on learner career choice.

	Estimate	Std. Error	Z value	*P*
(Intercept)	1.3063	0.0903	14.475	0.01
Period	0.0477	0.0811	0.587	0.557
Treatment	0.0962	0.0826	1.165	0.244
Treatment*Period	-0.1700	0.1141	-1.490	0.136

Table 4.10 Effect of treatment (control or experimental classes), period (before and after the learner interaction) and the interaction of treatment and period, on learner attitude towards littering.

	Estimate	Std. Error	Z value	*P*
(Intercept)	1.6207	0.0568	28.537	<0.01
Period	0.1145	0.0689	1.662	0.097
Treatment	-0.0945	0.0755	-1.252	0.211
Treatment*Period	-0.1331	0.1013	-1.314	0.189

5. Chapter 5: General Thesis Conclusions

This thesis has three sections that focus on three different aspects of pollinator-plant interaction restoration with a special focus on sunbirds and sugarbirds. Each section clearly defined and achieved its set objectives like defining the methodology to establish ecological corridors, applying the methodology to test its efficacy in restoring plant-pollinator interactions and using the study to introduce school learners to biodiversity. My main aim here was to test whether natural sciences and social sciences could converge.

Research reveals that there is lack of knowledge and awareness in developing countries on activities that cause habitat fragmentation (Rija et al., 2014). Thus with humanity now living in cities (Aronson et al., 2014) and the destruction of natural urban habitats on the rise (Concepción et al., 2016; McKinney, 2008), the outcomes of the lingcungcu study promote the value of placing biodiversity conservation and management at the forefront of urban planning (Fernández-Juricic and Jokimäki, 2001; Luck, 2007; Luck et al., 2010; Luck et al., 2013; Rija et al., 2014).

In my methodology chapter (Chapter 2), I assessed the study area on a landscape scale focusing on natural areas (Table Mountain National Park and False Bay Nature Reserve). I considered the urban matrix that isolated these two critical biodiversity areas and then plotted a migratory route targeting high schools in between them. What I found is that although efforts are being made to transform the urban landscape through various restoration strategies (Holmes and Richardson, 1999), a lot still need to be done. Though the lingcungcu study was done on school gardens, the methods are nevertheless applicable on a bigger landscape scale. However, we recommend that areas be planted with other plants in order to complete the ecosystems suitable for the pollinator guilds to complete their full cycle (Menz et al., 2011), i.e. habitat requirements.

In chapter 3, I conducted bird observations and collected data and the results suggest that restoring plant-pollinator mutualism can yield results (Bond, 1994; Fontúrbel et al., 2015). Bird abundances increased over time at the planted gardens, whereas very little occurred in the non-planted gardens. We also observed two individuals of *Nectarinia famosa* (Malachite sunbirds) at one of the well-established

gardens. We recommend that bird observations be conducted over a long-term period covering all seasons (summer, autumn, winter and spring).

In chapter 4, I used school gardens to introduce grade 10 learners to an outdoor learning environment (Tal and Morag, 2013). The learners were introduced to all aspects of the study and were encouraged to complete a questionnaire based on the Iingcungcu project. The responses to various questions by the experimental group showed an upward trend over time. We thus conclude that interaction between the two variables Period (time) and Treatment is statistically significant.

In chapter 5, I concluded that well established gardens planted with appropriate plants can restore plant-pollinator interactions (Cerra and Crain, 2016; Fernández-Juricic and Jokimäki, 2001; Menz et al., 2011; Ortega-ÁLvarez and MacGregor-Fors, 2011). I also found that leaners are always eager to engage in new projects to learn new things and that their attitudes can change over time towards biodiversity when engaged in projects like the *IINGCUNGCU* PROJECT (Bissing-Olson et al., 2013; DeNicola, 2005; Hutchinson et al., 2015; McLaughlin and Arbeider, 2008; Meinhold, 2005; Ylimaki and Jacobson, 2013). The study brings a different perspective to natural sciences, and produced results that can be used by practitioners wishing to engage in restoration projects. Moreover, the results can be used to contribute towards environmental education at schools and in various organisations.

Future studies should focus of the following:

5.1.1. How sustainable are restoration projects in the long term?
5.1.2. What species of plants and animals can benefit from restoration projects?
5.1.3. What impact does environmental education have on learners' learning abilities to achieve higher grades and change in other areas of life?

To achieve restorative efforts on a landscape scale especially in urban ecosystems (Bierwagen, 2007), I recommend that ecologists work together with social scientists to involve a wider range of communities (Clewell and Rieger, 1997; Ehrlich and Ehrlich, 2013). Biodiversity will continue its perilous path if it does not consider humanity its biggest partner in perpetual existence (Ehrlich and Ehrlich, 2013).

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Thesis Appendices
Chapter 2:

Appendix 2.1 List of nectar producing plants of the Cape floral Region (CFR)

THE IINGCUNGCU PROJECT: Restoring nectar feeding birds, building biodiversity leadership

Species List Nectar Producing Plants_CFR

M. Sc. Botany
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Reference Index: The plant genera reaserched and illustrated by Johnson, (1996) =J; Rebelo, (1987) = R; Manning and Goldblatt, (2012) = M&G; Mucina and Rutherford, (2006) = M&R; Manning et al., (2002) = M1; Manning, (2007) = M2; Pauw, (1998) =P1; A. Pauw unpublished observation of foraging birds =P2; Trinder-Smith, (2006)=T; Wester and Claßen-Bockhoff, (2006) =W&C.

Cape Flats Sand Fynbos = CFSF; Cape Flats Dune Strandveld = CFDS

Family	Genus	Species	Cape Flora	Cape Peninsula	CFDS CFSF	Blossom Type	Bird Pollinated	Poisonous	Prikles or Thorns	Long Flowering	Selected for Planting	Parasitic	Hardy	Source
Amaryllidaceae	*Brunsvigia*	*josephinae*	yes	no	no	gullet	yes	no	no	yes	no	no	yes	R, M1
Amaryllidaceae	*Brunsvigia*	*litoralis*	yes	no	no	gullet	yes	no	no	yes	no	no	yes	R, M1
Amaryllidaceae	*Brunsvigia*	*orientalis*	yes	yes	CFDS	gullet	yes	no	no	yes	yes	no	yes	R, M1, T, M&R
Amaryllidaceae	*Cyrtanthus*	*angustifolius*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M1
Amaryllidaceae	*Cyrtanthus*	*carneus*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M1
Amaryllidaceae	*Cyrtanthus*	*fergusoniae*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M1
Amaryllidaceae	*Cyrtanthus*	*labiatus*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M1
Amaryllidaceae	*Cyrtanthus*	*odorus*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M1
Amaryllidaceae	*Cyrtanthus*	*ventricosus*	yes	yes	no	tube	yes	no	no	yes	no	no	yes	R, M&R, T
Amaryllidaceae	*Haemanthus*	*amarylloides*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M1
Amaryllidaceae	*Haemanthus*	*canaliculatus*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M1

Amaryllidaceae	*Haemanthus*	*coccineus*	yes	yes	CFDS	brush	yes	no	no	yes	yes	no	yes	R, M1
Amaryllidaceae	*Haemanthus*	*pubescens*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M1
Amaryllidaceae	*Haemanthus*	*sanguineus*	yes	yes	no	brush	yes	no	no	yes	no	no	yes	R, M1, T
Apocynaceae	*Microloma*	*sagittatum*	yes	yes	CFDS	tube	yes	no	no	yes	yes	no	yes	P1
Apocynaceae	*Microloma*	*tenuifolium*	yes	yes	no	tube	yes	no	no	yes	no	no	yes	P2
Apocynaceae	*Microloma*	*calycinum*	no	no	no	tube	yes	no	no	yes	no	no	yes	P2
Apocynaceae	*Microloma*	*namaquense*	no	no	no	tube	yes	no	no	yes	no	no	yes	P2
Asphodelaceae	*Aloe*	*africana*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*arborescens*	yes	no	no	br/tb	yes	no	no	yes	yes	no	yes	R, M&G
Asphodelaceae	*Aloe*	*arenicola*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*bowiea*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*brevifolia*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*buhrii*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*ciliaris*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*claviflora*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*commixta*	yes	yes	no	br/tb	yes	no	no	yes	yes	no	yes	R, M&G
Asphodelaceae	*Aloe*	*comosa*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*comptonii*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*distans*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*falcata*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*ferox*	yes	no	no	br/tb	yes	no	no	yes	yes	no	yes	R, M&G
Asphodelaceae	*Aloe*	*framesii*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*glauca*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*gracilis*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*haemanthifolia*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*humilis*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*lineata*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*longistyla*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*maculata*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*micracantha*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*microstigma*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G

Asphodelaceae	*Aloe*	*perfoliata*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M2
Asphodelaceae	*Aloe*	*pictifolia*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*plicatilis*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*pluridens*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*speciosa*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*striata*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Aloe*	*succotrina*	yes	yes	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G, T
Asphodelaceae	*Aloe*	*variegata*	yes	no	no	br/tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Gasteria*	*glomerata*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Kniphofia*	*citrina*	yes	no	no	br-tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Kniphofia*	*praecox*	yes	no	no	br-tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Kniphofia*	*sarmentosa*	yes	no	no	br-tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Kniphofia*	*tabularis*	yes	no	no	br-tb	yes	no	no	yes	no	no	yes	R, M&G
Asphodelaceae	*Kniphofia*	*uvaria*	yes	yes	no	br-tb	yes	no	no	yes	no	no	yes	R, M&G, T
Boraginaceae	*Lobostemon*	*glaucophyllus*	yes	no	no	gullet	yes	no	no	yes	no	no	yes	R, M2
Bruniaceae	*Brunia*	*noduliflora*	yes	yes	no	tube	no	no	no	yes	no	no	yes	R, M&G, T
Bruniaceae	*Brunia*	*stokoei*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M&G
Capparaceae	*Cadaba*	*aphylla*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M&G
Crassulaceae	*Cotyledon*	*orbiculata*	yes	yes	CFDS	tube	yes	no	no	yes	yes	no	yes	R, M2, T, M&R
Crassulaceae	*Crassula*	*coccinea*	yes	yes	no	tube	no	no	no	yes	no	no	yes	R, M2, T
Crassulaceae	*Kalanchoe*	*rotundifolia*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M&G
Crassulaceae	*Tylecodon*	*paniculatus*	yes	no	CFDS	tube	yes	no	no	yes	yes	no	yes	R, M2
Ericaceae	*Erica*	*abelii*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R
Ericaceae	*Erica*	*abietina*	yes	yes	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M2, T
Ericaceae	*Erica*	*alfredii*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*ampullacea*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*annectens*	yes	yes	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*aristata*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*armata*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*astroites*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*atrovinosa*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G

Ericaceae	*Erica*	*axilliflora*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*banksia*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*barrydalensis*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*bauera*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*beatricis*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*berzelioides*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*bibax*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*blenna*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*bodkinii*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*borboniifolia*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*brachialis*	yes	yes	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*breviflora*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*caffra*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*calcareophila*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*caledonica*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*cameronii*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*casta*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*cerinthoides*	yes	yes	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G, M2
Ericaceae	*Erica*	*chloroloma*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*chlorosepala*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*chrysocodon*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*coccinea*	yes	yes	no	br-tu/tb	yes	no	no	yes	yes	no	yes	R, M&G, M2
Ericaceae	*Erica*	*colorans*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*conica*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*conspicua*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*cremea*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*curviflora*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G, M2
Ericaceae	*Erica*	*cygnea*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*cylindrica*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*daphniflora*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G, M2
Ericaceae	*Erica*	*densifolia*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G, M2

Ericaceae	*Erica*	*dianthifolia*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*diaphana*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*dichrus*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*discolor*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M2
Ericaceae	*Erica*	*doliiformis*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*embothriifolia*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*etheliae*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*eugenea*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*excavata*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*fairii*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*fascicularis*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*fastigiata*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*fervida*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*filamentosa*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*filipendula*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*foliacea*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*fontana*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*galgebergensis*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*gallorum*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*galpinii*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*gilva*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*glandulosa*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*glauca*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*glutinosa*	yes	yes	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, T
Ericaceae	*Erica*	*goatcheriana*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*gossypioides*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*grandiflora*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*grisbrookii*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*gysbertii*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*halicacaba*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*hameriana*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G

Ericaceae	*Erica*	*hanekomii*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*hebecalyx*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*heleogena*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*heleophila*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*hendricksii*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*hibbertia*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*holosericea*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*incarnata*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*inclusa*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*inflata*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*infundibuliformis*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*inordinata*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*insignis*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*insolitanthera*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*intonsa*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*irbyana*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*ixanthera*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*jasminiflora*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*junonia*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*kirstenii*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*kogelbergenisis*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*lageniformis*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*lananthera*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*lanipes*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*lanuginosa*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*latiflora*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*lawsonia*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*leucosiphon*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*leucotrachela*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*lineata*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*longifolia*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G, M2

Ericaceae	*Erica*	*longifolia*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*macilenta*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*macowanii*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*macroloma*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*mammosa*	yes	yes	CFSF	br-tu/tb	yes	no	no	yes	yes	no	yes	R, M&G, M2, T, M&R
Ericaceae	*Erica*	*mariae*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*massonii*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*maximiliani*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*mitchellensis*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*monadelphia*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*monsoniana*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*mucronata*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*nabea*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*nana*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*nematophylla*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*nevillei*	yes	yes	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G, T
Ericaceae	*Erica*	*oblongiflora*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*odorata*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*omninoglabra*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*pageana*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*paludicola*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*papyracea*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*patersonia*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*patersonii*	yes	yes	no	br-tu/tb	yes	no	no	yes	yes	no	yes	R, T
Ericaceae	*Erica*	*pectinifolia*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*perspicua*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M2
Ericaceae	*Erica*	*perspicua*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*phillipsii*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*abietina subsp. atrorosea (=phylicifolia)*	yes	yes	no	br-tu/tb	yes	no	no	yes	yes	no	yes	R, M&G

Ericaceae	*Erica*	*physodes*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*pinea*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M2
Ericaceae	*Erica*	*plena*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*plukenetii*	yes	yes	no	br-tu/tb	yes	no	no	yes	yes	no	yes	R, M&G, M2, T
Ericaceae	*Erica*	*porteri*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*praenitens*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*primulina*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*propendens*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*pudens*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*pyramidalis*	yes	yes	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*quadrisulcata*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*recta*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*regia*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*retorta*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*rufescens*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*sacciflora*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*sagittata*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*savilea*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*saxigena*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*schumannii*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*sessiliflora*	yes	yes	no	br-tu/tb	yes	no	no	yes	yes?	no	yes	R, M&G, M2, T
Ericaceae	*Erica*	*shannonea*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*similis*	yes	yes	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, T
Ericaceae	*Erica*	*sociorum*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*sparrmannii*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*speciosa*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*squarrosa*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*steinbergiana*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*strigilifolia*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*taxifolia*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*tenax*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G

Ericaceae	*Erica*	*thomae*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*toringbergensis*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*trachysantha*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*trichophora*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*trichroma*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*tubercularis*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*tumida*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*turrisbabylonica*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*urna-viridis*	yes	yes	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G, M2, T
Ericaceae	*Erica*	*ustulescens*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*vallisaranearum*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*vallisgratiae*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*velitaris*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*ventricosa*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*versicolor*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G, M2, T
Ericaceae	*Erica*	*verticillata*	yes	yes	CFSF	br-tu/tb	yes	no	no	yes	yes	no	yes	R, M&G, M2, T, M&R
Ericaceae	*Erica*	*vestita*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*viridescens*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*viscaria*	yes	yes	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*walkeria*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*wendlandiana*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*winteri*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*xanthina*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*xerophila*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Ericaceae	*Erica*	*zitzikammensis*	yes	no	no	br-tu/tb	yes	no	no	yes	no	no	yes	R, M&G
Geraniaceae	*Pelagornium*	*cucullatum*	yes	yes	no	tube	no	no	no	yes	no	no	yes	R, M&G, M2, T
Geraniaceae	*Pelagornium*	*fulgidum*	yes	no	CFDS	tube	yes	no	no	yes	yes	no	yes	P2
Gesneriaceae	*Streptocarpus*	*meyeri*	yes	no	no	tube	no	no	no	yes	no	no	yes	R, M&G
Gesneriaceae	*Streptocarpus*	*rexii*	yes	no	no	tube	no	no	no	yes	no	no	yes	R, M&G
Hyacinthaceae	*Albuca*	*juncifolia*	yes	yes	no	tube	yes	no	no	yes	no	no	yes	R, M2

Hyacinthaceae	*Daubenya*	*zeyheri*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M1
Hyacinthaceae	*Lachenalia*	*aloides*	yes	yes	CFDS	tube	yes	no	no	yes	yes	no	yes	R, M&G, T
Hyacinthaceae	*Lachenalia*	*bulbifera*	yes	yes	CFDS	tube	yes	no	no	yes	yes	no	yes	R, M&G
Hyacinthaceae	*Lachenalia*	*reflexa*	yes	yes	CFSF	tube	yes	no	no	yes	yes	no	yes	R, M&G, T
Hyacinthaceae	*Lachenalia*	*rubida*	yes	yes	no	tube	yes	no	no	yes	yes	no	yes	R, M&G, T
Hyacinthaceae	*Lachenalia*	*viridiflora*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M&G
Hyacinthaceae	*Massonia*	*depressa*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M&G, M1
Hyacinthaceae	*Massonia*	*pustulata*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M&G, M1
Hyacinthaceae	*Veltheimia*	*bracteata*	yes	no	no	gullet	yes	no	no	yes	no	no	yes	R, M&G, M1; M2
Hyacinthaceae	*Veltheimia*	*capensis*	yes	no	no	gullet	yes	no	no	yes	no	no	yes	R, M&G, M1; M2
Iridaceae	*Babiana*	*ringens*	yes	yes	no	br-tb	yes	no	no	yes	yes	no	yes	R, M&G, M1, T
Iridaceae	*Babiana*	*thunbergii*	yes	no	no	br-tb	yes	no	no	yes	no	no	yes	R, M&G, M1
Iridaceae	*Chasmanthe*	*aethiopica*	yes	yes	CFDS	br-tb	yes	no	no	yes	yes	no	yes	R, M&G, M1, T, M&R
Iridaceae	*Chasmanthe*	*bicolor*	yes	no	no	gullet	yes	no	no	yes	no	no	yes	R, M&G, M1
Iridaceae	*Chasmanthe*	*floribunda*	yes	yes	no	gullet	yes	no	no	yes	yes	no	yes	R, M&G, M1
Iridaceae	*Gladiolus*	*bonaspei*	yes	no	no	gullet	yes	no	no	yes	no	no	yes	R, M&G, M1
Iridaceae	*Gladiolus*	*cunonius*	yes	no	CFDS	gullet	yes	no	no	yes	yes	no	yes	R, M&G, M1
Iridaceae	*Gladiolus*	*splendens*	yes	no	no	gullet	yes	no	no	yes	no	no	yes	R, M&G, M1
Iridaceae	*Gladiolus*	*teretifolius*	yes	no	no	gullet	yes	no	no	yes	no	no	yes	R, M&G, M1
Iridaceae	*Gladiolus*	*watsonius*	yes	yes	no	gullet	yes	no	no	yes	no	no	yes	R, M&G, M1, T
Iridaceae	*Klattia*	*flava*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M&G, M2
Iridaceae	*Klattia*	*stokoei*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M&G, M2
Iridaceae	*Witsenia*	*maura*	yes	yes	no	tube	yes	no	no	yes	no	no	yes	R, M&G, M&R, T
Iridaceae	*Watsonia*	*aletroides*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M&G, M2
Iridaceae	*Watsonia*	*angusta*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M&G, M2
Iridaceae	*Watsonia*	*fourcadei*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M&G, M2
Iridaceae	*Watsonia*	*hysterantha*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M&G, M2
Iridaceae	*Watsonia*	*meriana*	yes	yes	CFSF	tube	yes	no	no	yes	yes	no	yes	R, M&G, M2, M&R
Iridaceae	*Watsonia*	*pillansii*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M&G, M2
Iridaceae	*Watsonia*	*schlechteri*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M&G, M2

Iridaceae	*Watsonia*	*stokoei*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M&G, M2
Iridaceae	*Watsonia*	*spectabilis*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M&G, M2
Iridaceae	*Watsonia*	*tabularis*	yes	yes	no	tube	yes	no	no	yes	yes	no	yes	R, M&G, M2, T
Iridaceae	*Watsonia*	*zeyheri*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M&G, M2
Lamiaceae	*Leonotis*	*leonurus*	yes	yes	no	tube	yes	no	no	yes	yes	no	yes	R, M&G, M&R, T
Lamiaceae	*Leonotis*	*ocymifolia*	yes	no	no	tube	yes	no	no	yes	yes	no	yes	R, M&G, M&R
Lamiaceae	*Salvia*	*africana-lutea*	yes	yes	CFDS	tube	yes	no	no	yes	yes	no	yes	R, M&G, T, M&R
Lamiaceae	*Salvia*	*thermarum*	yes	no	no	tube	yes	no	no	yes	no	no	yes	W&C
Lamiaceae	*Salvia*	*lanceolata*	yes	yes	CFSF	tube	yes	no	no	yes	yes	no	yes	W&C
Melianthaceae	*Melianthus*	*elongatus*	yes	no	no	funnel	yes	no	no	yes	no	no	yes	R, M&G, M2
Melianthaceae	*Melianthus*	*major*	yes	no	no	funnel	yes	no	no	yes	no	no	yes	R, M&G, M2
Orchidaceae	*Satyrium*	*carneum*	yes	yes	CFDS	gullet	yes	no	no	yes	yes	no	yes	R, M&G, M2, T, J
Orchidaceae	*Satyrium*	*coriifolium*	yes	yes	CFDS	gullet	yes	no	no	yes	yes	no	yes	J
Papilionaceae	*Liparia*	*parva*	yes	yes	no	flag	no	no	no	yes	no	no	yes	R, M&G, T
Papilionaceae	*Liparia*	*splendens*	yes	yes	no	flag	yes	no	no	yes	no	no	yes	R, M&G, T
Papilionaceae	*Lessertia*	*frutescens*	yes	yes	no	flag	yes	no	no	yes	no	no	yes	R, M&G, M2, T
Peneaceae	*Saltera*	*sarcocolla*	yes	yes	no	tube	yes	no	no	yes	no	no	yes	R, M&G, M2, T
Proteaceae	*Leucospermum*	*arenarium*	yes	no	no	brush	no	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*bolusii*	yes	no	no	brush	no	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*calligerum*	yes	no	no	brush	no	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*catheinae*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*conocarpodendron*	yes	yes	CFSF	brush	yes	no	no	yes	yes	no	yes	R, M&G, T
Proteaceae	*Leucospermum*	*cordatum*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*cordifolium*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*cuneiforme*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*erubescens*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*formosum*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*fulgens*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*glabrum*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*gracile*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*grandiflorum*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G

Proteaceae	*Leucospermum*	*gueinzii*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*hamatum*	yes	no	no	brush	no	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*harpagonatum*	yes	no	no	brush	no	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*heterophyllum*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*hypophyllocarpodendron*	yes	yes	CFSF	brush	no	no	no	yes	no	no	yes	R, M&G, T, M&R
Proteaceae	*Leucospermum*	*lineare*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*muirii*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*mundii*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*oleifolium*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*parile*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*pattersonii*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*pedunculatum*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*pluridens*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*praecox*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*praemorsum*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*profugum*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*prostratum*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*reflexum*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*rodolentum*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*royenifolium*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*saxatile*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*spathulatum*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*tomentosum*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*tottum*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*truncatulum*	yes	no	no	brush	no	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*truncatum*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*utriculosum*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*vestitum*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*winteri*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Leucospermum*	*wittebergense*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*acuminata*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G

Proteaceae	*Protea*	*aristata*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*aurea*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*burchellii*	yes	yes	CFSF	brush	yes	no	no	yes	yes	no	yes	R, M&G, M&R
Proteaceae	*Protea*	*canaliculata*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*compacta*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*coronata*	yes	yes	no	brush	yes	no	no	yes	no	no	yes	R, M&G, T
Proteaceae	*Protea*	*cynaroides*	yes	yes	no	brush	yes	no	no	yes	yes	no	yes	R, M&G, T
Proteaceae	*Protea*	*denticulata*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*effusa*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*eximia*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*foliosa*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*glabra*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*grandiceps*	yes	yes	no	brush	yes	no	no	yes	no	no	yes	R, M&G, T
Proteaceae	*Protea*	*holosericea*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*inopina*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*lacticolor*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*lanceolata*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*laurifolia*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*lepidocarpodendron*	yes	yes	no	brush	yes	no	no	yes	yes	no	yes	R, M&G, T
Proteaceae	*Protea*	*longifolia*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*lorifolia*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*magnifica*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*mucronifolia*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*mundii*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*nana*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*nerifolia*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*nitida*	yes	yes	no	brush	yes	no	no	yes	no	no	yes	R, M&G, T
Proteaceae	*Protea*	*obtusifolia*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*odorata*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*pendula*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*pityphylla*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G

Proteaceae	*Protea*	*punctata*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*recondita*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*repens*	yes	yes	CFSF	brush	yes	no	no	yes	yes	no	yes	R, M&G, T, M&R
Proteaceae	*Protea*	*rupicola*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*scolymocephala*	yes	yes	CFSF	brush	no	no	no	yes	no	no	yes	R, M&G, T, M&R
Proteaceae	*Protea*	*speciosa*	yes	yes	no	brush	yes	no	no	yes	no	no	yes	R, M&G, T
Proteaceae	*Protea*	*stokoei*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*subvestita*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*sulphurea*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*susannae*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Protea*	*witzenbergiana*	yes	no	no	brush	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Mimetes*	*arboreus*	yes	no	no	br-tb	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Mimetes*	*argenteus*	yes	no	no	br-tb	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Mimetes*	*capitulatus*	yes	no	no	br-tb	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Mimetes*	*cucullatus*	yes	yes	no	br-tb	yes	no	no	yes	yes	no	yes	R, M&G, T
Proteaceae	*Mimetes*	*fimbriifolius*	yes	yes	no	br-tb	yes	no	no	yes	yes	no	yes	R, M&G, T
Proteaceae	*Mimetes*	*hirtus*	yes	yes	no	br-tb	yes	no	no	yes	no	no	yes	R, M&G, T
Proteaceae	*Mimetes*	*hottentoticus*	yes	no	no	br-tb	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Mimetes*	*palustris*	yes	no	no	br-tb	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Mimetes*	*pauciflorus*	yes	no	no	br-tb	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Mimetes*	*saxatilis*	yes	no	no	br-tb	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Mimetes*	*splendidus*	yes	no	no	br-tb	yes	no	no	yes	no	no	yes	R, M&G
Proteaceae	*Mimetes*	*stokoei*	yes	no	no	br-tb	yes	no	no	yes	no	no	yes	R, M&G
Retziaceae	*Retzia*	*capensis*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M&G, M2
Rubiaceae	*Burchellia*	*bubalina*	yes	no	no	tube	yes	no	no	yes	no	no	yes	R, M&G
Scrophulariaceae	*Harveya*	*bolusii*	yes	no	no	tube	yes	no	no	yes	no	yes	yes	R, M&G, M2
Scrophulariaceae	*Harveya*	*capensis*	yes	yes	no	tube	yes	no	no	yes	no	yes	yes	R, M&G, M2, T
Scrophulariaceae	*Harveya*	*purpurea*	yes	yes	no	tube	yes	no	no	yes	no	yes	yes	R, M&G, M2, T
Scrophulariaceae	*Harveya*	*squamosa*	yes	yes	no	tube	yes	no	no	yes	no	yes	yes	R, M&G, M2, T
Scrophulariaceae	*Hyobanche*	*atropurpurea*	yes	no	no	tube	yes	no	no	yes	no	yes	yes	R, M&G, M2
Scrophulariaceae	*Hyobanche*	*glabrata*	yes	no	no	tube	yes	no	no	yes	no	yes	yes	R, M&G, M2

Scrophulariaceae	*Hyobanche*	*sanguinea*	yes	yes	no	tube	yes	no	no	yes	no	yes	yes	R, M&G, M2,T
Scrophulariaceae	*Halleria*	*lucida*	yes	yes	no	tube	yes	no	no	yes	yes	no	yes	R, M&G, T
Solanaceae	*Lycium*	*afrum*	yes	yes	CFDS	br-tb	yes	no	no	yes	yes	no	yes	R, M&G, T
Solanaceae	*Lycium*	*ferocissimum*	yes	yes	CFDS	br-tb	yes	no	no	yes	yes	no	yes	R, M&G, T

Chapter 3:

Appendix 3.1 Bird survey data sheet used at school gardens and entire school grounds

Data Collection Sheet | Mark with a cross where appropriate (X) | Start Time: _____ End Time: _____

Collectors' Name and Surname: | Date: _____

School Name: _____ | Planted Garden [ ] | Entire School Grounds [ ]

Selected Control Site [ ]

Weather Conditions:	Cloud Cover	Wind	Before Planting Observations: [ ]
Sunny		No wind	After Planting Observations: [ ]
Cloudy		Moderate	
Rainy		Windy	

Are any of the plants species flowering?

Haemanthus coccineus	[ ]	Watsonia tabularis	[ ]	Aloe arborescens	[ ]	Salvia lanceolata	[ ]
Lachenalia rubida	[ ]	Chasmanthe aethiopica	[ ]	Aloe commixta	[ ]	Salvia africana-lutea	[ ]
Watsonia meriana	[ ]	Chasmanthe floribunda	[ ]	Cotyledon orbiculata	[ ]	Leonotis leonorus	[ ]
Leonotis ocymifolia	[ ]	Pelargonium fulgidum	[ ]	Leucospermum conocarpodenddron	[ ]	Halleria lucida	[ ]
Erica verticilata	[ ]	Protea cynaroides	[ ]	Lycium ferrocissimum	[ ]		
Erica mammosa	[ ]	Protea repens	[ ]	Mimetes fimbrifolius	[ ]		

Bird Spp. Observed	Feeding	Plant Spp. Fed on	Bird count	Other

Mark with a cross where appropriate (X)

Start Time: _____

End Time: _____

Before Planting Observations: ☐ Planted Garden ☐ Entire School Grounds ☐

After Planting Observations: ☐ Selected Control Site ☐

Bird Spp. Observed	Feeding	Plant Spp. Fed on	Bird count	Other

Appendix 3.2 Bird survey date sheet used at Table Mountain National Park and False Bay Nature Reserve-Rondevlei

Data Collection Sheet

Mark with a cross where appropriate (X)

Collectors' Name and Surname: _____

Before Planting Observations [ ] After Planting Observations [ ]

Start Time _____

Source Site: Muizenberg/Silvermine Mountain Range [ ] Plot 1 [ ] Date: _____ End Time _____

Destination Site: False Bay Nature Reserve (Rondevlei) [ ] Plot 2 [ ]

Weather Conditions:

Cloud Cover		Wind	
Sunny	[ ]	No wind	[ ]
Cloudy	[ ]	Moderate	[ ]
Rainy	[ ]	Windy	[ ]

Bird Spp. Observed	Feeding: Yes/No	Plant Spp. Fed on	Bird count	Male/ Female	Other Activities

Before Planting Observations ☐ After Planting Observations ☐

Start Time _____

Source Site: Muizenberg/Silvermine Mountain Range ☐ Plot 1 ☐ Date: _____ End Time _____

Destination Site: False Bay Nature Reserve (Rondevlei) ☐ Plot 2 ☐

Weather Conditions:

Cloud Cover		Wind	
Sunny	☐	No wind	☐
Cloudy	☐	Moderate	☐
Rainy	☐	Windy	☐

Bird Spp. Observed	Feeding: Yes/No	Plant Spp. Fed on	Bird count	Male/ Female	Other Activities

Chapter 4:
Appendix 4.1: Ethical Clearance Approval

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jou kennisvennoot · your knowledge partner

Approved with Stipulations
New Application

18-Mar-2016
Pauw, Charl CA

Proposal #: SU-HSD-002256
Title: THE IINGCUNGCU PROJECT: restoring birds, building biodiversity leadership.

Dear Prof Charl Pauw,

Your **New Application** received on **14-Mar-2016**, was reviewed
Please note the following information about your approved research proposal:

Proposal Approval Period: **18-Mar-2016 -17-Mar-2017**

The following stipulations are relevant to the approval of your project and must be adhered to:
This is an ethically low risk potentially valuable project that straddles a border area between research and education. However this is a research project, not exclusively an education programme and the information collected will be used for purposes other than education and awareness raising including towards a degree. In a research context such as this there are a few prima facie principles that need to be considered:

1) Written permission needs to be obtained from the Dept. of Education and from each school.

2) Parents of children involved in the project need to be informed about it and usually need to provide written consent. In this case the REC agrees that the need for formal parental consent can be waived. However parents must be informed about the project e.g. at meeting or by using a flyer or other appropriate means of communication. This communication should inform parents that participation is not compulsory and provide some mechanism for 'opt out' in the unlikely event that a parent would want to follow this route i.e. the contact details of the researcher must be made available.

3) Assent from minors who participate in research, no matter how low risk should always be obtained if they are old enough to give assent. This can be obtained verbally in this instance. Also participation in research should not be compulsory even when the research is low risk and embedded in an education program such as this. Please ensure that this voluntariness is made clear to participants and that they know they do not have to complete the surveys if they don't want to OR that their answers won't be used for the research project if they indicate this i.e. the survey tool should be modified to make this clear and allow learners to check a 'NO' box if they so wish.

Please provide a letter of response to all the points raised IN ADDITION to HIGHLIGHTING or using the TRACK CHANGES function to indicate ALL the corrections/amendments of ALL DOCUMENTS clearly in order to allow rapid scrutiny and appraisal.

Please take note of the general Investigator Responsibilities attached to this letter. You may commence with your research after complying fully with

these guidelines.

Please remember to use your **proposal number** (**SU-HSD-002256**) on any documents or correspondence with the REC concerning your research proposal.

Please note that the REC has the prerogative and authority to ask further questions, seek additional information, require further modifications, or monitor the conduct of your research and the consent process.

Also note that a progress report should be submitted to the Committee before the approval period has expired if a continuation is required. The Committee will then consider the continuation of the project for a further year (if necessary).

This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki and the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health). Annually a number of projects may be selected randomly for an external audit.

National Health Research Ethics Committee (NHREC) registration number REC-050411-032.

We wish you the best as you conduct your research.

If you have any questions or need further help, please contact the REC office at 2188089183.

Included Documents:
REC: Humanities New Application

Sincerely,

Clarissa Graham
REC Coordinator
Research Ethics Committee: Human Research (Humanities)

Appendix 4.2: Signed permission letters from the Western Cape Education Department.

THE IINGCUNGCU PROJECT: restoring birds, building biodiversity leadership

M. Sc. Botany
Supervisor: Prof A Pauw and Co-supervisor: Dr S. Geerts
Department of Botany and Zoology, University of Stellenbosch, Private Bag X1 Matieland, 7602, Stellenbosch, South Africa.
Bongani Mnisi
083 591 7791
Bongani.Mnisi@capetown.gov.za


Malachite Sunbird


Southern Double-collared Sunbird


Orange-breasted sunbird


Cape Sugarbird

Short Project Introduction

Iingcungcu is a isiXhosa name referring to Sunbirds and Sugarbirds with long beaks. These birds are important pollinators of more than 350 plant species in the Cape Floral Region, but are threatened by habitat fragmentation, urbanization, road traffic and frequent fires. Some species, such as Malachite Sunbirds and Sugarbirds are particularly sensitive to urbanization and do not venture far into the urban areas that now separate the Table Mountain National Park from the Boland Mountains and from the smaller nature reserves on the Cape Flats. This study aims to restore these broken migration routes by planting gardens of indigenous bird pollinated plants on school grounds on the Cape Flats, thus proving a series of stepping stones for nectar feeding birds. Thus, the aims of this study are to bring about a convergence between ecology and society. The academic component of the study will attempt to answer the ecological question of whether corridors can be established and facilitate the movement of specialist nectar feeding birds across a landscape where they have been commonly known to occur in the past. The civil society component of the project will be a hands-on attempt at community engagement, in particular involving high schools. The project will be rolled out in Cape Town as a pilot project transferable to other urban areas. The ultimate aim is for Municipalities to take ownership of the project. My research questions therefore are; 1) whether planting of nectar plants will restore nectar feeding birds; and 2) whether restoring nectar feeding birds will have a positive effect on school children and in particular will help identify and nurture leadership for biodiversity?

Section Relating to Schools and Approval Request to Conduct a Survey with Grade 10 leaners using a Questionnaire

General Research questions

1) Whether this study will help identify and nurture leadership for biodiversity?

a) Did the study manage to identify future leaders for biodiversity?

Hypothesis

2) Providing biodiversity knowledge to leaners can lead to an increased awareness of nature and inspire leadership for biodiversity whereas little or limited awareness could be reported from leaners who did not receive such knowledge.

Questionnaire

The aim of the questionnaire is to test the effectiveness of our intervention with the high school Grade 10 learners, especially to show significance of the role the lingcungcu Project has played in inspiring a shift in attitudes towards biodiversity interest, knowledge and leadership. The questionnaire should possibly take a maximum of 10 minutes to complete.

While all leaners at selected classes are encouraged to participate, completion of the questionnaire itself is nevertheless voluntary.

Approval Request

In order to satisfy the ethics approval as granted by the University of Stellenbosch' Research Ethics Committee: Human Research (Humanities) (***see attached letter of approval***), the following is required.

1. Written permission needs to be obtained from the Dept. of Education and from each school.

a. The School grants permission for the project X	b. The Dept. of Education grants permission for the project

MUIZENBERG HIGH SCHOOL

Name & Surname	Leonie Jacobsen	**Name & Surname**	Clifton Frolick
Title:	Acting Principal	**Title:**	Mr (Chief Director)
Signature:		**Signature:**	
Date:	5 April 2016.	**Date:**	2016/10/20

2. Parents of children involved in the project need to be informed about it and usually need to provide written consent. In this case the REC agrees that the need for formal parental consent can be waived. However parents must be informed about the project e.g. at meeting or by using a flyer or other appropriate means of communication. This communication should inform parents that participation is not compulsory and provide some mechanism for 'opt out' in the unlikely event that a parent would want to follow this route i.e. the contact details of the researcher must be made available.

   It is requested that the school informs the parents of this project using its appropriate communication channels. ***Please Mark using a CROSS.***

   The school **AGREES** [X] **DOES NOT AGREE** [ ] to communicate to parents about the project

   Assent from minors who participate in research, no matter how low risk should always be obtained if they are old enough to give assent. This can be obtained verbally in this instance. Also participation in research should not be compulsory even when the research is low risk and embedded in an education program such as this. Please ensure that this voluntariness is made clear to participants and that they know they do not have to complete the surveys if they don't want to OR that their answers won't be used for the research project if they indicate this i.e. the survey tool should be modified to make this clear and allow learners to check a 'NO' box if they so wish. ***Please refer to the attached Questionnaire.***

Hypothesis

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Questionnaire

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While all leaners at selected classes are encouraged to participate, completion of the questionnaire itself is nevertheless voluntary.

Approval Request

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1. Written permission needs to be obtained from the Dept. of Education and from each school.

a. The School grants permission for the project	b. The Dept. of Education grants permission for the project

STEENBERG HIGH SCHOOL

Name & Surname	JAMES HENDRICKS	**Name & Surname**	Clifton Fredricks
Title:	DEPUTY PRINCIPAL	**Title:**	Mr (Chief Director)
Signature:		**Signature:**	
Date:	6/04/2016	**Date:**	2016/10/20

2. Parents of children involved in the project need to be informed about it and usually need to provide written consent. In this case the REC agrees that the need for formal parental consent can be waived. However parents must be informed about the project e.g. at meeting or by using a flyer or other appropriate means of communication. This communication should inform parents that participation is not compulsory and provide some mechanism for 'opt out' in the unlikely event that a parent would want to follow this route i.e. the contact details of the researcher must be made available.

   It is requested that the school informs the parents of this project using its appropriate communication channels. ***Please Mark using a CROSS.***

   The school **AGREES** [✓] **DOES NOT AGREE** [ ] to communicate to parents about the project

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Approval Request

In order to satisfy the ethics approval as granted by the University of Stellenbosch' Research Ethics Committee: Human Research (Humanities) (***see attached letter of approval***), the following is required.

1. Written permission needs to be obtained from the Dept. of Education and from each school.

a. The School grants permission for the project	b. The Dept. of Education grants permission for the project
CRESTWAY HIGH SCHOOL	
Name & Surname V. E SÄFERS	**Name & Surname** C. Frolick
Title: PRINCIPAL	**Title:** Mr. (Chief Director)
Signature:	**Signature:**
Date: 08 APRIL 2016	**Date:** 2016/10/20

2. Parents of children involved in the project need to be informed about it and usually need to provide written consent. In this case the REC agrees that the need for formal parental consent can be waived. However parents must be informed about the project e.g. at meeting or by using a flyer or other appropriate means of communication. This communication should inform parents that participation is not compulsory and provide some mechanism for 'opt out' in the unlikely event that a parent would want to follow this route i.e. the contact details of the researcher must be made available.

   It is requested that the school informs the parents of this project using its appropriate communication channels. ***Please Mark using a CROSS.***

   The school **AGREES** [X] **DOES NOT AGREE** [ ] to communicate to parents about the project

   Assent from minors who participate in research, no matter how low risk should always be obtained if they are old enough to give assent. This can be obtained verbally in this instance. Also participation in research should not be compulsory even when the research is low risk and embedded in an education program such as this. Please ensure that this voluntariness is made clear to participants and that they know they do not have to complete the surveys if they don't want to OR that their answers won't be used for the research project if they indicate this i.e. the survey tool should be modified to make this clear and allow learners to check a 'NO' box if they so wish. ***Please refer to the attached Questionnaire.***

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Questionnaire

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While all leaners at selected classes are encouraged to participate, completion of the questionnaire itself is nevertheless voluntary.

Approval Request

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1. Written permission needs to be obtained from the Dept. of Education and from each school.

a. The School grants permission for the project	b. The Dept. of Education grants permission for the project

LAVENDER-HILL HIGH SCHOOL

Name & Surname	F. MANIE	**Name & Surname**	C. Frolick
Title:	PRINCIPAL	**Title:**	Ms. Chief Director
Signature:	pp	**Signature:**	
Date:	16/4/2016	**Date:**	2016/10/20

Wes-Kaap Onderwysdepartement
Western Cape Education Department
Isebe leMfundo leNtshona Koloni
2016 -10- 20
PRIVAATSAK/PRIVATE BAG X9114
KAAPSTAD/CAPE TOWN/IKAPA 8000

2. Parents of children involved in the project need to be informed about it and usually need to provide written consent. In this case the REC agrees that the need for formal parental consent can be waived. However parents must be informed about the project e.g. at meeting or by using a flyer or other appropriate means of communication. This communication should inform parents that participation is not compulsory and provide some mechanism for 'opt out' in the unlikely event that a parent would want to follow this route i.e. the contact details of the researcher must be made available.

   It is requested that the school informs the parents of this project using its appropriate communication channels. ***Please Mark using a CROSS.***

   The school **AGREES** [X] **DOES NOT AGREE** [ ] to communicate to parents about the project

   Assent from minors who participate in research, no matter how low risk should always be obtained if they are old enough to give assent. This can be obtained verbally in this instance. Also participation in research should not be compulsory even when the research is low risk and embedded in an education program such as this. Please ensure that this voluntariness is made clear to participants and that they know they do not have to complete the surveys if they don't want to OR that their answers won't be used for the research project if they indicate this i.e. the survey tool should be modified to make this clear and allow learners to check a 'NO' box if they so wish. ***Please refer to the attached Questionnaire.***

Appendix 4.3: Learner worksheet

THE IINGCUNGCU PROJECT: restoring birds, building biodiversity leadership

_____/25

The worksheet includes multiple choice and true/false type questions.

School Name:_____

Date:_____ **Grade 10**:_____

Name:_____ **Surname**:_____

1. What is the aim of the lingcungcu project? **(2)**

   _____

   _____

2. What is South Africa's national flower (provide the common name)? **(1)**

   _____

3. South Africa's national flower is bird-pollinated (**True or False**) **(1).**

   _____

4. When male and female reproductive parts are present in the same flower it is referred to as. **(1) (underline the correct answer)**
   a. Monoecious
   b. Hermaphrodite
   c. Dioecious
   d. Deciduous
5. This relationship between plants and pollinators is a? **(1) (underline the correct answer)**
   a. Mutualism
   b. Commensalism
   c. Parasitism
   d. Symbiosis
6. Using common or scientific names, kindly name any three plant species currently growing in the School Garden. **(3)**

   _____

   _____

   _____

7. From the list of characteristics below, underline three which are typical of a bird pollinated plant. **(3) (underline the correct answers)**

a. Flowers without a strong smell
b. Tall plants
c. Sturdy inflorescences
d. Bright green leaves
e. Absence of nectar
f. Tubular flowers
g. Red / pink / yellow / orange flowers

8. How many microliters of nectar are there in a bird-pollinated flower? Also indicate what flower you measured. **(2)**

_____

_____

9. What percentage of the nectar is sugar? **(1) E.g. 15%**

_____

10. Name any two bird species that play an important role in the pollination of plants in the Fynbos Biome? **(2)**

_____

_____

11. Name one bird species that you have seen in the garden today that plays a role in seed dispersal. **(1)**

_____

12. What would you expect to pollinate these daisies (can be more than one)? **(2) (flowers to be provided)**

_____

_____

13. What happens to the flower after it has been pollinated? **(1)**

_____

14. What can you do to help your school garden? Name three things **(3).**

_____

_____

_____

15. Soil preparing before planting in your garden is very important (**True or False**). **(1)**

_____

Appendix 4.4: Questionnaire

THE IINGCUNGCU PROJECT: restoring birds, building biodiversity leadership

1) Whether this study will help identify and nurture leadership for biodiversity?

a) Did the study manage to identify future leaders for biodiversity?

Hypothesis

2) Providing biodiversity knowledge to leaners can lead to an increased awareness of nature and inspire leadership for biodiversity whereas little or limited awareness could be reported from leaners who did not receive such knowledge.

Questionnaire

The aim of this questionnaire is to test the effectiveness of our intervention with the high school learners, especially to show significance of the role the Iingcungcu Project has played in inspiring a shift in attitudes towards biodiversity interest, knowledge and leadership.

The questionnaire should possibly take a maximum of 10 minutes to complete.

NB: Participation in this research is not compulsory, but encouraged.

* Required

Sex *

- Male
- Female

Date of Birth *

dd/mm/yyyy

Does your school have a bird friendly garden? *

- Yes
- No

Are you aware of the IINGCUNGCU PROJECT running at your school? *

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

1	2	3	4	5	6	7
○	○	○	○	○	○	○

Name other schools, which are part of the IINGCUNGCU PROJECT. *

Does your school encourage leaners to plant a bird friendly garden at home? *

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

1	2	3	4	5	6	7
○	○	○	○	○	○	○

Do you have a bird friendly garden at home? *

Skip the next two questions if your answer is No, here.

- ☐ Yes
- ☐ No

I talk to my family and friends about the Iingcungcu Project. *

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

1	2	3	4	5	6	7
○	○	○	○	○	○	○

I take notice of birds around me. *

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

1	2	3	4	5	6	7
○	○	○	○	○	○	○

What season is the right time to plant a bird friendly garden? *

Choose the best possible answer from the list provided.

- ○ Summer
- ○ Spring
- ○ Autumn

- Winter
- None of the above

What does a Sunbird or Sugarbird feed on? *

Choose the best possible answer from the list provided.

- Insects, Lizards and small frogs
- Green flowers with Long tubes
- Long-tubed, yellow and red flowers; and insects
- Scented tubular flowers with nectar.
- All of the above

Which kind of flowers in your opinion attracts sugarbirds and sunbirds birds? *

Choose the best possible answer from the list provided.

- Tubular flowers
- Red and yellow tubular flowers
- Nectar producing flowers
- Proteas and Ericas
- All of the above

Planting more nectar rich plants in my garden can attract more birds. *

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

1	2	3	4	5	6	7
○	○	○	○	○	○	○

Using common or scientific names; name as many plants currently growing in your school garden. *

Pigeons are good pollinators. *

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

1	2	3	4	5	6	7
○	○	○	○	○	○	○

Protecting nature is not cool. *

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

1	2	3	4	5	6	7

○ ○ ○ ○ ○ ○ ○

Littering at my school is not cool. *

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

1 2 3 4 5 6 7

○ ○ ○ ○ ○ ○ ○

People make too much of a big deal of littering in my opinion. *

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

1 2 3 4 5 6 7

○ ○ ○ ○ ○ ○ ○

Vandalising my school garden is not cool. *

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

1 2 3 4 5 6 7

○ ○ ○ ○ ○ ○ ○

I would like to study natural sciences, nature conservation or horticulture after leaving high school. *

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

1 2 3 4 5 6 7

○ ○ ○ ○ ○ ○ ○

I participate in community litter clean-up projects after school. *

☐ Yes

☐ No

Involvement in group projects encourages me to take on responsibility.

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

1 2 3 4 5 6 7

○ ○ ○ ○ ○ ○ ○

Being involved in natural sciences projects makes me feel good about myself. *

Strongly Disagree 1 2 3 4 5 6 7 Strongly Agree

1 2 3 4 5 6 7

I am happy for my answers to be used for the Iingcungcu Project.

- [ ] Yes
- [ ] No

Which Grade 10 Class are you from i.e. A, B, C, D, E & F *

- [ ] Grade 10 A
- [ ] Grade 10 B
- [ ] Grade 10 C
- [ ] Grade 10 D
- [ ] Grade 10 E
- [ ] Grade 10 F