Foraging for fruits: natural resource use and its conservation potential in urban environments

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

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Abstract

Wild edible fruits (WEFs) are a type of natural resource that humans across the world collect from diverse natural landscapes. They are among the most used non-timber forest products (NTFPs) and wild foods, and often serve more than a nutritional purpose for humans, in the form of fibre, fuel, medicine, and other products. The use of WEFs may augment household dietary diversity, food security, and income in some contexts. The prevalence of WEF species across the spectrum of natural to modified ecosystems presents the potential for integrated landscape-level conservation efforts centred on these species. The first half of this thesis investigates the state of knowledge about this versatile and ubiquitous resource in the wider context of other wild foods and NTFPs, and compares the patterns of use of WEFs with those of other wild foods and NTFPs. Through these studies, I find that WEFs are indeed a widely occurring, resilient, and useful resource along the rural-urban gradient. They are unique in that their use transcends the geographical and socio-economic criteria that influence the use of other wild foods and NTFPs.

Based on these findings, in the second half of the thesis, I propose the use-based conservation of WEF species in urban landscapes through the practice of urban foraging. Through interviews with urban land managers and foragers, I describe the state of urban green space management and urban foraging, and identify synergies between the two. Green space management is increasingly devolved and well-defined in developed cities, and relatively diffused in smaller towns, but nevertheless supportive of use-based biodiversity conservation. Planting and foraging for WEFs in urban green spaces ties in with local and national objectives of urban land use management policy. However, the lack of information on species, spaces, and sustainability related to foraging are a hindrance to addressing this activity and harnessing its conservation potential. Foragers use a variety of WEF species collected from natural as well as highly used and urbanised areas in their cities. Although most foragers consider foraging as a cultural and recreational activity, many of them agreed with the prospect of commercialising or popularising it to protect and promote the biodiversity and culture associated with their foraging spaces.

The synthesis of this study presents four possible pathways to conserve the diversity of WEF species, and to extend the benefits of WEF use to landscape stewardship. It identifies key stakeholders in implementing these pathways and possible collaborations between these stakeholders; the multiple conservation objectives and policies these pathways respond to; and context-specific considerations for policy and implementation related to planting and foraging of WEFs.

Keywords: land use policy, natural resource management, stewardship, urban biodiversity, urban foraging, use-based conservation, wild edible fruits

Declaration

I, Mallika Sardeshpande, hereby declare that the work contained in this thesis is my own original work, and that all sources used or quoted have been fully acknowledged and referenced. The work has not been submitted for examination or award of any other degree at any other university.

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List of abbreviations

BOSMAP	Biodiversity and Open Spaces Management Plan
CBD	Convention on Biological Diversity
CPR	Common-Pool Resource
DAFF	Department of Agriculture, Forests, and Fisheries
DHS	Demographic and Health Surveys
DMOSS	Durban Metropolitan Open Space System
EDTEA	Department of Economic Development, Tourism, and Environmental Affairs
EPIP	Extended Public Infrastructure Programme
EPWP	Extended Public Works Programme
ESMP	Ecosystem Services Management Plan
HFIAS	Household Food Insecurity and Access Score
NGO	Non-Governmental Organisation
NTFP	Non-Timber Forest Product
RDP	Reconstruction and Development Programme
SANBI	South African National Biodiversity Institute
SASSA	South African Social Security Agency
SDG	Sustainable Development Goal
SES	Social-Ecological System
WCT	Wildlands Conservation Trust
WEF	Wild Edible Fruit

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Chapter 1. Introduction

1.1. Background

Around the world, about a billion people depend on wild landscapes such as forests and grasslands to gather natural resources for their subsistence and livelihoods (Agrawal et al. 2013). Particularly in developing nations, a significant part of the income of rural households is based on natural resources collected from surrounding landscapes (Angelsen et al. 2014). These natural resources, collectively known as non-timber forest products (NTFPs), include all biological products, excluding high-value timber, extracted from unmanaged or modified natural landscapes for human use (Shackleton et al. 2011). NTFPs are a diverse suite of mostly uncultivated, gathered natural resources that provide food in the form of bushmeat, fruits, fungi, honey, insects, nuts, and vegetables (Hickey et al. 2016, Coad et al. 2019), medicine extracted from bark, fruits, leaves, and roots (Furukawa et al. 2016, Toda et al. 2017), as well as fibre and wood used for a variety of household purposes such as baskets, construction, and fuel (Angelsen et al. 2014, Wunder et al. 2014a). Some NTFPs have significance in traditional crafts (Virapongse et al. 2014, Gebauer et al. 2016) and cultural ceremonies (Sonricker Hansen et al. 2012, Levang et al. 2015, Soumya et al. 2019). The use and sale of NTFPs not only contributes to the regular household economy, but also helps individuals and households tide over conditions of socioeconomic or environmental vulnerability and shock. Access to NTFPs allows people to provision for or supplement their household economy in case of death or disease of family members, or unforeseen poverty (Paumgarten and Shackleton 2011, Ncube et al. 2016, Weyer et al. 2018), and also during severe droughts, floods, winters, or wars (Adam et al. 2013, Hummer 2013, Woittiez et al. 2013, Zeidemann et al. 2014).

1.1.1. The context of NTFP use

In most literature, NTFPs are traditionally regarded as a group of biological resources that are generally collected and traded informally, by forest-dwelling or rural households, from wild, fallow, or modified landscapes (Angelsen et al. 2014, Wunder et al. 2014a, 2014b, Hickey et al. 2016). It is thus inferred, and in some cases statistically proven, that NTFP use is associated with household proximity to wilderness (Brashares et al. 2011, Cooper et al. 2018) such as forests and protected areas, from which these resources are collected or hunted. Similarly, NTFP use is also observed to be prevalent in areas with access to road networks (Kar and Jacobson 2012, Hitztaler and Bergen 2013) and markets (Ofundem et al. 2017, Mugido and Shackleton 2018), allowing for the transportation and trade of these resources. The use of NTFPs is associated with outcomes of improved household food security (Powell et al. 2015, Vira et al. 2015) by supplementation of agricultural or market-purchased produce. In some cases, NTFP use may lead to greater household dietary diversity

(Bakkegaard et al. 2017, Chakona and Shackleton 2019) resulting from the use of wild foods that may not be available or affordable in the mainstream market. Further, NTFP use may also result in poverty alleviation (Paumgarten et al. 2018, Shackleton and Pullanikattil 2018), either through savings on household expenditure, or by additional income from the sale of raw or processed NTFPs (Cosyns et al. 2011). This relationship between NTFP use and household income have led some authors to suggest that NTFPs provide only subsistence and supplementary benefits to poor households, but do not contribute to wealth creation, and are therefore 'poverty traps' (Sheil and Wunder 2002, Belcher et al. 2005, Ros-Tonen and Wiersum 2005). However, this proposition has since been much debated, and current empirical evidence posits that the links between NTFP use and household status and location are context-specific (Wunder et al. 2014a, 2014b), and including but not defined by household poverty or wealth (Belcher and Schreckenberg 2007, Shackleton and Pullanikkatil 2018).

Although the aforementioned links between NTFPs and local and household characteristics hold true within their study areas, the literature also contains examples of exceptions to these generalisations. NTFPs are extracted not only in wilderness areas, but also in intensively managed agricultural and silvicultural landscapes (Levang et al. 2015, Tomao et al. 2017, Leakey 2018, Novello et al. 2018), as well as highly modified and developed urban areas (Hurley et al. 2015, Kaoma and Shackleton 2015, Shackleton et al. 2017). While informal NTFP trade in local markets may be difficult to quantify (Brokamp et al. 2011, Mugido and Shackleton 2018), there are notable examples of well-established, organised, regional supply chains and markets for certain NTFP species or their processed products (Trevisan et al. 2015, da Silva et al. 2017). The links between NTFP use and household food security, dietary diversity, and poverty may not always be causal or directional. For example, in some cases, wealthy households with already high food security use more bushmeat than poorer food insecure households that cannot afford to purchase hunting equipment (Sakai et al. 2016). Similarly, households with greater dietary diversity from wild food use may reflect a level of poverty that prevents them from purchasing food from markets (Chakona and Shackleton 2019), or a level of wealth that allows them to purchase it at an extra cost that is otherwise unaffordable for the average household (Sneyd 2013). NTFPs are used by households across the economic spectrum (Angelsen et al. 2014, Wunder et al. 2014a), and while they might help some to ameliorate their living conditions, they are also used by wealthy households capable of investing capital and effort in sourcing and adding value to them (Sakai et al. 2016, Bakkegaard et al. 2017). One of the main gaps in the knowledge on NTFPs is the lack of conclusive evidence on the scale and context at which different ecological and socioeconomic factors influence or motivate the use of NTFPs.

1.1.2. Biodiversity conservation and NTFPs

In biodiversity conservation initiatives, NTFPs are commonly recognised for their provisioning ecosystem services, and promoted as a livelihood alternative, or a use-based trade-off between conservation and human development (Shackleton and Pandey 2014, Bauch et al. 2014, Krause and Nielsen 2014, Loaiza et al. 2015, Pailler et al. 2015). NTFP extraction occurs in and around protected areas, and communal and state-owned forests (Clements et al. 2014, Mansourian et al. 2014, Zeidemann et al. 2014), where it is often encouraged as an incentive to counter illegal and unsustainable hunting and logging (Rasolofoson et al. 2015). The Reducing Emissions from Deforestation and Degradation of forests (REDD+) scheme (Jagger et al. 2012), and concession or conservation areas within and around commercial plantations in the rainforests of the Amazon (Shanley et al. 2012) and Borneo (Sakai et al. 2016) are examples of policy mechanisms to promote NTFP extraction. The effectiveness of such a strategy is debated by scientists for various reasons. One concern is that human presence and activity may deter wildlife from using habitats (Karanth et al. 2006, Anand et al. 2008). A second issue is that extraction of NTFPs, if done indiscriminately or intensively, may impact the health of the NTFP species, population, or ecosystem they occur in (Shackleton et al. 2018). For instance, overextraction of fruits may reduce seedling recruitment and therefore the population of *Euterpe edulis* palms (Muler et al. 2014). Similarly, overextraction of fruits may increase light penetration to the understory of *Bertholletia excelsa* plants (Rockwell et al. 2015). Whereas the removal of leaves can significantly reduce their contribution to soil nutrients, removal of fruits is less detrimental (Ruwanza and Shackleton 2017). Thirdly, illegal activities sometimes continue to occur under the guise of legal NTFP extraction (Gubbi and MacMillan 2008, Bauch et al. 2014, Rasolofoson et al. 2015). As an example, some communities living within conservation areas undertake cattle ranching illegally alongside NTFP collection in the Brazilian Amazon (Lopes et al. 2019). Therefore, the promotion of NTFP use in areas of conservation value requires consideration to human-wildlife interactions, sustainable practices, and resource and ecosystem monitoring.

Research on plant NTFPs has found that different species have differing responses to various disturbances and harvest practices (Rockwell et al. 2015, Gaoue et al. 2016). For example, among palms, some *Phoenix* spp. are resilient to fire and herbivory (Mandle et al. 2013), and some *Chamaedorea* spp. are unaffected by removal of up to 50% of their foliage (Lent et al. 2014), but some *Astrocaryum* spp. cannot survive removal of more than 5% of their leaves (Garcia et al. 2016). The literature contains some notable examples of resilient wild edible fruit species, such as *Bertholletia excelsa* (Scoles and Gribel 2015), and *Phyllanthus* spp. (Varghese et al. 2015), which respond positively to harvest, and multiple species that thrive in fallow landscapes (Lankoandé et al.

2017, Mabhaudhi et al. 2017). It is necessary to disseminate information on NTFP species that are resilient to human harvesting and extreme ecological conditions, as well as information about sustainable harvest levels and practices, among land managers, policymakers, and NTFP users. Such an exchange of information will help to optimise harvests and benefits from NTFPs extraction, and also to design related incentives and policies.

Besides occurring naturally in relatively unmodified and biodiverse landscapes, NTFP species are also introduced or retained within commercial plantations and agricultural systems to supplement production (McLellan and Brown 2017, Tomao et al. 2017, Novello et al. 2018), as part of biodiversity offsets (Shanley et al. 2012, Rockwell et al. 2015, Sakai et al. 2016), and also to serve as wildlife passages through areas of high human disturbance, such as cities (Champness et al. 2019, Zietsman et al. 2019). NTFPs offer a gene pool of a range of alternative food species, which can supplement production and are resilient to climatic extremes (Mabhaudhi et al. 2017, Hazarika and Pongener 2018). Such species are especially important in a changing climate that requires adaptable food systems (Shackleton 2014, Vira et al. 2015, Balama et al. 2016, Leakey 2018). Thus, besides their provisioning and supporting ecosystem services, NTFPs are a valuable biodiversity resource. NTFPs offer diversification of species as well as products, and integration of other biodiversity such as birds and insects, within production systems (Isbell et al. 2015, Montoya-Molina et al. 2016). They are therefore a crucial component of inclusive agroecological systems, as opposed to industrial agriculture, which aims to optimise intensive production, sparing prisitine ecosystems for biodiversity in the process (Phalan et al. 2011, Wilhelm and Smith 2018). Although NTFPs also occur and are foraged in cities, the literature on NTFP use in urban areas is scarce (Shackleton et al. 2017), and its links to biodiversity are yet to be explored (Buijs et al. 2019, Nyman 2019, Sardeshpande and Shackleton 2019). Another significant gap in the knowledge on NTFPs is the sources and use of NTFPs in urban contexts, and how their management can be linked to biodiversity conservation in cities. A relatively recent approach to conservation, the biocultural diversity framework (Elands et al. 2019), espouses the need to recognise the cultural services and role of biodiversity and integrate it into conservation strategies. With their long-standing cultural significance spanning forest-dwelling, agrarian, and urban communities, NTFPs represent an important interface between cultural and biological diversity (Mabhaudhi et al. 2016, Kowarik 2018, Landor-Yamagata et al. 2018, Ribeiro et al. 2018, Soumya et al. 2019). Therefore, the study of the cultural significance of NTFPs provides valuable opportunities for further research and development of the concept of biocultural diversity as well as conservation strategies based on it. I elaborate on the links between the culture and natural resource management regimes in the following sections.

1.1.3. Access and management of NTFPs

NTFPs are usually readily available, untended and uncultivated common pool resources extracted from natural and modified environments by users (Richardson 2010, Mansourian et al. 2014, Cooper et al. 2018). The literature posits that open access to NTFPs allows users the benefits of food, fibre, fuel, and healthcare at relatively low costs or investment of effort as compared to purchasing or cultivating these resources (Paumgarten and Shackleton 2011, Weyer et al. 2018). However, access to NTFPs does not necessarily lead to their utilisation. Examples of such cases include the underutilisation of wild foods, either due to lack of knowledge among the rural or urban populace (Ngome et al. 2017, Chakona and Shackleton 2019), or due to their unavailability or unaffordability in mainstream markets (Sneyd 2013, Mollee et al. 2017). In some cases, the benefits of profitable NTFPs such as highly valued bushmeat or secondary fruit products tend to accrue with wealthier households that can invest capital in procuring or processing them (Cosyns et al. 2011, Angelsen et al. 2014, Bakkegaard et al. 2017). Some NTFPs, particularly wild edible fruits (WEFs), can be found growing abundantly in agroecological landscapes (Fentahun and Hager 2010, Haglund et al. 2011, Adam et al. 2013, Novello et al. 2018), whereas some others occur only in specific ecological conditions or regions, or require technical know-how or specialised equipment for selective picking or hunting (Brokamp et al. 2011, Wunder et al. 2014a, Isaza et al. 2017, Bakkegaard et al. 2017). Thus, access to NTFPs influences the nature and extent of benefits they provide to their users. Access to, and subsequent use of NTFPs may vary along the gradients of biological diversity, human population density, rainfall, temperature, and urbanisation (Bakkegaard et al. 2017, Broegaard et al. 2017, Rasmussen et al. 2017, Cooper et al. 2018). The existing literature consists of meta-analyses of small-scale studies across the world, but few studies look at regional-level relationships between these factors and NTFP use (Sardeshpande and Shackleton 2019).

Natural resource management in forested and communal areas, especially in the case of NTFPs, is often governed by long-standing traditional regimes. Traditional governance tends to incorporate wider goals of biodiversity conservation by propagating genetic resources in agroforestry and silvipastoral systems (Parra et al. 2012, Contreras-Negrete et al. 2015, Novello et al. 2018) and landscape management practices including fire and grazing (Lent et al. 2014, Levang et al. 2015, Varghese et al. 2015). Often, these management strategies are based on devolved and dynamic tenure rights that encourage judicious spatio-temporal use, and equitable distribution of access and benefits among the community (Jagger et al. 2012, Clements et al. 2014, Mansourian et al. 2014), and employ local ecological knowledge to sustain NTFP harvests as well as their ecosystems (Wynberg 2017). For instance, Canadian indigenous peoples use temporal and aesthetic observations to assess the quality of resources and the ecosystem (Mantyka-Pringle et al. 2017), and

Brazilian harvesters of the *Bertholletia excelsa* nut demonstrated traditional knowledge on productivity that matched scientific calculations (Thomas et al. 2017). Thus, NTFPs present a crucial confluence of traditional ecological knowledge, natural resource management, landscape governance, and biodiversity conservation. However, in some cases, traditional regimes may not be formally recognised, and are overridden by centralised institutions or private entities that claim ownership of the land for conservation or commercial purposes (Phelps et al. 2010, Ruiz-Mallén and Corbera 2013, Tieguhong et al. 2015, El Tahir and Vishwanath 2015, Ball and Brancalion 2016, Lund et al. 2017). Such centralisation or privatisation of land use and governance can destabilise the social-ecological systems under which NTFP harvests have erstwhile been sustainable. On the other hand, natural resource management in cities, particularly urban open space governance, is usually either highly informal or highly regulated (Sténs and Sandström 2013, Rupprecht and Byrne 2014, Wang et al. 2014). In such a scenario, the extraction of NTFPs in urban areas is either mostly unregulated or mostly prohibited (Synk et al. 2017, Charnley et al. 2018). Sustainable management of NTFPs and the ecosystems they occur in calls for the recognition of both traditional as well as scientific knowledge on their ecology, and collaboration between different land users towards their governance.

1.1.4. Governance and policy for sustainable NTFP use

Governance of natural resource and supply chain management can play a pivotal role in NTFP use and trade. NTFP governance is effected in different cases through communal traditional regimes (Ruiz-Mallén and Corbera 2013, Winter and Lucas 2017), conservation schemes such as joint forest management programmes (Pailler et al. 2015, Rasolofoson et al. 2015), as well as by national policy (Awono et al. 2016, Ingram 2017). The role of governance is to ensure secure access and tenure rights to spaces from which NTFPs are extracted, as well as guidelines on quantity and temporal allocations, such as who has access to these spaces, and when. In some cases, governments also offer institutional support to NTFP users in the form of capacity building and infrastructure to store, process, and market NTFPs, although this is often with a focus on scaleable commercialisation of specific species (Shumsky et al. 2014, Ndeinoma et al. 2018). In other contexts, citizen groups and non-governmental organisations self-organise to bring about such development (Ingram 2017, Ndeinoma and Wiersum 2017). NTFP supply chains may be relatively short, such as forager to restaurant supply chains (Schmutz et al. 2017, Thomas-Francois et al. 2017), or long and spanning regional scales, as in the case of some Amazonian palm products (Brokamp et al. 2011, da Silva et al. 2017) and the African baobab (Gebauer et al. 2016). Policy instruments to track and ensure transparency, sustainability, and equitable benefit distribution in such value chains are scarce, and these chains are usually self-regulated or unregulated (Sardeshpande and Shackleton 2019).

Informal or unregulated markets may drive overharvesting or domestication of NTFPs, or result in incongruous benefit distribution (Ball and Brancalion 2016, Ofundem et al. 2017, Mugido and Shackleton 2018). For instance, in some cases, lack of infrastructure or policy allows intermediaries to capture revenue without adding value in NTFP supply chains (Awono et al. 2013, El Tahir and Vishwanath 2015). Although supply chain certification can help overcome unsustainable harvest and promote benefit penetration, ambiguous policy and high costs may inhibit this process (Schunko et al. 2015). Policy on natural resource management needs to recognise the diverse and devolved governance and supply chain systems that NTFPs are used in, and provide assistance without the end goal of formalisation or commercialisation.

In the urban context, governance of NTFPs and policy responses are further diluted, often due to unclear or restrictive access and tenure (Sténs and Sandström 2013, Hurley et al. 2015, Shackleton et al. 2017). NTFP use in urban areas can be tied into existing land use planning and policy, particularly in urban green spaces. The recent literature discusses potential avenues for developing multifunctional green infrastructure (Artmann et al. 2019, Hansen et al. 2019). Whereas some authors emphasise the role of NTFPs in urban green spaces for their provisioning and supporting services (Rupprecht and Byrne 2014, Kaoma and Shackleton 2015), others highlight the recreational and cultural significance of NTFPs and the activity of foraging for them (Hurley et al. 2015, Landor-Yamagata et al. 2018). The inclusion of NTFPs in urban open spaces adds an interface for improved governance through co-management of these spaces and the resources that they harbour (Molin and van den Bosch 2014, Mathers et al. 2015, Rist et al. 2016). Further, legitimising the use of NTFPs in urban open spaces allows for the propagation of cultural practices and traditional knowledge associated with them, which is the central aspect of biocultural diversity (Buijs et al. 2019, Elands et al. 2019). The current literature on urban NTFPs is limited (Shackleton et al. 2017), and focuses on the nature of the green spaces they occur in (Rupprecht et al. 2015, Ward and Shackleton 2016), or their users and their motivations and practices (Kowarik 2018, Threlfall and Kendal 2018). The links between urban NTFP use and policy in the literature are explored, but limited to local user and land manager perspectives (McLain et al. 2012, Charnley et al. 2018), and predominantly from the Global North (Kabisch et al. 2015, Botzat et al. 2016). Given the role NTFPs play in alleviating food insecurity and poverty and biodiversity conservation, there is ample reason to incorporate them into urban planning.

1.2. Conceptual framing: the focus on Wild Edible Fruits (WEFs)

I argue that due to the varied nature of resources grouped together as NTFPs, their relationships to scale and context, biodiversity conservation, management, and policy are confounded. For instance, the influencing factors and implications of the use and trade of fuelwood, a relatively accessible and commonly used resource, are very different from those that apply to the medicinal bark of a tree (Baldauf et al. 2014), a multipurpose fruit with a global market (Venter and Witkowski 2013), or underutilised nutritious herbs (Ngome et al. 2017). Fuelwood extraction is generally more geographically widespread, remunerative, and non-specific in terms of species, ecology, land tenure, and users (Angelsen et al. 2014, Kazungu et al. 2020). Conservation policies that advocate the use of other NTFPs do not encourage the use of fuelwood due to the potential adverse ecosystem impacts of forest fragmentation and degradation (Rasmussen et al. 2017). Medicinal bark removal forms a relatively small proportion of NTFPs harvested globally, and may or may not impact the vitality of the plant depending on the species (Schumann et al. 2010, Haarmeyer et al. 2013, Baldauf et al. 2014). Wild edible fruits (WEFs) are widely used across the world, with some WEFs being further processed into high value products that are in great demand in local and international markets (Brokamp et al. 2011). Examples include *Adansonia digitata* (Gebauer et al. 2016), *Caryocar coriaceum* (da Silva et al. 2017), and *Sclerocarya birrea* (Maroyi 2014). The extent of the use and trade of these NTFPs and their products requires policy safeguards to ensure sustainable harvests, equitable access and benefit distribution, and supply chain transparency (Wynberg 2017). On the other hand, underutilised food species require policy and institutional support for valorisation and propagation (de Oliveira Beltrame et al. 2018, Gregory et al. 2019).

Therefore, in my thesis, I trifurcate NTFPs into three groups, namely, WEFs, other wild foods (including bushmeat, herbs, honey, vegetables, etc.), and non-food NTFPs (such as fuelwood, fibre, leather, etc.). I define the term wild edible fruit as the reproductive structure of angiosperms, of any undomesticated species. This trifurcation is based on three rationales: (i) the patterns of food and non-food NTFP use and trade are likely to be different with respect to determinants, drivers, and household food security and dietary diversity. For example, WEFs and other wild foods may have more direct connections to household food security and dietary diversity, whereas the use of non-food NTFPs may be dependent on proximity to wilderness areas (Cooper et al. 2018, Rasmussen et al. 2020); (ii) WEFs are among the most used, most versatile wild foods and NTFPs, globally, as well as in South Africa (Hickey et al. 2016, Sardeshpande and Shackleton 2019, Welcome and Van Wyk 2019); and (iii) the degree of impacts on species and ecosystems varies with the type of resource extraction. As examples, among the different plant parts extracted as NTFPs, WEFs have the highest ratio of yield to sustainable harvest, about 90% of all fruits (Gaoue et al. 2016, Sardeshpande and

Shackleton 2019); similarly, with regard to ecosystem impacts, extraction of WEFs results in low biomass removal and subsequent soil nutrient subtraction (Ruwanza and Shackleton 2017). Therefore, with these three aforementioned categories of natural resources, I investigate the first problem statement:

What are the patterns of use of the three categories of natural resources across ecological, economic, and social gradients?

The first research question addresses the aspects of context of NTFP use and access to NTFPs. It investigates the documented availability and observed utilisation of WEFs across South Africa's biomes; and compares the three classes of NTFPs based on their sources, user attributes, and urbanisation gradient as indicators of access. On the basis of the finding that WEFs are most readily accessible NTFPs across the socioeconomic and urbanisation continuum, the second research question seeks ways of improving access to WEFs, and governing their use as a common pool resource. Based on the high occurrence and use of WEFs as well as other NTFPs in urban centres in the highly biodiverse Indian Ocean Coastal Belt, the second research question seeks to identify opportunities to link WEF foraging to urban biodiversity conservation through policy and multi-stakeholder collaboration in urban green space management. My second problem statement is:

What synergies exist and can be established between the use and management of wild edible fruits and wider goals of biodiversity conservation and sustainable development?

I use this information to construct four potential pathways for the future where land management authortities proactively plant species for urban WEF foraging, and elaborate the ways to achieve them. I also list various specific concerns and considerations that would have to be taken into account if urban foraging were to be encouraged and taken up widely, and identify the different actors and collaborations that would be crucial to the realisation of these scenarios. Ultimately, the thesis ties together the governance and policy mechanisms required for sustainable WEF use and conservation with the existing governance and policy mechanisms and commitments on biodiversity conservation and sustainable development, on the national and global level.

1.3. Theoretical framing: collaborative conservation of common-pool resources

In this thesis, I use the common-pool resource (CPR) theory to investigate the pathways of use and conservation of NTFPs, and specifically, wild edible fruits (WEFs). CPR theory examines the conditions under which resources are managed, with the objective of sustainable governance through collective action (Fleischman et al. 2014). The theory was developed by Ostrom (1990) on the premise that openly accessible resources with little or no tenure or regulation are vulnerable to depletion due to overuse and misuse. Such degradation of shared resources due to lack of collective governance was termed the tragedy of the commons (Olson 1965, Hardin 1968). CPR theory responds to this standpoint on the tragedy of the commons by identifying different actors, institutions, and regimes that either have, or can, govern such shared resources for long-term sustainability. CPR theory conceptualises the context of CPR governance in the form of the social-ecological system (SES) framework, and evaluates how its components interact to give rise to different outcomes. A SES typically comprises of four components, namely, actor groups, governance systems, resource units, and resource systems (Ostrom 2009). Actor groups are defined as groups of individuals, organisations, or entities that interact with the CPR; governance systems are a set of arrangements, such as policies, rules, or regimes, instituted by one or more actor groups to manage the CPR; resource units are the CPR in focus; and resource systems are the ecological environment in which the CPR occurs. Resource units and resource systems may often be grouped together as environmental commons, or simply commons (Cox 2014). In this thesis, the actor groups in focus are the users of WEFs, other wild foods, and non-food NTFPs, particularly urban WEF foragers, and urban land managers; governance systems constitute the different stakeholder groups, and local, regional, and national policies involved in biodiversity conservation, sustainable development, and urban land management; resource units include various types of WEFs, other wild foods, and NTFPs used and governed by the actor groups and governance systems; and resource systems are represented by the biomes and ecosystems these CPRs occur in, especially urban open and green spaces.

The SES framework has proved useful in conceptualising, analysing, and linking various independent and nested theories, frameworks, and concepts on natural resource management, as well as in allied fields such as land use change, political economy, and systems resilience (Cox et al. 2016). Criticisms of the SES framework include that in focussing on specific systems, it may not account for interactions, especially between governance systems, across different scales, on regional or global levels (Stern 2011, Araral 2014). Being an analytical framework, it can provide a fine-scale description of an SES, but can rarely be used to model or predict processes or changes over time (Binder et al. 2013, Cole et al. 2019). Nevertheless, it provides a widely accepted terminology and typology to approach complex and dynamic systems (Fischer et al. 2015), and as a starting point to identify pathways for adaptation, transformation, and resilience in these systems (Carpenter et al. 2012, Barnes et al. 2017). One of the most central themes in CPR theory is community-based natural resource management (Cox 2014). I use the design principles for community-based natural resource management put forth by Cox et al. (2010) to evaluate the potential for use-based conservation of NTFPs, specifically, WEFs. The eight design principles advocate for demarcation of boundaries for

CPR users and CPR systems, definition of use and provision rules for the CPRs, collective participatory agreements around CPR use, accountability and monitoring of CPR use, sanctions against violation of rules and agreements, mechanisms to resolve conflicts regarding CPRs, allowing CPR users to self-organise, and nested levels for CPR governance (Table 1.1). The third chapter identifies the environmental commons (users and resource systems) and the prevailing nature of appropriation and provision of the CPRs across South Africa. The fourth chapter examines the current governance framework for mechanisms on appropriation and provision, collective-choice arrangements, monitoring, sanctions, conflict resolution, and institutionalistion. The fifth chapter investigates the existence, if any, and desirability, of the aforementioned design principles, as well as user and resource boundaries, among users. The final chapter presents four ways forward incorporating varying degrees and combinations of the eight design principles.

Design principles 7 and 8 open up avenues for devolved, polycentric, and collaborative governance. Indeed, such governance has proven instrumental to the implementation of conservation projects on large scales such as continental and marine protected area networks (Wyborn and Brixler 2013, Gruby and Basurto 2014), the Great Barrier Reef (Evans et al. 2014), large-range multiple use landscapes of conservation value (Guerrero et al. 2015), and river ecosystems across international borders (Villamayor-Tomas et al. 2016). Collaborative governance implicitly requires the alignment of shared motivations among stakeholders, and a level of trust between them (Emerson et al. 2012, Walsh et al. 2015, Borg et al. 2015). The process of learning through exchange of information and application of different types of knowledge is a key component of collaborative governance (Lauber et al. 2011, Cheng and Sturtevant 2012). Wyborn (2015) proposes a framework for co-production of governance through the iteration and interaction of cognitive, material, social, and normative knowledge. In this thesis, I identify these four types of knowledge, namely: what the literature offers on WEFs, other wild foods, and non-food NTFPs as CPRs (cognitive); what the use patterns of these CPRs are across different biomes and SESs (material); what use and governance mechanisms operate in these SESs (social); and how these use and governance mechanisms can collaboratively contribute to achieving common goals of the SES and CPR conservation (normative). The scope of this thesis allows for an iterative process only, and I do not analyse the interactions with power relations that may be inherent in, or may arise from, such co-production of governance (e.g. Fischer et al. 2015, Goodwin 2019). Figure 1.1 presents an overview of the conceptual, methodological, and theoretical framework of the the thesis.

Table 1.1: Design principles for community-based natural resource management (Cox et al. 2010)

Principle	Explanation
1A	User boundaries: Clear boundaries between legitimate users and nonusers must be clearly defined.
1B	Resource boundaries: Clear boundaries are present that define a resource system and separate it from the larger biophysical environment.
2A	Congruence with local conditions: Appropriation and provision rules are congruent with local social and environmental conditions.
2B	Appropriation and provision: The benefits obtained by users from a common-pool resource (CPR), as determined by appropriation rules, are proportional to the amount of inputs required in the form of labor, material, or money, as determined by provision rules.
3	Collective-choice arrangements: Most individuals affected by the operational rules can participate in modifying the operational rules.
4A	Monitoring users: Monitors who are accountable to the users monitor the appropriation and provision levels of the users.
4B	Monitoring the resource: Monitors who are accountable to the users monitor the condition of the resource.
5	Graduated sanctions: Appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and the context of the offense) by other appropriators, by officials accountable to the appropriators, or by both.
6	Conflict-resolution mechanisms: Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials.
7	Minimal recognition of rights to organize: The rights of appropriators to devise their own institutions are not challenged by external governmental authorities.
8	Nested enterprises: Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.

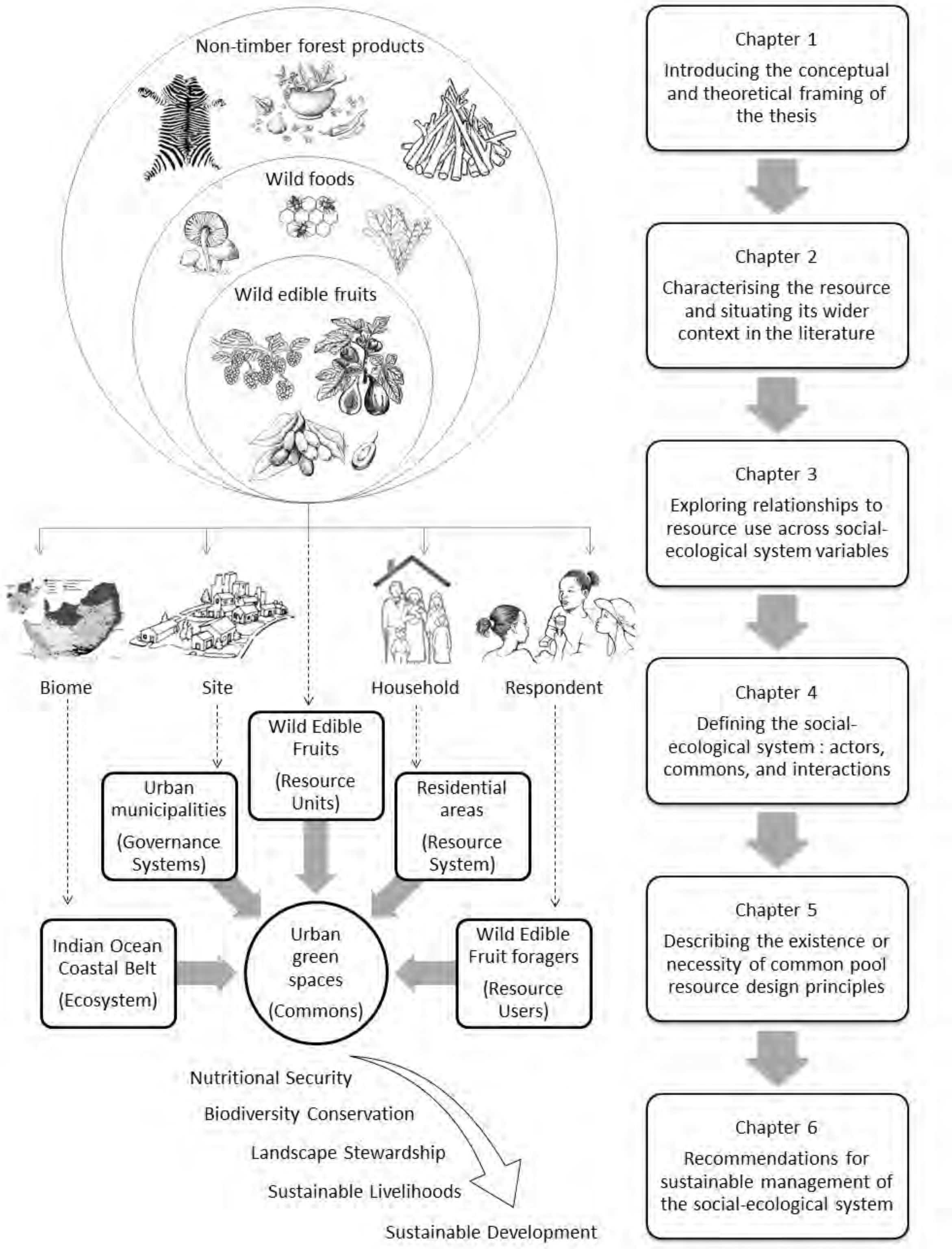

Figure 1.1 Conceptual, methodological, and theoretical framing of the thesis.[1]

[1] Representative illustrations sourced from various free vector websites that do not require attribution.

1.4. Structure of the thesis

This thesis is presented in four results chapters, each in the form of an independent research paper, followed by a synthesis and conclusion. Each chapter employs one or more different conceptual framework and methods to answer one or more research questions as summarised below:

Chapter 2: Systematic literature review of the literature on wild edible fruits

I established a baseline of the existing knowledge on WEFs, and contextualised it within the wider literature on other wild foods and non-food NTFPs. My research questions were (i) what is the current state of knowledge on WEFs? (ii) what are the gaps and gluts in the knowledge? (iii) what are the similarities, differences, or relationships, if any, between WEFs, other wild foods, and non-food NTFPs? This chapter has been published as a review paper in the journal *Forests* (2019, Volume 10).

Chapter 3: Scoping survey on the use of wild edible fruits, other wild foods, and non-food NTFPs

I surveyed 503 households across South Africa to establish a baseline of natural resource use and trade. Research questions sought out relationships and patterns, if any, between (i) household use of WEFs, other wild foods, and non-food NTFPs (ii) household attributes (demographics, food security, wealth) and the use of the three categories of natural resources (iii) ecological attributes (rainfall, temperature, human population) and the use of the three categories of natural resources.

Chapter 4: Land managers' perspectives on urban foraging of wild edible fruits

Through interviews with 15 land managers in eight urban municipalities, I ascertained the policies and actors that govern urban open spaces, and if foraging contravened or contributed to their objectives. Research questions were: (i) what are the different types of urban open spaces, and the institutions and policies governing them, if any? (ii) can or do the aims of these land management policies or institutions directly or indirectly address urban foraging, and how? (iii) what are the potential enablers and barriers to foraging in urban green spaces, and are environmental worldviews part of them?

Chapter 5: The nature of urban foraging for wild edible fruits

I interviewed 80 foragers in four urban municipalities in the Indian Ocean Coastal Belt to determine the motives behind urban foraging, the nature (location, frequency, yields) of foraging, and foragers' normative views of the future of foraging. Research questions included: (i) what are the pathways through which knowledge about foraging is propagated? (ii) what are the motivations, activities, and lands associated with foraging? (iii) what is the effort invested in and yield obtained from foraging? (iv) would foragers like for foraging to be popularised, legitimised, or commercialised, why, and how?

Chapter 6: Synthesis

The main findings from all the chapters are highlighted, and their links to biodiversity conservation and sustainable development are elaborated. The governance and policy implications of promoting planting and foraging of WEFs are also explored. Based on the information collected in the preceding chapters, I propose four potential ways forward for the active promotion of urban foraging for WEFs. These pathways are mapped on to the design principles for community-based natural resource management for a comparison. In conclusion, I identify opportunities for stakeholders to collaborate on improving the state of knowledge and synergies with regard to sustainable WEF use.

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Chapter 2. Wild edible fruits: a systematic review of an under-researched multifunctional NTFP[2]

Abstract

Wild edible fruits (WEFs) are among the most widely used non-timber forest products (NTFPs), and important sources of nutrition, medicine and income for their users. In addition to their use as food, WEF species may also yield fibre, fuel, and a range of processed products. Besides forests, WEF species also thrive in diverse environments such as agroforestry and urban landscapes, deserts, fallows, natural lands, and plantations. Given the multi-functional, ubiquitous nature of WEFs, I conducted a systematic review on the literature specific to WEFs, and highlighted links between different domains of the wider knowledge on NTFPs. I found that literature specific to WEFs was limited, and a majority of it reported ethnobotanical and taxonomic descriptions, with relatively few studies on landscape ecology, economics, and conservation of WEFs. This review identifies priorities and emerging avenues for research and policymaking to promote sustainable WEF management and use, and subsequent biodiversity and habitat conservation. In particular, I recommend that ecosystem services, economic incentives, market innovations, and stakeholder synergies are incorporated into WEF conservation strategies.

Keywords: conservation, markets, non-timber forest products, policy, research priorities, sustainability, wild edible fruits

2.1. Introduction

Non-timber forest products (NTFPs) can be defined as biological products, other than high value timber, harvested by humans from wild biodiversity in natural or human-modified environments (Shackleton et al. 2011a). About one billion people worldwide derive livelihoods and food from forest products (Agrawal et al. 2013), and around 300 million of these people depend extensively on NTFPs (Bharucha and Pretty 2010). It is estimated that on average, a quarter of the rural household income in developing nations comes from NTFPs (Angelsen et al. 2014). In central Africa alone, as many as 500 species of plants and 85 species of animals collected from forests and savannas contribute to the household economy (Ingram et al. 2010). In tropical and low income countries NTFPs are widely used for medicine (Ingram et al. 2010, Sakai et al. 2016, Toda et al. 2017) and nutrition (Jimoh and Haruna 2007, Ngome et al. 2017). While bushmeat is an important source of protein for rural and forest-dwelling communities (Nasi et al. 2011), animal parts feature in ceremonial practices in various cultures (Sonricker Hansen et al. 2012). At the household level,

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NTFPs improve food security worldwide (Quang and Anh 2006, Richardson 2010, Ahenkan and Boon 2011, Levang et al. 2015, Pailler et al. 2015, Ngome et al. 2017), through regular, direct consumption of harvested products, or as famine foods and safety nets in adverse periods, or income earned from selling them. Trade in NTFPs allows economically weaker households to maintain financial stability, especially during circumstances of shock and vulnerability (Shackleton and Shackleton 2004, Belcher et al. 2005, Shackleton et al. 2011a).

Wild foods such as bushmeat, insects, honey, fungi, wild vegetables, and wild edible fruits (WEFs) are a subset of NTFPs, and an important source of nutrition for one in six people worldwide (Vira et al. 2015). Wild foods can provide an open access source of food and income, especially to vulnerable groups such as the poor, malnourished children (McGarry and Shackleton 2009) and those affected by HIV/AIDS (Ncube et al. 2016). Diets including wild foods often also reflect greater diversity and quality of nutrients compared to those derived from cultivated foods (Rasmussen et al. 2017). Wild foods have also been found to improve household food security both under normal circumstances (Broegaard et al. 2017) as well as during periods of crop scarcity (Erskine et al. 2015), and in rural (Ngome et al. 2017) as well as urban contexts (Clark and Nicholas 2013). Wild foods need not be procured from forests alone, but also from managed landscapes like fallows and agroforestry systems, where they supplement and diversify food production and income, and enhance ecosystem services and climate resilience (Mbow et al. 2014, Shackleton 2014, Vira et al. 2015).

WEFs are among the most commonly used NTFPs (Cunningham and Shackleton 2004, Hickey et al. 2016), and some may also possess medicinal properties, therefore being used in treatment of ailments (Deshmukh and Shinde 2010, Hazarika et al. 2012, Hazarika and Pongener 2018). WEFs are used for a range of other purposes, such as cosmetics (Gebauer et al. 2016), crafts (Atato et al. 2012, Hazarika and Sigh 2018), fibre (Balslev et al. 2010, Karun et al. 2014), and fuel (Saied et al. 2008, Debela et al. 2012, Klimas et al. 2012). In the nutrition and pharmaceutical literature, WEFs have been widely studied and recommended as rich sources of antioxidants, minerals, and vitamins (Kamatou et al. 2011, Mahapatra and Panda 2012, Bvenura and Sivakumar 2017). I adhere to the definition of the term fruit as any part of the reproductive structure of angiosperms, and consider any undomesticated product extracted from wild or managed landscapes as wild. Thus, this definition of WEFs excludes mushrooms and horticulturally grown species such as apples, but includes undomesticated species from agroforestry systems, vacant lands, and private and public gardens.

In this review, I analyse the literature focused specifically on WEFs and identify priorities for WEF research and conservation. The questions that frame this review are: 1. What is the state of knowledge regarding the ecology, use, trade, policy, sustainability, and conservation of WEFs? 2. What are the gaps in knowledge about WEF ecology, use, and conservation? 3. What are the commonalities, differences, and relationships between knowledge on WEFs and other wild foods and NTFPs? The results are therefore presented in a manner that narrows down from broader information on NTFPs to wild foods and to specific evidence about WEFs.

2.2. Methods

The combinations 'non'+'timber'+'forest'+'product'+'fruit' and 'wild'+'edible'+'fruit' were used as English language search terms on Scopus and Web of Science, in mid-2017, for all time. Articles were refined to include the topics of agriculture, biology, economics, environmental science and studies, food science, forestry, plant science, social science, and urban studies. Thus, articles related to chemistry, engineering, genetics, immunology, medicine, microbiology, etc. were excluded. Together, these searches yielded a total of 1 080 unique results. This literature was screened for relevance to wild edible fruit conservation, ecology, economics, and ethnobotany. At this stage, articles on nutrient composition, historic and horticultural records, and pharmacology and toxicology of wild fruits (598) were excluded. Articles on wider topics such as NTFPs (150), wild edible plants (113), and mushrooms (34) were classified as secondary literature to provide the wider contextual setting for the literature specific to WEFs. The remaining articles (185) were classified into categories based on focus on fruit, and study category (Table 2.1). I acknowledge that articles that did not use the terms 'non-timber forest product' or 'wild edible' along with 'fruit' in their keywords or title are likely to have been excluded. Examples include articles referring to 'indigenous' or 'exotic' fruits (Leakey et al. 2004, Jamnadass et al. 2011), those using only common or scientific fruit names (Wynberg et al. 2003, Wynberg and Laird 2007, Shackleton et al. 2011b), and those that refer to a range of products of which fruits are a subset (Brokamp et al. 2011, da Silva et al. 2017). However, the 185 shortlisted articles are likely to present a reasonable representation of the knowledge about WEFs across different domains. I supplement this body of literature with articles from my own knowledge.

Studies that fit the inclusion criteria were also classified according to the region of the respective study sites. Findings and recommendations from these studies were summarised in the form of salient points in MS Excel.

Table 2.1: Selection and classification criteria for articles

A. Exclusion criteria	**Explanation**
Chemical composition	Articles on chemical and nutrient composition, medicinal and industrial use, and toxicology of wild edible fruits.
History and horticulture	Articles on archaeological evidence, historic use, domestication and cultivation of wild edible fruits.
Wild plants	Articles about various (edible and non-edible) uses of different (non-fruit) parts of wild plants.
Mushrooms	Mushroom sporocarps were not included under the definition of wild edible fruits.
Non-edible uses	Articles describing use of wild fruits other than food.
B. Inclusion criteria	**Explanation** (Fruit = seed-bearing angiosperm part)
1. Relevance of fruit in study	
Primary study subject is wild edible fruit	Studies on wild edible fruits of single or multiple use species, or wild edible fruits from a range of taxa.
Wild edible fruit is one of multiple study subjects	Studies on multiple use species that also bear wild edible fruit.
2. Category of study	
Conservation	Studies on sustainability, impacts of harvest across degrees of species and landscape management, threats, and best practices towards wild edible fruit resources.
Description	Articles documenting the regional diversity of wild edible fruit species used in certain regions, the range of uses, morphological characteristics, and regional distribution of taxa.
Ecology	Studies on the ecological dynamics of a taxon and or its ecosystem.
Economics	Articles documenting trade markets and supply chains of wild edible fruits, policy, and governance mechanisms.

2.3. Results

Of the 185 articles on WEFs, a quarter (n=47) focused on multi-use species that also bear edible fruits. The literature on WEFs has increased over the last three decades (Figure 2.1). Fewer articles were found on conservation and management, and the economics of WEF trade. About a third of the articles were based on studies in Africa, and a quarter from South America (Figure 2.2). Nearly half the articles were ethnobotanical and taxonomic descriptions (Table 2.2), while just over a quarter focused on the species or landscape ecology of WEF species.

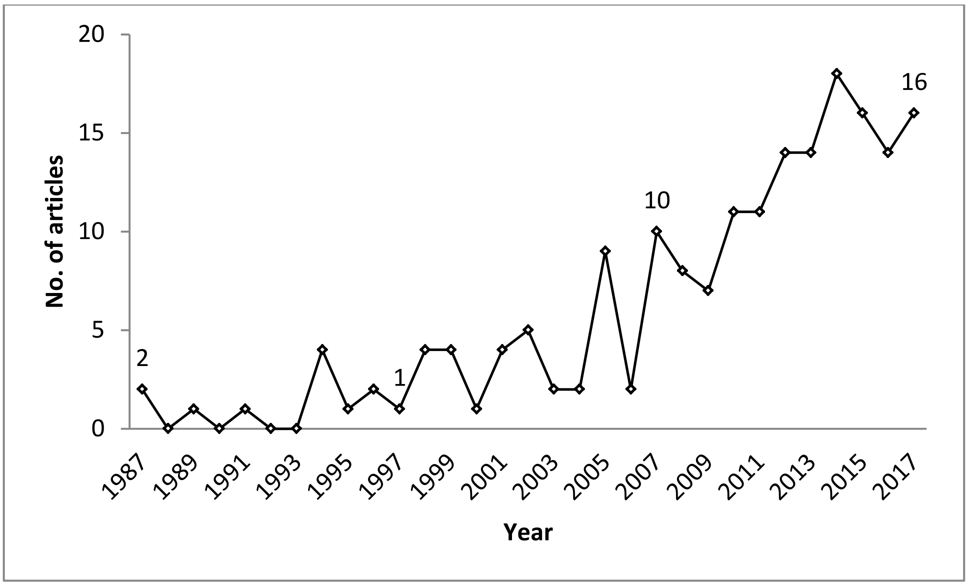

Figure 2.1: Number of articles per year on wild edible fruits. The count for 2017 was taken in October 2017.

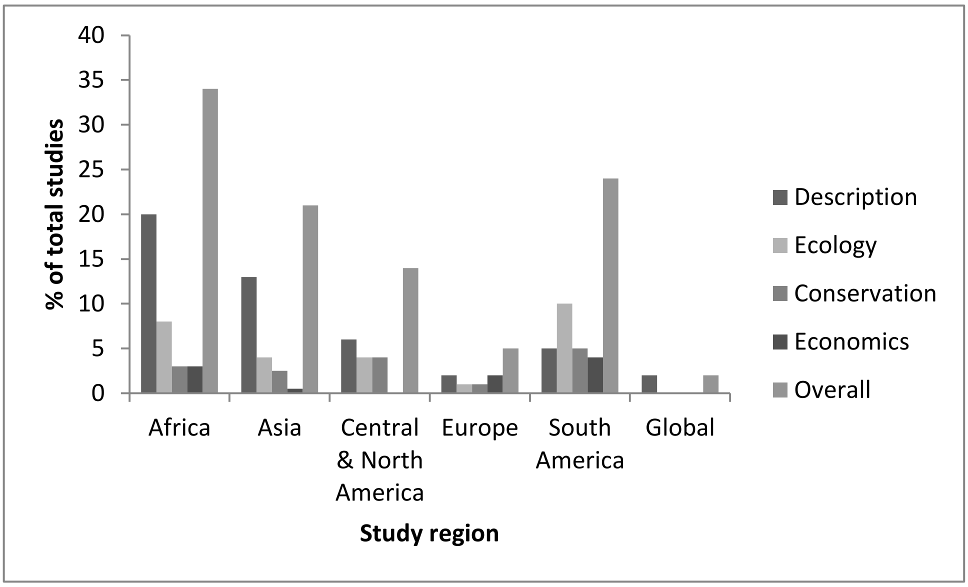

Figure 2.2: The distribution of study categories by region. Percentages are calculated from n=185.

Table 2.2: Numbers of different categories of articles

Category	Class	Africa	Asia	Central & North America	Europe	South America	World	Total	Per-cent-age
Description	Regional	18	17	0	1	1	0	37	20
	Taxonomic	20	7	11	2	9	4	53	28
Ecology	Species	11	5	8	2	14	0	40	21
	Landscape	3	3	0	0	5	0	11	6
Conservation	Threats	1	2	0	0	2	0	5	3
	Management	5	3	7	1	8	0	24	13
Economics	Supply chain	4	1	0	2	6	0	13	7
	Policy	1	0	0	1	1	0	3	2
Total	All	63	38	26	9	46	4	185	100

Several articles (27) reviewed the different aspects of a single species over large regions. For example, fruit-bearing palms are important multi-functional species in the Amazon, used in construction of walls and roofs, making of beverages and bags, and breeding of edible insects (Mesa-C and Galeano 2013), while *Ficus* spp. are important WEF species in Asia (Shi et al. 2014), Europe (Sezen et al. 2014) and Africa (Agbahoungba et al. 2016). In Africa, *Adansonia digitata* (Kamatou et al. 2011, Adam et al. 2013, Venter and Witkowski 2013a), *Berchemia discolor*, *Diospyros mespiliformis*, and *Sclerocarya birrea* (Cheikhyoussef and Embashu 2013) were identified as priority species. The baobab (*A. digitata*) is reported to have 25 different local uses including food, fodder, medicine and shelter (Schumann et al. 2012), and also has a growing export market for food, nutrition and cosmetic products in Europe (Gebauer et al. 2014). Besides the fruit of the marula (*S. birrea*) which is consumed raw or fermented, it is used to extract oil, treat flu and other ailments, as livestock feed, and in making wooden artefacts and utensils (Hall et al. 2002, Maroyi 2014).

2.4. Ecology

2.4.1. Species ecology

The ecology and life history of a species may render it suitable or otherwise for profitable extraction (Newton 2008, Gaoue et al. 2016). For instance, while some palms can survive harvesting of up to 50% of their leaves (Lent et al. 2014), others can tolerate removal of only 5% or less (Garcia et al. 2016). High dependence on seed dispersers (Ortiz et al. 2010) and low seedling recruitment (Herrero-Jáuregui et al. 2011) can potentially hinder recruitment in populations of WEF species. In multiple use species, harvest of one part may affect productivity of another; for example, debarking of *Himatanthus* trees increases fruiting (Baldauf et al. 2014), but debarking of *Lannea* trees reduces fruiting (Haarmeyer et al. 2013). As in the case of the baobab (Schumann et al. 2010) where debarking does not affect fruiting, the vitality and reproduction of some species of NTFPs remain unchanged under harvest (Siebert 2004, Schmidt et al. 2007, Avocèvou-Ayisso et al. 2009, Dantas et al. 2016). While Gaoue et al. (2016) prescribe an empirical 40% optimal harvest level, sustainable harvest levels for some NTFP species have been estimated to be 50% of their leaves (Ghimire et al. 2004), 75% of their stems (Vallejo et al. 2014), and up to and above 90% (Venter and Witkowski 2013b) of their fruits. In particular, fruit harvest has the highest sustainable threshold, ranging between 60% (Moupela et al. 2011) and 92% (Emanuel et al. 2005).

2.4.2. Landscape ecology

Although overexploitation is perceived as a major threat to NTFPs, they may also be at risk from landscape change such as agricultural or urban expansion, habitat fragmentation, invasive species, fire, and grazing (Newton 2008). For instance, long-term soil sedimentation may affect yield from WEF species regardless of harvest (Martin et al. 2014). NTFPs are often extracted alongside logging for fuelwood and timber, and supplementary to agricultural production (Levang et al. 2015). Newton (2008) proposes that NTFP management must be adaptive, to address situation-specific threats, failing which a combination of threats could form a feedback cycle of degradation. Examples of such combinations of threats include: illegal logging and hunting alongside cardamom extraction (Gubbi and MacMillan 2008), *Araucaria araucana*, a protected species threatened by grazing and fire (Newton 2008), development and deforestation cycles alongside Brazil nut extraction (Celentano et al. 2012, Zeidemann et al. 2014), livestock and baboon consumption of baobab fruit (Venter and Witkowski 2013b), invasion by *Lantana* and mistletoe in *Phyllanthus* trees (Ticktin et al. 2012), forest fragmentation by roads and logging around wild nutmeg habitat (Sharma et al. 2012), elephant trampling and herbivory (Mandle and Ticktin 2012), and fire and browsing livestock in areas of mountain date palm harvest (Mandle et al. 2013). Ravikanth et al. (2009) speculate that harvesting may reduce the genetic diversity in some populations of NTFP species, and Horn et al. (2012) highlight that lowered genetic stock from harvesting could exacerbate external threats such as those mentioned above. Studies in this review found that management and harvest of WEF species do not constrain genetic flow (Parra et al. 2012, Contreras-Negrete et al. 2015, Novello et al. 2018), but can render propagules (seeds) more vulnerable in harsh environmental conditions such as low humidity and high solar radiation (Gaoue and Ticktin 2008, Guillen et al. 2015).

2.4.3. Sustainability

As in the case of many wildlife resources, sustainable use of NTFPs has time and again been advocated as a strategy to conserve the resource base (Pfaff et al. 2014, Tierney et al. 2014).

Although the review by Stanley et al. (2012) concludes that the majority of case studies surmise that NTFP harvests are ecologically sustainable, commercialisation of some NTFPs has raised and confirmed concerns (Ros-Tonen and Wiersum 2005, Kusters et al. 2006, Rasolofoson et al. 2015) about the ecological and economic sustainability of NTFPs as a source of income and livelihood. In the attempt to make benefits from NTFPs a viable alternative to deforestation, extraction has assumed a commercial scale in some cases, such as the marula (*Sclerocarya birrea*) fruit (Maroyi 2014), the Brazil nut (*Bertholletia excelsa*) (Zeidemann et al. 2014), and the bush mango (*Irvingia gabonensis*) (Ofundem et al. 2017). When harvest is lethal to the individual (e.g. extraction of an entire plant, or its root, bushmeat), or market demand for products is high, production may turn intensive. Examples of WEF species domesticated or farmed in monoculture plantations include the cape gooseberry (*Physalis peruviana*) in Uganda (Barirega 2014), myrtle (*Myrtus communis*) to match demand from the Mediterranean liqueur industry (Mulas 2011), *Allanblackia* trees for their multiple use fruits in central Africa (Ofori et al. 2013), and chiquitania almonds (*Dipteryx alata*) for their local value in Bolivia (Vennetier et al. 2012). However, Newton (2008) argues that cultivation of NTFPs creates a competing source of products that promotes forest conversion and contradicts the concept of NTFPs as an incentive for forest conservation. Further, certain species like the aguaje palm (*Mauritia flexulosa*), though in great demand, are difficult to cultivate *en masse* due to their preference for specific habitats, in this case, marshy lands (Brokamp et al. 2011).

On the other hand, non-lethal harvest may lead to reduced productivity or vitality (Endress et al. 2004, Siebert 2004, Gaoue and Ticktin 2008, Brokamp et al. 2011), at times driving extraction to become more extensive, i.e. the area of harvest is increased (Belcher and Schreckenberg 2007). Landscape level outcomes of NTFP extraction are often speculated, but seldom quantified (Karanth et al. 2006, Mandle et al. 2013, Muler et al. 2014). Disturbance in forests may result in lower abundance, diversity, and vitality of plants (Ndangalasi et al. 2007, Sahoo and Davidar 2013) and animals (Moegenburg and Levey 2003, Anand et al. 2008). Collection of WEFs may lead to altered light penetration in ecosystems as in the case of Brazil nuts (Rockwell et al. 2015), although Hitzalter and Bergen (2013) also show that wild berry collection is more prevalent in degraded forest because light penetration is conducive to berry fruiting. It is hypothesised that collection of some NTFPs can potentially alter ecosystem dynamics by changing understory composition, community structure, and abiotic functions (Mandle et al. 2013, Shackleton et al. 2018), but it is difficult and inadvisable to generalise across species and contexts until such time there is a far larger meta-dataset. Muler et al. (2014) found that besides changing the light regime, intensive harvesting of *Euterpe* palms also reduces plant species richness. Ruwanza and Shackleton (2017) show that soil nutrients are reduced with increased biomass removal, with fruit harvest resulting in the least nutrient reduction.

Some species of NTFPs respond favourably to disturbances such as harvesting (Ghimire et al. 2004), grazing (Mandle et al. 2013), and fire (Masaphy and Zabari 2013). In the case of WEFs, Brazil nut (Scoles and Gribel 2015) and *Phyllanthus* spp. (Varghese et al. 2015) have been observed to produce more fruits in response to harvest-related lopping. *Lophira lanceolata* trees recruit well in areas under human pressure and disturbance, through fruit abandoned during harvest (Lankoandé et al. 2017). However, despite the resilience of such species, they are often overexploited beyond recovery to optimal vitality, as illustrated by 14 of the 25 studies explicitly addressing harvest sustainability in this review.

2.5. Economics

2.5.1. Determinants and drivers

NTFPs have long been debated as a source of income and a means of poverty alleviation (Sheil and Wunder 2002, Shackleton et al. 2007, Wunder et al. 2014a, Shackleton and Pullanikkatil 2018). It is argued that to remote rural communities, NTFPs provide a 'natural subsidy' on nutrition, healthcare, shelter, and energy (Barany et al. 2004, Shackleton and Shackleton 2004), and a 'natural insurance' as a response to shock (Paumgarten and Shackleton 2011), reducing costs for aid that the government would normally be expected to incur. NTFP collection often features as a prominent household income contributor in a suite of diversified seasonal livelihood strategies (Angelsen et al. 2014, da Silva et al. 2017). Dependence on NTFPs has been labelled by some as a 'poverty trap' (Belcher et al. 2005, Ros-Tonen and Wiersum 2005), implying that for the poorest users, NTFPs provide subsistence functions of shelter, fuel, and food in times of shortage, while wealthier users benefit from diet enrichment from bushmeat and cash income from high value products. However, more recent literature (Belcher and Schreckenberg 2007, Wunder et al. 2014b) finds no consistent relationship between poverty and NTFP use, and that evidence in support of NTFP poverty traps is scarce (Shackleton and Pullanikkatil 2018). While benefits of WEFs may accrue with wealthier households (Sakai et al. 2016, Shackleton et al. 2017a), they are an important source of food and nutritional diversity for remote households (Zeidemann et al. 2014, Ngome et al. 2017), and during times of food shortage due to drought (Woittiez et al. 2013), winter (Hummer 2013), and war (Adam et al. 2013).

Determinants of NTFP use and trade are usually studied as a function of the household socio-economic circumstances. For example, poverty level, food security, female labour, household size, education level, ethnicity, and accessibility (road density and proximity) have been variously linked to the prevalence of NTFP trade in different settings (Belcher et al. 2005, Quang and Anh 2006, Kar and Jacobson 2012, Hitzalter and Bergen 2013, Venter and Witkowski 2013a, Westholm 2016).

However, landscape-level drivers of the use and trade of harvested NTFPs, specifically WEFs, are seldom addressed. As broader examples, Newton et al. (2012) demonstrated that the type of forest Amazonian communities are situated in influences their livelihood strategies and the extent of their use of NTFPs, and Weyer et al. (2018) found that natural shocks such as drought and crop failure prompted households to take up NTFP trade as a livelihood in southern Africa. In a more specific context, Cunningham and Shackleton (2004) indicate that rainfall gradient and human-induced dispersal and survival may be linked to WEF use in South Africa, and Fentahun and Hager (2010) found that land shortage, altitude, and slope influenced uptake of WEF integrated into agroforestry landscapes. An understanding of the drivers behind WEF use and trade is likely to aid the formulation of better policy, incentives, and standards for sustainable use and trade.

2.5.2. Trade and supply chains

On an average, more than half of the NTFPs harvested (67% plants, 53% bushmeat) in central Africa are traded (Ingram et al. 2010). About a quarter of the NTFPs collected in eastern Europe and Russia are WEFs, and more than half the harvest is traded for cash (Bakkegard 2014). Yet, only 12 studies were found to discuss the economics of WEF trade. Trade in NTFPs can be difficult to quantify, partly due to the often informal nature of transactions (Diamante-Camacho et al. 2009, Brokamp et al. 2011, Shanley et al. 2012). For instance, up to 30% of the harvest of WEFs is exchanged as barter or cultural gifts in Cameroon (Ingram et al. 2010). Even in cases where NTFP trade is an important contributor to household income, price setting may be uninformed by market dynamics or formal values (Mugido and Shackleton 2018). Turtiainen and Nuutinen (2012) found that official data for trade in WEFs in European nations is either lacking or inconsistent. Trade in NTFPs is profitable when the formal market value of products is significantly higher than their direct use value; for example, the baobab fruit can be sold at four times its domestic use value (Venter and Witkowski 2013a), and the fruit of *Phytelephas* palms can earn up to 600 times its local market value on the international market (Brokamp et al. 2011).

Analysis of NTFP value chains consistently brings up issues of revenue capture by intermediaries, lack of networking and connectivity between stakeholders, gaps in information on sustainable practices, product processing and market value, and shortage of capital (Kusters et al. 2006, Newton et al. 2006, Te Velde et al. 2006, Ingram et al. 2012, Awono et a. 2013, Jusu and Sanchez 2014, Wunder et al. 2014b, Meaton et al. 2015). At times, firms with legal permission to harvest overexploit NTFP resources and labour illegaly to maximise profits (Ingram et al. 2012), and at others, state control over value chains leads to mismanagement and misappropriation of rights and funds (Lele et al. 2010). In cases where NTFP yield is inconsistent or perishable and production costs are dynamic, market prices may not succeed in capturing profit (Newton et al. 2006, Pomper et al. 2007, Schmidt et al. 2007, Brokamp et al. 2011, Ingram et al. 2012, Ofundem et al. 2017). One of the two WEF value chains found in this review was the Shea butter (*Vitellaria paradoxa*) value chain. While Jasaw et al. (2015) describe the material used in the value addition processing, Pouliot (2012) explores the role of women in the chain. Avocèvou-Ayisso et al. (2009) find that the formation of producer cooperatives and fewer intermediaries has improved benefit penetration. This finding is consistent with those from other successful NTFP supply chains supported by institutions that enable investment and improved marketing and profit distribution (Virapongse et al. 2014, El Tahir and Vishwanath 2015, Egwu et al. 2016, da Silva et al. 2017). The other value chain was that of the bush mango (*Irvingia gabonensis*) in Cameroon, where Ofundem et al. (2017) report that the sustained demand and organised local as well as cross-border trade has led to farming of the species.

2.5.3. Policy

Access to NTFPs is an important determinant of NTFP use, and their contribution to the household economy and food security (Richardson 2010, Adam et al. 2013). While some speculate that open access renders NTFPs vulnerable to overexploitation and less commercially viable due to dissipation of profits (Belcher et al. 2005, Ngome et al. 2017), secure land tenure has been linked to sustainable use and trade of some NTFPs (Shaanker et al. 2004, Varghese and Ticktin 2008, Clements et al. 2014, Mansourian et al. 2014). Devolved management rights usually foster sustainable practices (Lele et al. 2010, Phelps et al. 2010, Jagger et al. 2012, Mansourian et al. 2014), and improved synergy and inter-institutional collaboration (Newton et al. 2012, Chan 2015). Dedicated stewardship and secure access of resources encourages users to consider long-term impacts and investments in sustainability (Lent et al. 2014, Varghese et al. 2015). Further, traditional ownership and management regimes have sustained extraction of some NTFPs over decades in biodiverse landscapes (Guariguata et al. 2008, Menton et al. 2009, Shanley et al. 2012, Levang et al. 2015). Although riddled with gray areas over tenure and access, NTFP collection is increasingly observed in urban landscapes (Sténs and Sandström 2013, Kaoma and Shackleton 2015, Shackleton et al. 2017b). Land use planning in both rural and urban areas needs to take into account NTFP collection as an active land use contributing to provisioning (Kaoma and Shackleton 2015, Ward and Shackleton 2016) and cultural (Hurley et al. 2015, Levang et al. 2015, Lascurain et al. 2016) services, and consider local land tenure allocation.

Institutional failure to regulate use and trade of NTFPs is manifested in corrupt politics in resource allocation and lack of monitoring (Jensen and Meilby 2006, Lele et al. 2010, Ingram et al. 2012, Tieguhong et al. 2015). In some countries, the national legislation leaves harvesters with no option but to trade through intermediaries, either due to logistic reasons (El Tahir and Vishwanath 2015), or legal requirements (Awono et al. 2013). In one of the only two studies found to engage primarily with governance and policy related to wild edible fruits, Ball and Brancalion (2016) corroborate these drawbacks. In the other study, Foundjem-Tita et al. (2014) found that lack of awareness and aversion to enforcement amongst stakeholders hinder policies promoting uptake of indigenous fruit trees in agroforestry. Lack of knowledge communication can also result in the over- or underutilisation of wild edible plants (e.g. Termote et al. 2012, Ngome et al. 2017) and NTFPs (e.g. Barirega and van Damme 2014). The application of traditional ecological knowledge is often linked to sustainable harvest (Ghimire et al. 2004, Schmidt et al. 2007, Parra et al. 2012, Shanley et al. 2012, Hitzalter and Bergen 2013, Novello et al. 2018), although relatively few studies (Wynberg and Laird 2007, Rist et al. 2010, Schumann et al. 2010) assess or quantify this relationship. Failure to recognise and communicate this knowledge can result in misappropriation of benefits from commercialisation of wild medicinal plants (Wynberg and van Niekerk 2014, Willcox et al. 2015) and teas (Wynberg 2017). Rist et al. (2016) advocate improvements in knowledge sharing between harvesting communities, land managers, and scientists and researchers in order to attain sustainable social, economic, and ecological outcomes.

2.6. Conservation

2.6.1. Harvest practices

In the literature reviewed, 30 articles described and critiqued mechanisms used to conserve NTFPs, but only 16 of these were related specifically to WEFs. With respect to species, domestication is an oft-recommended and discussed option for commercial production of NTFPs, especially WEFs, but it is not considered in this review (Section 1). The reproductive strategies of a species and its response to disturbance and extraction (Section 4.1) need careful consideration in designing sustainable harvest practices and regimes. In some cases, chemical indices can be developed to determine optimal fruit harvest conditions for a species (e.g. Hernandez et al. 2010). In others, sustainability can be ensured by slightly modifying existing harvest practices (Sharma and Pramanick 2012, Isaza et al. 2016, Furukawa et al. 2016) to minimise damage to the plant. However, many favour short-term profits over long-term benefits (Lent et al. 2014), and may be averse to investing in acquiring capacity and infrastructure for sustainable harvesting practices (Varghese et al. 2015). Recent years have seen development of products from fruits of South American palms in an effort to curb leaf harvest by felling, but destructive practices continue to be used for fruit harvest in some regions (Manzi and Coomes 2009, Brokamp et al. 2011, Trevisan et al. 2015, Isaza et al. 2016, Isaza et al. 2017). WEF species that share habitats with other charismatic species may benefit mutually, as well as serve to protect their habitats, by promoting uptake of sustainable use practices leveraged by conservation incentives (see also Section 6). Examples of such species include *Schisandra* berries and giant pandas (Brinckmann and Morgan 2012), *Garcinia* fruits and lion-tailed macaques (Kumara and

Santhosh 2014), *Theobroma cacao* and gorillas (Original Beans 2017), and *Terminalia* fruits and hornbills (Bride et al. 2015).

2.6.2. Management strategies

As concerns the broader landscape, interactions between harvested species and their ecosystem, and land uses co-occurring in the extraction landscape (Sections 4) influence the magnitude of the socio-ecological impacts of harvesting. Co-management strategies such as community-based conservation/natural resource management (CBC/NRM) and community/joint forest management (C/JFM) commonly involve NTFPs as an incentive for conservation. Co-management regimes can improve household food security (Pailler et al. 2015) and increase income (Bauch et al. 2014) from NTFPs, bring about voluntary cessation of unsustainable NTFP harvest (Zimsky et al. 2012), and integrate socio-cultural connotations to promote sustainable NTFP harvest (Mukhopadhyay et al. 2012). Social monitoring of NTFP resources is recommended as a conservation strategy by Ortega-Martinez and Martinez-Pena (2008) and Pacheco-Cobos et al. (2015) in their studies on involving harvesters in inventorying and monitoring forest mushroom diversity. Community engagement in forest restoration and NTFP management can evoke a sense of empowerment and stewardship (Mansourian et al. 2014). However, these mechanisms may also be ridden with corruption in resource allocation (e.g. Tri Dung and Webb 2008), and could fail to reduce deforestation (e.g. Bauch et al. 2014, Rasolofoson et al. 2015). With reference to WEFs, three studies found in this review focused on effects of co-management on NTFPs (including WEFs) in the Brazilian Amazon. Guariguata et al. (2008) find that logging regulations overriding traditional management of Brazil nut harvests can render co-management ineffective. However, Menton et al. (2009) show that communities involved in co-management contracts had higher income and lower fruit harvests than those not involved, and Shanley et al. (2012) find that logging reduces access to NTFPs. Agroforestry is found to be a particularly effective conservation strategy, especially in the case of WEFs (Haglund et al. 2011, Foundjem-Tita et al. 2014, McLellan and Brown 2017), diversifying farmer income and augmenting food security and economic benefits.

2.6.3. Ecosystem services

From a landscape perspective, use of NTFPs has been proposed to incentivise conservation of forests (Dewees et al. 2010), in turn fostering ecosystem services and climate change resilience (Bharucha and Pretty 2010, Celentano et al. 2012, Balama et al. 2016), and strengthening food security (Djenontin et al. 2015, Kumar et al. 2015). Enrichment planting of WEFs has been proposed as an effective means of restoring degraded forests (Walsh et al. 2012, Lankoandé et al. 2017). WEF species such as *Berchemia discolor* (Debela et al. 2012) and *Ziziphus spina-christi* (Saied et al. 2008) have been recommended for agroforestry and restoration due to their adaptation to hot dry conditions and resilience to climate extremes. Silvicultural management has the potential to foster diversification in the plantation understory using mushroom and berry species (Bauhus and Schmerbeck 2010, Ashton et al. 2014, Tomao et al. 2017). Haglund et al. (2011) report increased household income, and indigenous fruit tree species diversity and density from agroecological landscapes using WEF species in restoration. Birch et al. (2010) found that ecosystem services from NTFPs consistently increased the cost-effectiveness of landscape restoration (compared to ecosystem services from land use for timber, pasture, and tourism). As an example from a WEF-specific study, Brazil nut (*Bertholletia excelsa*) stands in relatively disturbed forests show greater intact ecosystem functions such as pollination and act as wildlife buffers between logging areas (Rockwell et al. 2015). Explicit quantification of the ecosystem services associated with NTFPs and specifically WEFs can help formulate conservation policy and incentives for more beneficial, efficient, and wider reaching outcomes.

2.6.4. Economic incentives for conservation

Economic incentives have been used to influence people's behaviour towards conservation of biodiversity resources. Examples of direct incentives include payment for ecosystem services (PES) schemes such as the reducing emissions from deforestation and forest degradation (REDD+) (Wunder 2015) and trade of natural resources (such as NTFPs and game meat) and their non-use values (e.g. ecotourism, carbon offsets). Schemes like REDD+ can augment household food security and income (Bauch et al. 2014), albeit as long-term benefits (Pailler et al. 2015), but may not reduce forest dependency or deforestation (Rasolofoson et al. 2015). Further, the implementation of programmes such as REDD+ are found to be problematic, partly due to perceived imposition of 'western' ideals, and their inability to target high-risk areas due to their comparatively weak incentives (Krause and Nielsen 2014, Loaiza et al. 2015). The literature on payments for wild foods is restricted to mushroom harvest (Vaughan et al 2013, Prokofieva et al. 2017), and information on such payments specific to WEF use is scarce. Newton (2008) notes that local trade alone as an economic incentive for NTFP conservation may not be sufficiently large to address complex threats (Section 4). Certification is another form of direct incentivisation promoting sustainable harvest practices and fair and ethical trade (Brinckmann and Hughes 2010). Certification can improve socio-economic conditions for harvesters and forest communities (Cerutti et al. 2014), and can aid monitoring of forests and their ecosystem services (Savilaakso et al. 2015), but it is also associated with high investments and problematic economies of scale (Duchelle et al. 2014, Ting et al. 2016). Usually NTFP value chains are certified by standards developed for agriculture, forestry, product quality, and trade (Duchelle et al. 2014) and FairWild is a relatively new certification developed specifically for NTFP value chains (Morgan and Timoshyna 2016). While ecological outcomes of plantation and agroforest certification are emerging (Rueda and Lambin 2013, Rueda et al. 2015), the literature on NTFP certification is sparse.

2.7. Discussion

Although WEFs are a widely distributed and used subset of NTFPs and wild edible plants, they display remarkable multi-functionality (Section 3), be it the fruit itself, other plant parts, or as part of their landscape-level ecosystems (Sections 4, 6.3). While NTFPs in general have been studied in relation to livelihoods, markets, and policy, there is less information specific to WEFs (Section 3). I suggest that a focus on WEFs is necessary due to (1) their versatility and ubiquity even in the absence of forests (e.g. Contreras-Negrete et al. 2015, Guillén et al. 2015), (2) co-occurrence with various other land uses (e.g. Jamnadass et al. 2011, Shanley et al. 2012, Ticktin et al. 2012, Clark and Nicholas 2013, Rockwell et al. 2015, Varghese et al. 2015), (3) their significant contribution to nutrition, income, health, and culture of rural and urban peoples around the globe, and (4) their importance as a food source for many frugivorous species, including insects, birds, reptiles and mammals, some of which are obligate frugivores (Kitamura et al. 2002; Shackleton et al. 2018). I make specific recommendations for research and policy, and emphasise the role of communication between research, policy, and WEF users for effective management of WEF resources and associated ecosystems as well as livelihoods.

2.7.1. Avenues for research

With respect to species ecology, development and dissemination of methods to optimise sustainable WEF harvest (e.g. Hernandez et al. 2010, Gaoue et al. 2016) is a priority. Suitable conditions and quantities of harvest vary by species and context, and therefore, it is important to identify the diversity and extent of used WEF species and the context they are used in (such as shock, subsistence, trade, etc.). Species-landscape interactions also influence the quantity and sustainability of WEF harvest (Venter and Witkowski 2013b, Ruwanza and Shackleton 2017). As an example, the relationship between WEFs and frugivores remains understudied for most WEF species (Moupela et al. 2011, Pérez-Negrón et al. 2014), despite frugivores being important seed dispersers (Sekar and Sukumar 2015), and sometimes also providing bushmeat (Shanley et al. 2012, Shackleton et al. 2018). Research should be undertaken to ascertain how WEF harvesting interacts with ecosystem composition, functions, and flows to determine species and landscape resilience and responses to WEF extraction. Further, NTFP and WEF extraction are usually part of larger, often diverse bundles of ecosystem services (e.g. Birch et al. 2010, Debela et al. 2012, Clark and Nicholas 2013, Wunder 2015, Savilaakso et al. 2015). These bundles and services need to be explicitly defined to inform and facilitate planning and management decisions, and to incentivise conservation.

Stakeholder consultations (e.g. Foundjem-Tita et al. 2014, Figureau et al. 2015) and valuation (e.g. Travers et al. 2016) are some means through which research could achieve this.

As regards determinants and drivers of WEF use and trade, both household and landscape level trends need to be identified. Access to NTFPs and WEFs changes across different land uses (Shanley et al. 2012, Zeidemann et al. 2014, Mugido and Shackleton 2017), and implicitly, with tenure. While tenure is recognised as an important foundation for sustainable extraction in many settings (Shaanker et al. 2004, Varghese and Ticktin 2008, Clements et al. 2014, Phelps et al. 2010, Jagger et al. 2012, Mansourian et al. 2014), there is little evidence testing this hypothesis. A comparison between protected areas, communal lands, and private properties (both rural and urban) is likely to yield valuable insights on the socio-ecological outcomes of NTFP and WEF harvest under varying degrees of secure access. Access to WEFs may also be influenced by ecosystem characteristics such as biodiversity, rainfall, soil, and temperature (Peters 1998, Cunningham and Shackleton 2004, Fentahun and Hager 2010), but articles in this review found limited such evidence. This reiterates the need for generation and dissemination of knowledge (Section 5.3) of WEFs and other wild edible plants to encourage food security through sustainable use (Rist et al. 2010, Schumann et al. 2010, Termote et al. 2012, Rist et al. 2016). Such knowledge is key to identifying target areas and species for commercialisation as well as conservation, and informing resource governance and policy (Agbahoungba et al. 2016). Lastly, research can aid development of innovative value-added products (Trevisan et al. 2015, Isaza et al. 2017), supply chains (Kumara and Santhosh 2014, Bride et al. 2015) and optimal production systems to promote sustainable use and trade of WEFs. In terms of production systems there is much literature on the benefits of agroforestry, but too often it involves introduced tree species. A greater integration of multifunctional, indigenous WEFs into agricultural and residential spaces offers numerous social, ecological and economic benefits (Leakey 2012). However, the non-use values of WEFs should not be neglected, such as their contributions to local cultures, traditions, products and ceremonies, which need to be respected by planners and development agencies whose primary focus is usually on economics, incomes and value chains.

2.7.2. Recommendations for policy

For ecological sustainability, policy related to WEF resource use has to be informed by research on species ecology, determinants of use and trade, and sustainable harvest practices, while research on landscape ecology and ecosystem services can inform sustainable management strategies. Including NTFP and WEF users in stakeholder assessments (e.g. Jalilova at al. 2012) of prospects and risks associated with land use policy and change can guide sustainable harvest, and in some cases, help achieve multiple conservation objectives (e.g. Bride et al. 2015, Trevisan et al. 2015). On a larger scale, land use planning should consider local traditional knowledge and governance in decision and policy making. Recognising that natural resource users are often involved in landscape and resource stewardship (Krause and Nielsen 2014, Mansourian et al. 2014, Levang et al. 2015) will help policies and institutions to achieve synergised devolved governance (Chan 2015, Pacheco-Cobos et al. 2015). Urban green spaces are crucial intersections of tenure and food security (Sténs and Sandström 2013, Rupprecht et al. 2015, Shackleton et al. 2017b), making it a priority for urban planning to incorporate WEFs and wild edible plants in policies on green space management and urban foraging.

While ecological considerations and tenure safeguards can bolster sustainable use of WEFs, economic instruments are needed to reduce the risks of benefit capture, overextraction, and under-valuation associated with WEF trade (Section 5.2). Product diversification and infrastructure such as machinery are key to ensuring supply chain resilience and efficiency (Will 2008, Klimas et al. 2012, Trevisan et al. 2015). Further, supply chains can be strengthened through capacity building of personnel in terms of sustainable harvest practices, use of efficient infrastructure such as harvesting implements and processing machinery, and market price determination (Bride et al. 2015, Klimas et al. 2012, Ofundem et al. 2017). The integrity and transparency of supply chains can be enhanced by certification of practices and processes (Duchelle et al. 2014, Morgan and Timoshyna 2016). Economic incentives such as subsidies, premiums, and performance payments can be employed by governments and policymakers to encourage sustainable use and trade of WEFs (Wunder 2015). The quanta of these incentives can be based on research on determinants (Section 5.1) and ecosystem services (Section 6.3).

2.8. Conclusions

The literature on WEFs is dominated by ethnobotanical and taxonomic descriptions and studies on species level ecology. Different WEF species respond differently to harvesting as well as other environmental pressures such as fire and herbivory. Many WEF species occur in landscapes ranging from forests to highly disturbed ecosystems, and sometimes support pollinators, seed dispersers, and other keystone species. While fruit removal may potentially yield optimal product with minimal damage, poor harvest practices and lack of knowledge can result in unsustainable offtake.

While the motivations behind WEF use and trade remain unclear, the literature highlights the need for more information on WEF supply chains, and for more transparent policies that account for traditional tenure and management practices that emphasize sustainable resource use. WEF species are ideal candidates around which landscape conservation and management incentives could be designed. WEF species are versatile, resilient, and often highly productive, offering a promising prospect for climate change adaptation, ecosystem restoration, and food security.

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Chapter 3. Fruits of the veld: a comparative analysis between WEFs, wild foods, and NTFPs

Abstract

Wild edible fruits (WEFs) are an important non-timber forest product (NTFP) that provide nutritional, medicinal, cultural, and livelihood value to their users. The literature on NTFPs attests to the widespread use and versatility of WEFs in particular, but studies on the patterns of resource use invariably group WEFs together with other wild foods or NTFPs in general. I suggest that the ubiquity and utility of WEFs provide a useful contrast between other wild foods and non-food NTFPs, which contribute in different ways to the household economy, and may be used for different reasons, such as their access and availability. In this study, I describe the patterns of use of WEFs across socioeconomic and geographical gradients, and then compare them to the patterns of use of other wild foods and non-food NTFPs. I found that WEFs were used by a fifth of all sampled households, independent of the economic and urbanisation gradient, and were mostly grown in or collected from proximal surroundings. This was different from other wild foods and non-food NTFPs, which were used by more households, usually in rural areas, had context-specific relationships to socioeconomic variables, and were often purchased from other collectors. These findings establish the baseline for the use of different categories of NTFPs across the biomes of South Africa, and corroborate evidence from other studies linking the use of resources to their availability at the landscape level. Further, by segregating NTFPs into three categories, they also resolve the links between resource use and food security and wealth at the household level.

Keywords: natural resources, non-timber forest products, socioeconomic survey, urbanisation gradient, wealth, wild edibe fruits, wild foods

3.1. Introduction

Non-timber forest products (NTFPs) contribute significantly to human living and livelihoods around the world (Angelsen et al. 2014, Wunder et al. 2014a). These wild resources, often extracted from but not restricted to forests (Shackleton et al. 2011), provide food, shelter, fuel, medicine, as well as other utility and cultural value to their users. Beneficiaries of NTFP trade range from vulnerable sections of society such as those affected by climatic, economic, or political shocks (Adam et al. 2013, Woittiez et al. 2013, Weyer et al. 2018), to traders and intermediaries in widespread, well-established supply chains and networks (Brokamp et al. 2011, Sakai et al. 2016, da Silva et al. 2017). Wild foods are an important subset of NTFPs, examples of which include bushmeat (Ingram et al. 2010, Nasi et al. 2011), honey, wild fungi (Vaughan et al. 2013, Shrestha and Bawa 2014), wild edible plants (Turner et al. 2011, Termote et al. 2012), and wild edible fruits (WEFs). WEFs are among the most widely used type of wild foods and NTFPs (Hickey et al. 2016, Welcome and Van Wyk 2019), but while other wild foods such as leafy vegetables and mushrooms are well-studied, literature specific to WEFs is limited (Sardeshpande and Shackleton 2019).

In terms of nutritional value, pharmaceutical studies have found many WEFs to be rich in important micronutrients (see Broegaard et al. 2017, Bvenura and Sivakumar 2017). Certain WEF species also yield other useful parts such as leaves (Baldauf et al. 2014) and bark (Schumann et al. 2010), while some WEFs like *Carapa guianensis* can also be used for their fibre, fuel, and medicinal properties (Balslev et al. 2010, Klimas et al. 2012, Cheikhyoussef and Embashu 2013). As important sources of food within their ecosystems, some WEFs such as *Adansonia digitata* are keystone species that support a significant faunal diversity (e.g. Venter and Witkowski 2013a, Muler et al. 2014, Shackleton et al. 2018). Further, WEF species occur in a wide variety of landscapes, from rainforests to arid environments (Isaza et al. 2017, Guillén et al. 2015), in agroecological systems as well as degraded fallows (Novello et al. 2018, Lankoandé et al. 2018), and in both rural and urban areas (Ward and Shackleton 2016). Besides their broad ecological range as a group, some WEFs like *Berchemia discolor* are particularly resilient to extreme climatic conditions (Saied et al. 2008, Debela et al. 2012). In the face of rapid global environmental change, WEF species are an important genetic resource to conserve and develop as a response to biodiversity loss, climate uncertainty and food insecurity (Mbow et al. 2014, Shackleton 2014, Vira et al. 2015).

The literature often tends to group wild foods and WEFs together with NTFPs (Sardeshpande and Shackleton 2019), but I argue that given the varying utility and availability of these resources, a better understanding of their respective use patterns is instrumental in driving research and designing sustainable use strategies with the aim of perpetuating the resources. As examples, (i) extraction of different NTFPs entails varying degrees of biomass removal, which in turn can potentially affect the NTFP species (Haarmeyer et al. 2013, Lent et al. 2014) or alter the composition or functioning of the ecosystem the NTFP species occurs in (Hitztaler and Bergen 2013, Ruwanza and Shackleton 2018); (ii) market value for different types of NTFPs varies with their availability and demand, resulting in knock-on effects such as species domestication (Ofori et al. 2013), poaching and illegal trade (Sonricker Hansen et al. 2012), and product development (Wynberg 2017), each of which requires different sets of policy responses and regulations; (iii) different types of NTFPs contribute differently to the household, either in the form of direct subsistence inputs such as food, fibre, and fuel (Wunder et al. 2014a, 2014b), through specialised or processed, food or non-food products that are traded for income (Sakai et al. 2016, da Silva et al. 2017), or through indirect ‘subsidies’ or ‘safety nets’ in the form of medicinal extracts and famine foods (Shackleton and Shackleton 2004, Weyer et al. 2018).

Therefore, although WEFs are a subset of wild foods which are a subset of NTFPs, in data collection and analysis, I distinguish WEFs from other wild foods (e.g. bushmeat, honey), which in turn are distinct from non-food NTFPs (e.g. fuelwood, medicinal herbs), and each resource category is treated as an independent set. Using these definitions of resource categories, I put forth three research questions, namely: (i) what are the patterns and variations in the use of WEFs with respect to household characteristics (demographics, wealth, food security) and site-level attributes (temperature, rainfall, human population, biome, rural-urban gradient)? (ii) what are the patterns and variations in the use of other wild foods and non-food NTFPs with regard to these household and site-level attributes? (iii) are there any relationships or differences between the use of WEFs, other wild foods, and non-food NTFPs within households and across sites? Thus, I test the null hypothesis that there are no statistically significant differences between the prevalence of use of WEFs, other wild foods, and non-food NTFPs across ecological gradients, and the socioeconomic attributes of their users. In doing so, I also establish a baseline for the use and trade of these three resource groups along the ecological and socioeconomic gradients across South Africa.

The use of NTFPs as a whole (including WEFs and other wild foods) has traditionally been viewed as a livelihood strategy of remote, rural, low income households (Belcher et al. 2005, Ros-Tonen and Wiersum 2005), and although such a demographic does indeed benefit from the use and trade of NTFPs (Venter and Witkowski 2013b, Westholm 2016), the empirical evidence linking NTFP use to certain socioeconomic characteristics is inconclusive (Wunder et al. 2014b, Shackleton and Pullanikkatil 2018). I use standardised household wealth scores and food security scores as well as employment ratios and respondent education level as indicators of socioeconomic status to compare users and non-users of WEFs, other wild foods, and non-food NTFPs. Whereas proximity to forests, roads, and agricultural landscapes have often been linked to local use and trade of NTFPs (Quang and Anh 2006, Fentahun and Hager 2010, Newton et al. 2012), wider landscape-level factors such as human population density and resource availability have not usually been analysed. Further, research on wild foods has found that the availability of diverse food species does not necessarily translate into the inclusion of these species into local diets (Termote et al. 2012, Ngome et al. 2017). Using the biomes of South Africa (Mucina and Rutherford 2006) as ecological units, I map the occurrence (as a proxy of availability) of common WEF species, and compare the use of WEFs, other wild foods, and non-food NTFPs across these biomes.

3.2. Methods

3.2.1. Species selection

The book "Food from the Veld" (Fox and Norwood Young 1982) was used as a starting point for identifying species that fit the following criteria:

1. Bearing fruits whose pericarp is known to be consumed as food (excluding species bearing nutritious leaves, flowers, stems seeds and roots, e.g. Families *Fabaceae*, *Liliaceae*, and *Poaceae*).
2. Fruit diameter equal to or greater than 1 cm.
3. Occurring in at least one location in South Africa (including widespread, indigenous, as well as alien and invasive species bearing wild edible fruits, e.g. *Opuntia* spp, *Rubus* spp).
4. Not horticulturally domesticated or commercially cultivated (excluding species grown with extensive human support e.g. apple, avocado, and in monocultures, e.g. *Citrullus lanatus*, *Physalis peruviana*; including species that grow wild, but are also common in gardens and public spaces, e.g. *Harpephyllum caffrum*, *Carissa bispinosa*, *Berchemia discolor*).

Thus, 51 WEF species were shortlisted (Appendix 1), and their presence in each of the nine biomes in South Africa (Mucina and Rutherford 2006) was noted (Figure 3.1). A booklet was compiled to facilitate identification of these species by survey respondents with the help of pictures of fruits, flowers, leaves, and their morphometrics and local names.

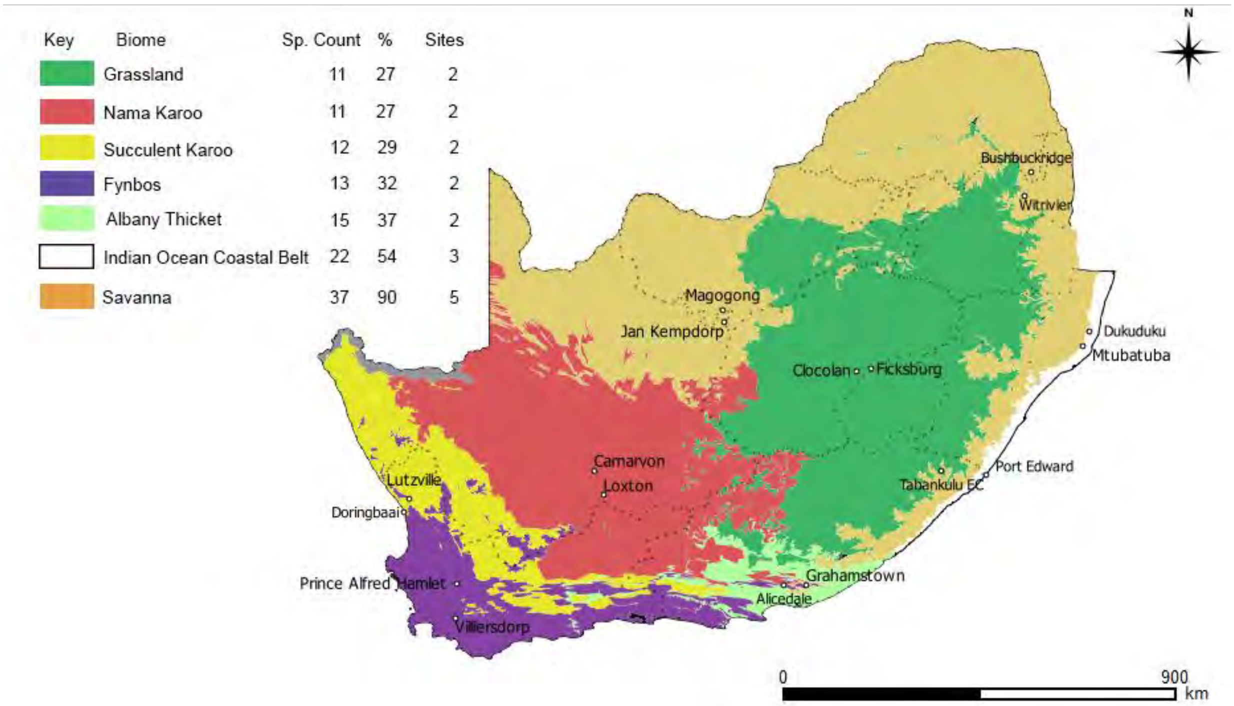

Figure 3.1: Distribution of WEF species and sample sites across biomes in South Africa

3.2.2. Sampling strategy

Sample sites were selected using stratified random sampling. The desert and forest, relatively small biomes, did not contain any WEF species not found in other biomes, and hence were not sampled. Each of the remaining seven biomes was assigned one degree squares from which sites were selected. Biomes with more than 50% of the selected WEF species were assigned two one degree squares, while the rest were assigned one one degree square. None of the degree squares were contiguous, and at least three-quarters of the area consisted of South African land (not sea or neighbouring nations). A total of nine such degree squares were delineated. Because the Indian Ocean Coastal Belt (IOCB) biome is very narrow, and the Albany Thicket biome is small and fragmented, degree squares in these biomes also included other biomes. Towns and villages were identified within each degree square at a constant scale of 10 km on Google Maps. These towns and villages were classified by municipality, and municipality sub-category (StatsSA 2016). Metropolitan municipalities, secondary cities, and large towns were excluded, and only small towns with significant urban populations (municipality category B) and rural areas were retained. The random number generator in MS Excel was used to select two sample sites per degree square: one each of a small town and a rural area. Thus, a total of 18 sample sites were selected (Figure 3.1, Table 3.2).

3.2.3. Data collection

Data was collected using paper questionnaires administered by the researcher in a door-to-door survey. Respondents were consenting adults approached opportunistically, irrespective of their status in the household. Interpreters with an understanding of the research topic and unbiased questioning techniques were enlisted when respondents did not consider themselves fluent in English. The survey questionnaire (Appendix 2) captured data on: (i) the number of WEF species, other wild food types, and non-food NTFP items used in the household, if any, (ii) the details of the use of these three items (e.g. quantity, seasonality, form, source), (iii) the details of trade of wild edible fruits, if any, (iv) household socio-economic composition, and (v) household food security status. A wealth index adapted from the Demographic and Health Surveys (DHS) (Wittenberg and Leibbrandt 2017) was used to score household economic status based on assets. Food security was gauged with Likert scale questions on availability, accessibility, and diversity of food sources based on the Household Food Insecurity and Access Score (HFIAS) framework of the Food and Agricultural Organisation (Coates et al. 2007).

One of the main assumptions of the sampling strategy was that biomes with a greater number of WEF species would require more sampling to capture distribution diversity. A limitation of the survey was that it relied solely on respondent recall to list WEFs, wild foods, and NTFP items used in the household; this may have resulted in under-reporting or incorrect reporting of the species and items actually used by the household.

3.2.4. Data analysis

Data were entered in MS Excel, and descriptive statistics were obtained therein. Food security scores were calculated by adding up points for every question in the food security matrix (Table 3.1) for a maximum possible score of nine points. This scoring scheme was adapted from the HFIAS scale by simplifying nine questions about food availability, accessibility, and diversity into three questions. In doing so, the data captured does not ascertain the reasons for or the nature of food insecurity, but still allows for a nuanced, fine scale assessment of household food security than simply ranking households based on the frequency of food insufficiency.

Table 3.1: Scoring scheme for food security score

Factor: Question	Rarely (<1 day/month)	At times (1-2 days/month)	Often (3-10 days/month)	Regularly (>10 days/month)
Availability: Does everyone in your household have enough food?	0 points	1 point	2 points	3 points
Accessibility: Do you ever skip meals for lack of food or money?	3 points	2 points	1 point	0 points
Diversity: On average, how many different types/items of food do you eat daily?	1	2	3	≥4
	0 points	1 point	2 points	3 points

Assets included in the questionnaire were based on Wittenberg and Leibbrandt (2017) for their relevance to the specific context of South Africa. As per the protocol for DHS wealth index calculation (Rutstein and Stavetig 2014), each asset in the wealth index was subjected to a PCA, yielding a weight against which every household was scored. Households were then ranked in quintiles based on the sum of these scores, yielding a normal distribution (Figure 3.2).

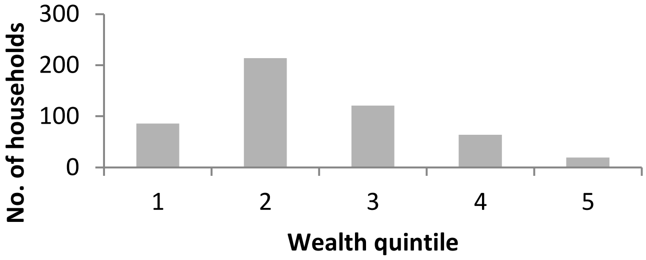

Figure 3.2: Distribution of surveyed households according to wealth quintiles

Inferential statistics were performed in R 3.2.3 (R Core Team 2015). Data for most variables were found to follow a non-normal distribution (using Shapiro-Wilk tests) at the household level (N=503), as well as when grouped by site (N=18) and biome (N=7). Non-parametric tests were therefore used to analyse differences and relationships between variables. Wilcoxon Rank Sum tests were used to analyse differences between binary variables such as users and non-users of WEFs, wild food and NTFPs, and gender and rural and urban sites. Kruskal-Wallis anovas were performed to find differences in continuous (e.g. age) or count (e.g. WEF species) variables, across nominal categories (e.g. biome) and ordinal variables (e.g. wealth quintile). Spearman-Rank correlations were used to determine correlations between continuous, count, and ordinal variables. Because most variables consisted of count data with non-normal heteroskedastic distributions and between a quarter and three-quarters of zero values (Crawley 2007, Dytham 2011), Poisson regression models were fitted to determine significant predictors of count variables (e.g. number of WEFs, other wild foods, non-food NTFPs used in the household) (Appendix 2, Table A1), but these models were poorly fitted, and hence not presented in the results. Multivariate logistic regression models were fitted to determine predictors of the use of WEFs, other wild foods, and non-food NTFPs in general, and for a comparison between rural and urban sites. None of the variables had significant correlations with other variables; hence all continuous, count, and ordinal variables were used in the multivariate logistic regression models. Chi-squared tests for goodness of fit were performed for each model and only models with $1\text{-}p\chi^2>0.05$ were reported (Archer et al. 2007). All models had 502 degrees of freedom.

3.3. Results

Of the 51 shortlisted WEF species, the morphology was predominantly trees (29), with fewer shrubs (15) and very few herbs (5) and cacti (3). Three species were endemic to South Africa (*Asclepias woodii*, *Cryptocarya wyliei*, *Erythroxylum pictum*), two species were endemic to South Africa and Namibia (*Berchemia zeyheri*, *Gethyllis* spp.), and 12 species were aliens. A majority of species were found growing only in the wild (32), and at least 20 species (including all aliens) were known to also grow in gardens. While 21 species had no other reported uses, 14 species had one other reported use (10 of these medicinal), and 17 species had more than one other reported use. The Savanna biome had the highest number of these WEF species (37), followed by the IOCB (22). Only about a quarter of the species occurred in the Grassland and Nama Karoo (11 each), and about a third in the Albany Thicket (15), Fynbos (13), and Succulent Karoo (12). No species were found to occur solely in the desert or forest biomes.

A total of 503 respondents were surveyed, each representing a unique household. About two-thirds (69%) of the respondents were female, and a third (31%) were male. The mean age of the respondents was 42±17 years, and the mean household size was five±2.7 members. One-third (33%) of the respondents said no one in their households had regular employment, while in the remaining (67%) households, two ±0.9 members were employed on average. Nearly two-thirds (63%) of the respondents reported that their household received one or more social welfare grants. A mean sample of 28± 2.4 respondents was surveyed at each of the 18 sites.

Only a fifth (21%) of all the respondents (N=503) reported to using WEFs within the last year. A total of 36 fruit species were reportedly used (Appendix 1). Guava (*Psidium guajava*) was the most commonly used WEF, followed by fig (*Ficus* spp.), prickly pear (*Opuntia ficus-indica*), waterberry (*Syzygium cumini*), and loquat (*Eriobotrya japonica*). Half of all the WEFs reported by respondents were collected from within their own gardens and yards, under a third (31%) from wilderness areas away from human settlement, and about a fifth (19%) from the respondents' close surroundings, such as street sides and vacant plots close to human settlement. Over a quarter (n=140) of the sample households reported to using domesticated species of fruit (e.g. apples, peaches), which I included *a posteriori* as a count variable to predict and compare use and non-use, and rural and urban users of the three categories of resources.

3.3.1. WEF use and respondent and household attributes

Respondent and household attributes had very little bearing on WEF use in the sample. No significant relationships were found between the number of WEF species used, and respondent age or education level, or household wealth quintile or food security. The household food source diversity score had a weak positive correlation with the number of WEF species ($r=0.20$, $p<0.001$) used in the household. The number of WEF species used in the household did not vary significantly between households with or without children, earning, or social grant-receiving members. Logit regressions highlighted differences between households that used and did not use WEF species ($1-p\chi^2=0.85$). Respondents ranking fruit as less important were 26% less likely to use WEFs ($z=-2.72$, $p=0.007$), households with more than one source of food were 51% more likely to use WEFs ($z=2.97$, $p=0.003$), and households using domesticated fruit species were 33% more likely to use WEFs ($z=3.83$, $1-p\chi^2=0.85$, $p<0.001$).

3.3.2. WEF use across sites and biomes

A Kruskal-Wallis analysis of variance revealed that there were significant differences in the number of WEF species ($\chi^2= 83.39$, df=17, $p<0.001$) used in the household across sites. The percentage of WEF user households per site had a strong positive correlation to average annual temperature at site ($r= 0.57$, $p=0.01$). There were significant differences between the number of WEFs ($\chi^2=48.82$, df=6, $p<0.001$) used per household across the biomes. The highest reported WEF species use was in the IOCB biome, and the least was in the Succulent Karoo biome (Table 3.2). In the IOCB biome, the number of WEF species used in the household had moderate positive correlations with the number of household food sources (r= 0.35, p=0.002), and the number of NTFP items used in the household (r= 0.35, p=0.002). The large significant differences are representative of the widely varying and non-normal distribution of variables within sample sites.

Table 3.2: Mean resource use per household by biome, and distribution of users of wild edible fruits, other wild foods, and non-food NTFPs by site. Percentages are based on the sample size of each site, and do not add up to 100 as some households used none or more than one of the resources.

Biome	Mean resource use per household (±SD)			Site class	Site name	Sample size (n)	Percentage user households at site		
	WEF spp.	Wild foods	NTFP items				WEF	Wild food	NTFP
Albany thicket	0.37 (±1.30)	0.40 (±0.56)	1.25 (±1.07)	Urban	Grahamstown	30	10	31	48
				Rural	Alicedale	31	29	42	94
Fynbos	0.15 (±0.41)	0.02 (±0.14)	1.26 (±1.35)	Rural	Prince Alfred	29	7	4	68
				Urban	Villiersdorp	25	20	0	64
Grassland	0.19 (±0.73)	0.52 (±0.77)	2.06 (±1.47)	Urban	Ficksburg	28	12	8	76
				Rural	Clocolan	31	10	59	90
IOCB	1.49 (±2.73)	0.54 (±0.77)	2.00 (±1.53)	Urban	Port Edward	23	27	32	68
				Urban	Mtubatuba	26	50	15	69
				Rural	Dukuduku	30	60	70	100
Nama Karoo	0.26 (±0.52)	0.11 (±0.31)	1.07 (±1.33)	Urban	Carnarvon	29	24	14	69
				Rural	Loxton	29	21	7	57
Savanna	0.27 (±0.61)	0.29 (±0.62)	1.63 (±1.39)	Rural	Tabankulu	30	10	3	70
				Urban	Witrivier	28	21	11	68
				Rural	Bushbuckridge	30	40	57	93
				Urban	Jan Kempdorp	28	7	11	71
				Rural	Magogong	30	0	20	67
Succulent Karoo	0.13 (±0.34)	0.49 (±0.51)	1.27 (±1.05)	Urban	Lutzville	26	16	0	64
				Rural	Doringbaai	30	10	90	80

3.3.3. WEF use along the rural-urban gradient

When compared across the rural-urban continuum, there was no significant difference in the number of WEF species used in the household (0.45±1.39 species) between rural and urban sites

(W=31817, df=501, p= 0.80). In urban areas, WEF use had a strong positive correlation with average annual temperature at site (r=0.70, p=0.04). Binomial logistic regression models were fitted to ascertain and compare WEF user and non-user households and relationships specific to rural (1-$p\chi^2$=0.59) and urban (1-$p\chi^2$=0.91) contexts. Users of domesticated fruits were 31% more likely to use WEFs in rural areas (z=2.34, p=0.02) and 35% more likely to do so in urban areas (z=3.12, p=0.002). Respondents ranking fruits as a less important part of their diet were (32%) less likely to use WEFs in rural (but not urban) areas (z=-2.45, p=0.01), and households with more than one source of food were highly (97%) likely to use WEFs in urban (but not rural) areas (z=3.13, p=0.002).

3.3.4. Patterns of use of wild foods and NTFPs

Whereas only a fifth of all respondents used WEFs, over a third (38%) of them reported to having used other wild food recently, and about three-quarters (74%) of the respondents said they had used NTFPs recently. The IOCB biome had the largest proportion of respondents using WEFs and wild foods, while the Grassland had the largest respondent proportion of NTFP users (Table 3.2). A Chi-squared test showed that there was a significant association between the sources of WEFs, wild foods, and NTFPs (χ^2= 139.65, df=8, p<0.001). Unlike WEFs, which were collected by household members, a majority of the wild foods and NTFPs used by the respondents were purchased from other collectors or hunters (Table 3.3). In terms of overlap of resource categories, NTFPs and wild foods was the most common combination of resource use, followed by NTFPs and WEFs, and all three categories were used by only 6% of all respondent households (Figure 3.3).

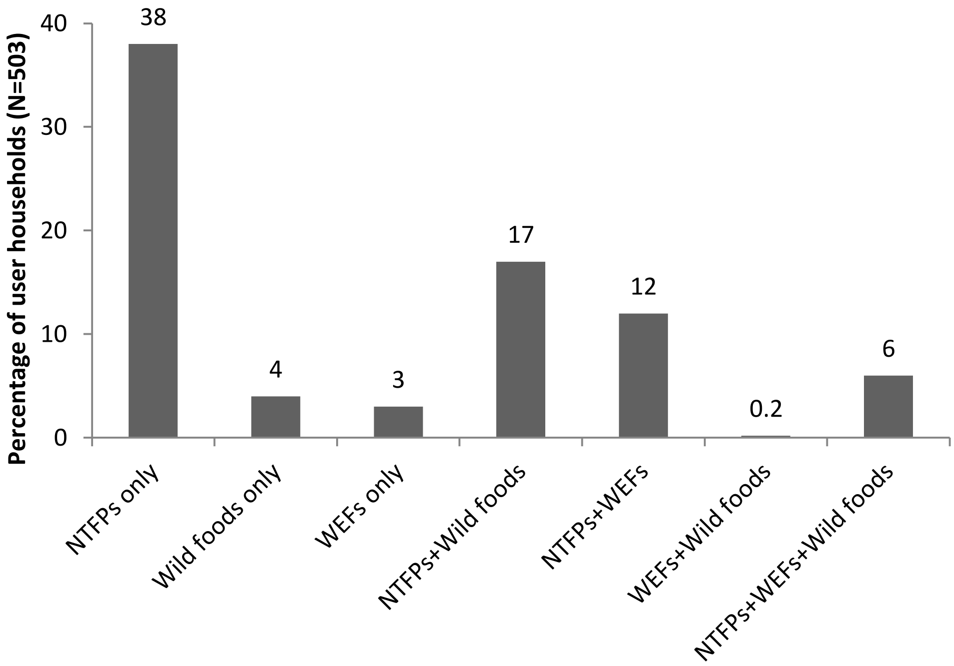

Figure 3.3: Overlaps between users of WEFs, wild foods, and NTFPs; numbers in the bar graph do not add up to 100 as some households used none of the resources.

Table 3.3: Proportions of sources of all of the WEFs, wild foods, and NTFPs as reported by the respondents (χ^2= 139.65, df=8, p<0.001). Some resources were collected from more than one source, and percentages are calculated based on the total number of sources for each category.

Source	WEFs (%)	Wild Foods (%)	NTFPs (%)
Grown within the yard	50	2	13
Foraged from proximal surroundings	19	4	22
Informal exchange with family and friends	0	2	3
Purchased from collectors or traders	0	67	44
Foraged from the wilderness	31	10	18
Hunted or fished	NA	15	0
Total	100	100	100

3.3.4.1. Respondent and household attributes

Unlike WEFs, respondent age and education were significantly different between households that used and did not use wild foods and NTFPs. Respondents whose households used wild foods were on average slightly older (44±17 years) than those whose households did not use wild foods (41±17 years) (W=22065, df=502, p=0.04), and also had slightly lower levels of education (secondary school users, matriculated non-users) (W=28144, df=502, p=0.03). Similarly, respondents whose households used NTFPs were on average older (43±17 years) than those whose households did not use NTFPs (39± 16) (W=20987, df=502, p=0.01), and also had lower levels of education (secondary school users, matriculated non-users) (W=27605, df=502, p=0.03). As with WEFs, household food source diversity score had weak positive correlations with the number of wild foods (r=0.25, p<0.001), and NTFPs (r=0.28, p<0.001) used in the household. In a comparison between user and non-user households, households with higher food security scores were 17% less likely to use wild foods (z=-2.12, 1-pχ^2=0.12, p=0.03), and those with higher wealth quintiles were 52% more likely to use NTFPs (z=2.28, 1-pχ^2=0.23, p=0.02). These are notable departures from findings on the likelihood of WEF users being independent of household food security and wealth (Section 3.1.). However, similar to WEFs, households with more than one source of food were 83% more likely to use wild foods (z=4.58, 1-pχ^2=0.12, p=0.03) and 49% more likely to use NTFPs (z=2.59, 1-pχ^2=0.12, p=0.03).

3.3.4.2. Sites and biomes

Similar to WEFs, Kruskal-Wallis anovas revealed significant differences in the number of wild foods (χ^2= 171.5, df=17, p<0.001), and NTFPs (χ^2= 91.024, df=17, p<0.001) used in the household across sites. Whereas WEF use was strongly correlated to average annual temperature at site, wild food and NTFP use had no such significant correlations with site attributes. There were significant differences between the number of WEFs (χ^2=48.82, df=6, p<0.001), wild foods (χ^2= 50.23, df=6, p<0.001), and NTFPs (χ^2= 30.296, df=6, p<0.001) used per household across the biomes (Table 3.2).

3.3.4.3. Rural-urban gradient

In contrast with WEFs, which were used consistently across the rural-urban gradient, rural households used significantly more wild foods (W=39758, df=501, p<0.001) and NTFPs (W=39965, df=501, p<0.001) than urban households (Appendix 2, Table A2). Moderate positive correlations were found between number of NTFP items used and household food source diversity (r=0.35, p<0.001) and number of wild food types used (r=0.35, p<0.001) in rural households. With regard to geographic variables, average annual temperature at site had a strong positive correlation with NTFP use in rural (r=0.67, p=0.05, but not urban) areas.

3.3.5. Relationships between WEF, wild food, and NTFP use

There was a weak positive correlation (r= 0.18, p<0.001) between number of WEF species and the number of NTFP items used in the household, but none between the number of WEF species and other wild foods used in the household. There was a weak positive correlation between the number of wild food types and number of NTFP items used in the household (r=0.25, p<0.001). Thus, household use of NTFPs was likely to have an incremental effect on household use of wild food types. This was corroborated by logistic regressions, which showed that households using NTFPs were 32% more likely to use wild foods (z=3.44, 1-pχ^2=0.12, p<0.001), and households using wild foods were 74% more likely to use NTFPs (z=2.20, 1-pχ^2=0.23, p= 0.03). Additionally, the use of domesticated fruits predicted slightly higher use of WEFs (z=3.84, e=1.33, 1-pχ^2=0.85, p<0.001) and NTFPs (z=2.04, e=1.22, 1-pχ^2=0.23, p= 0.04), but not wild foods.

3.3.6. Trade

Of the 503 households surveyed, 33 (6.6%) were involved in trade of WEFs, wild food, or NTFPs. Of these, seven traded WEFs, eight traded wild food, and 19 traded NTFPs. Only one household in the IOCB traded both WEFs and NTFPs, while the rest traded only in one of the three categories. Three WEF species were traded, namely *Opuntia ficus-indica* in the Albany Thicket (four households), *Psidium guajava* in the Savanna (two households) and the IOCB (one household), and *Psidium cattleianum* in the IOCB (one household). Honey, bushmeat, and riverine fish were the wild foods traded in the Savanna (one household each), and fish acquired by artisanal fishers in a marine reserve were traded in the Succulent Karoo (six households). One household each traded medicinal herbs, wood, fur hats, and fuelwood in the Albany Thicket, Fynbos, Grassland, and Savanna respectively. Brooms were traded in the Grassland (one household) and Savanna (two households). Households in the IOCB traded mats (10 households), fuelwood (two households), leather and medicinal herbs (one household each).

3.4. Discussion

The findings highlight some striking differences between the contexts in which WEFs, other wild foods, and other NTFPs are used, and also corroborate findings from other parts of the world. More than half the WEF species shortlisted had multiple uses, and about 40% of the shortlisted species are already also found in human managed and dominated landscapes. In the case of WEFs being combined together with wild foods and NTFPs, fuelwood was the single most commonly used type of NTFP (n=122) in the sample, followed by WEFs (n=105), and medicinal herbs (n=74). However, when considered as separate categories, users of other NTFPs and other wild foods formed larger proportions of the sample. In terms of the sources of the resources, WEFs were most often grown in respondents' gardens, whereas wild foods and NTFPs were most often purchased from other collectors or resellers (Table 3.3). Based on these findings, I suggest that there is scope for the introduction of more WEF species in tree planting in household yards, given that less than half the known available WEF species are grown in gardens (Section 3.3), as well as in public green spaces, as incorporating WEF species into green infrastructure has the potential to reduce food insecurity and poverty and ameliorate climate impacts. Further, WEFs can often be harvested with minimal damage and disturbance (Gaoue et al. 2016, Ruwanza and Shackleton 2018), and some species offer the possibility of versatile processed products with a long shelf life (Brokamp et al. 2011, Gebauer et al. 2016, da Silva et al. 2017), making them ideal candidates for supply chains to augment or diversify the livelihoods of users.

3.4.1. Socioeconomic aspects of resource use

Respondent age and education did not significantly vary between users and non-users of WEFs, as was the case with other wild foods and other NTFPs; however, no further links were found. At the household level, I found that wild foods and NTFPs were variously linked with household food and wealth indices, but no such relationships were found with WEFs. The use of wild foods inherently implies increased access to and diversity in sources and types of food in the household (Chakona and Shackleton 2019), but this does not necessarily translate into higher household food security scores, as wild food use may be a coping strategy (Mollee et al. 2017). This is also reflected in the sample, in that households with higher food security were linked to lower wild food use. I hypothesize that this relationship may represent the availability of unskilled and or unemployed labour within the household that can devote effort towards wild food collection (e.g. Hunter et al. 2011, Bakkegaard et al. 2017). In the sample, households using non-food NTFPs belonged to higher wealth quintiles overall than non-user households (Section 3.3). Recent research finds that households with higher wealth and food security form a significant proportion of NTFP users (Brashares et al. 2011, Pouliot and Treue 2013, Sakai et al. 2016, Cooper et al. 2018), and this link may be explained by the capacity of such households to invest in business and infrastructure centred on NTFPs (Angelsen et al. 2014, Sakai et al. 2016, Bakkegaard et al. 2017). I acknowledge that large proportions of the sample purchased wild foods and NTFPs, which may have influenced the representation of household food security and wealth.

3.4.2. Ecological contexts of resource use

With respect to geographic variables, temperature was strongly linked to WEF use, and also to NTFP use in rural areas. Although I did not statistically test the relationship between resource occurrence, use, and geographic variables, I hypothesize that the link between temperature and WEF use is representative of WEF availability. The savanna and IOCB biomes, with high average annual temperatures, are also where the maximum WEF species occur (Section 3.3). With regard to biomes, the IOCB, with the highest average annual rainfall, and high mean annual temperatures and population densities, had the highest number of WEF and wild food users. It was also the biome with most statistically significant relationships, with NTFP users linked to lower education, household income, and food security. However, I believe it is important to note that no such associations were found in the six other biomes which also had varying degrees of NTFP users. The IOCB was also the only biome where WEF use was correlated to NTFP use. Among the smallest and most biodiverse biomes in South Africa, half of the biodiversity in the IOCB is critically endangered (Driver et al. 2012). The IOCB also harbours high human population density and economic hubs of regional, national, and global significance. Given this co-occurrence of biodiversity, human population and use of resources, and economic development, I suggest further investigation of the nature of WEF, wild food, and NTFP use in the IOCB. In particular, the IOCB holds high potential for promoting the use of WEF and wild food species as a means to encourage sustainable food production, augment livelihoods, and protect biodiversity in both rural and urban areas.

3.4.3. The rural-urban continuum

One of the key findings is that in a comparison between rural and urban contexts, WEFs are used by as many households across the rural-urban gradient, unlike other wild foods and non-food NTFPs, which are used more widely in rural areas. The availability of WEFs in household yards (Table 3.3) may facilitate their use even in urban settings. Household NTFP use was linked to wild food use in rural households, but in urban households, NTFP use was linked to WEF use. This leads me to suggest that NTFP users in urban areas either possess wealth to purchase NTFPs or the resources to have them extracted from wilderness areas for consumption or trade (see Brashares et al. 2011, Sakai et al. 2016), while users in rural areas collect NTFPs on a subsistence basis. Wild food use in urban areas was linked to greater household wealth. In rural areas, physical free access allows for wild food use to augment household food security (Chakona and Shackleton 2019), whereas in urban areas, financial resources permit households to purchase wild foods, that are not easily available and may be outpriced by low-cost crop foods (Sneyd 2013). I reiterate my recommendation and that of other researchers (e.g. Ngome et al. 2017) for urban planners to incorporate more wild food and WEF plants into public open spaces to promote food security through the use of culturally important, biologically diverse, and climate resilient species.

3.4.4. Interrelationships in resource use

Weak positive correlations were found between household use of NTFPs and wild foods and WEFs, and NTFP use was more closely linked to wild food use than WEF use (Section 3.5). While users of NTFPs were associated with greater use of WEFs and wild foods, there was no such significant relationship between WEF and wild food use. Comparisons between sites, biomes, and rural and urban areas above indicate that access to these resources, whether in the form of natural occurrence in the biome, proximity to wilderness areas or WEF-bearing trees, or the power to purchase these products, influences the extent to which these resources are used by households. Large-scale international comparative studies similarly posit that although respondent and household characteristics provide some context in which different types of NTFPs are used, the influence of these variables is negligible on landscape level, where NTFP use is better predicted by resource availability, and as a corollary, the geographic location of households (Brashares et al. 2011, Wunder et al. 2014a, 2014b, Cooper et al. 2018).

3.4.5. Trade of resources

The sample had a small proportion (7%) of traders of WEFs, wild foods, and NTFPs, similar to findings of other studies from South Africa (Mugido and Shackleton 2017) and around the world (Hickey et al. 2016). Some authors suggest that the contribution of NTFPs can be better represented as environmental income, which could be sourced from forest products and non-forest environmental products (Pouliot and Treue 2013). However, wild foods tend to be extracted from both forest as well as non-forest environments (Pouliot and Treue 2013, Hickey et al. 2016), and the definition of wild foods varies in the literature, making it difficult to compare or quantify sources, or make management decisions or recommendations based on them (Powell et al. 2015). In the sample, WEFs collected from proximal surroundings comprise non-forest environmental products, and bushmeat, fish, and honey are forest products, while traditional brooms, fur hats, and mats are value added products made from forest products. Globally, wild foods and NTFPs extracted from the forest are more likely traded, while those extracted from non-forest areas are used for subsistence (Pouliot and Treue 2013, Angelsen et al. 2014, Hickey et al. 2016), and my findings tie in with this evidence. However, I suggest that WEFs, being easily accessible non-forest environmental products, have the potential for further development towards contributing to household income. All three species of WEFs traded in the sample are exotic, as are four of the five most commonly used WEF species in the sample. With appropriate use and management strategies, the ecological impact of alien species may be balanced by the socioeconomic benefits they provide (Shackleton et al. 2019), but I also recommend that indigenous WEF species are planted and used to preserve and promote traditional knowledge and culture (Sylvester et al. 2016, Paumgarten et al. 2018).

3.5. Conclusion

WEFs are the most commonly used NTFP after fuelwood in South Africa, and a considerable number of WEF species have non-food uses, and are found in human modified landscapes. Unlike other wild foods and NTFPs, the use of WEFs is not linked to household demographics, food security, or wealth. WEFs provide user households with dietary diversity, and their use is consistent across the rural-urban continuum. As is the case with other wild foods and NTFPs, WEF use is related to household access to these resources. However, whereas other wild foods and NTFPs are procured mainly from wild areas, and more widely traded, WEFs are more often grown in and procured from domestic gardens and residential areas in both rural and urban contexts.

There is scope to improve both rural and urban access to WEFs and wild foods in South Africa through planting of these species. Such planting can focus especially on domestic gardens and public spaces in densely populated residential areas, to meet demand for affordable, local, nutritious food. Adequate consideration needs to be given to land tenure and plant and yield management implications to ensure equitable and sustainable distribution of benefits. There is scope for introduction and popularisation of indigenous WEF species in home gardens, public spaces, and NTFP markets through planting and propagation.

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Appendix 1 – Lists of WEF species, wild food types, and NTFP items used in surveyed households

List A1: WEF species

Sr. No.	Species	User hh n	Sr. No.	Species	User hh n
1	*Psidium guajava* L.	48	27	*Coccinia sessilifolia* (Sond.) Cogn.	1
2	*Ficus* spp. L.	40	28	*Cordia caffra* Sond.	1
3	*Opuntia ficus-indica* (L.) Mill.	23	29	*Diospyros mespiliformis* Hochst ex A.DC.	1
4	*Syzygium cumini* (L.) Skeels	20	30	*Englerophytum magalismontanum* (Sonder) T.D.Penn.	1
5	*Eriobotrya japonica* (Thunb.) Lindl.	14	31	*Grewia flavescens* Juss.	1
6	*Passiflora edulis* Sims	8	32	*Grewia occidentalis* L.	1
7	*Strychnos spinosa* Lam.	8	33	*Hylocereus undatus* Britton & Rose	1
8	*Vangueria infausta* Burch.	8	34	*Mimusops zeyheri* Sond.	1
9	*Carissa edulis* Vahl	7	35	*Rubus niveus* Thunb.	1
10	*Phoenix reclinata* Jacq.	7	36	*Rubus pinnatus* Willd.	1
11	*Sclerocarya birrea* Hochst.	7	37	*Berchemia discolor* (Klotzsch) Hemsl.	0
12	*Annona senegalensis* Pers.	4	38	*Carissa bispinosa* Desf.	0
13	*Harpephyllum caffrum* Bernh.	4	39	*Cucumis africanus* L.f.	0
14	*Hyphaene coriacea* Gaertn.	4	40	*Garcinia livingstonei* T.Anderson	0
15	*Rubus cuneifolius* Pursh	4	41	*Hexalobus monopetalus* Engl. & Diels	0
16	*Carissa macrocarpa* (Eckl.) A.DC.	3	42	*Lannea discolour* Engl.	0
17	*Cucumis metuliferus* Naudin	3	43	*Opuntia engelmannii* Salm-Dyck	0
18	*Eugenia uniflora* L.	3	44	*Osyris compressa* A.DC.	0
19	*Tabernaemontana elegans* Stapf	3	45	*Parinari curatellifolia* Planch. ex Benth.	0
20	*Ximenia caffra* Sond.	3	46	*Rhoicissus* spp. Planch.	0
21	*Berchemia zeyheri* (Sond.) Grubov	2	47	*Solanum betaceum* Cav.	0
22	*Dovyalis caffra* Sim	2	48	*Syzygium cordatum* Hochst.	0
23	*Flacourtia indica* (Burm.f.) Merr.	2	49	*Syzygium guineense* DC.	0
24	*Psidium cattleianum* Sabine	2	50	*Syzygium jambos* (L.) Alston	0
25	*Strychnos madagascariensis* Poir.	2	51	*Ximenia americana* L.	0
26	*Ancylobothrys capensis* (Oliv.) Pichon	1			

List A2: Wild food types

Wild food type	No. of user households
Fish	75
Bushmeat (small wild mammals, birds, insects)	59
Wild spinach	31
Honey	28
Game meat (large, semi-wild mammals)	8
Mushrooms	2
Spekboom	1

List A3: NTFP items

NTFP item category	No. of user households
Fuelwood	259
Medicinal herbs	161
Brooms	144
Baskets	60
Mats	46
Construction wood	43
Leather	23
Artefacts and decorations	21
Shells	14
Tools and utensils	8
Furniture	7
Straw hats	7

Appendix 2 – Supporting Information

Survey Questionnaire

1. Wild Foods

Here, 'wild foods' implies foods that are not grown on a farm commercially. Thus, any plant or animal material collected from backyards, fields, forests, or gardens and used as food qualifies. Examples of wild foods include bushmeat, fruits, herbs, honey, etc. You may collect these foods yourself, or buy them from someone somewhere. Please also consider any prepared food that contains wild foods.

1.1 When last did anyone in your household use any foods that are procured from the wild?
(Please tick one)

☐ Never ☐ More than a year ago ☐ This year

(If 'Never', proceed to section 2 Trade.
If 'More than a year ago', continue to question 1.2.
If 'This year', proceed to question 1.3.)

1.2 Could you describe what food was used, how, when, and why?
(Also, why is this food not used now?)

1.3 Which of these wild foods does your household use?
(Tick as many as applicable, and please list specific items and their source)

Wild Food	Yes / No	Which items are used? (e.g. apples, fish, carrots)	Where are they from? (e.g. yard, street, forest)
Fruits (Berries, citrus, melons)			
Meat (Bushmeat, eggs, fish, insect)			
Vegetables (e.g. yam)			
Green leafy vegetables (e.g. spinach)			
Other (Please specify)			

(If 'Fruits' ticked, continue to question 2.3. Else, please proceed to section 2 Trade)

1.7 Could you please list the wild fruits that are used by your household?
(Please list names, and further details in columns)

Fruit name	In what ways is it used?	Which months is it used?	Where is it sourced from?	Are there other uses?	Do animals or birds use it?

In what ways is it used:

R: Raw B: Beverage C: Cooked F: Fermented P: Preserved

Where is it sourced from:

From the market / shop From someone who collects We collect (farm / forest / garden)

Are there other plant uses:

B: Bark F: Flowers L: Leaves R: Roots W: Wood

2. Trade

Here, 'trade' implies selling wild foods in exchange for money, goods, or services. Please also consider any prepared food that contains wild foods.

2.1 When last did anyone in your household trade any foods that are procured from the wild?
(Tick one)

☐ Never ☐ More than a year ago ☐ This year

(If 'Never', proceed to section 3 Other Wild Products. If 'More than a year ago', continue to question 2.2. If 'This year', proceed to question 2.3.)

2.2 Could you describe what food was traded, how, when, and why?
(Also, why is this food not traded now?)

2.3 Which of these wild foods are traded by your household? What quantities are sold, how often, and what price do they fetch? (Tick as many as applicable, and please enter numbers per category)

Wild Food	Yes / No	Frequency of sale (daily/monthly…)	Quantity sold (kg)	Price per unit (R)
Fruits (Berries, citrus, melons)				
Meat (Bushmeat, eggs, fish, insect)				
Vegetables (e.g. yam)				
Green leafy vegetables (e.g. spinach)				
Other (Please specify)				

(If 'Fruits' ticked, continue to question 3.3. Else, please proceed to section 4 Other Wild Products)

2.4 Could you please list the wild fruits that are traded by your household?
(Please list names, quantities, seasons during which, prices at which they are sold, and source)

Fruit name	How often is it sold?	In what quantities is it sold?	At what price is it sold?	Where is it sourced from?

Where is it sourced from:

From a reseller   From someone who collects   We collect (farm / forest / garden)

2.5 Why do you trade wild edible fruits?
(Is it because you need the income? Are they easily available? Is it to get rid of excess?)

2.6 Who in the household trades the wild edible fruits? How?
(Who collects/buys them? Who prepares them (if applicable)? Who sells them? Why?)

2.7 Where do you trade wild edible fruits?
(How far is the reseller/shop/market you trade with? Are there other traders there?)

3. Other Wild Products

Here, ‘wild products’ implies products that are not grown on a farm or plantation. Thus, any plant or animal material collected from backyards, fields, forests, or gardens and used for domestic purposes qualifies. Examples of wild products include bones, canes, firewood, grasses, hides, medicinal herbs, etc. You may collect these products yourself, or buy them from someone somewhere. Please also consider household items such as artifacts, brooms, mats, and personal products like cosmetics, herbal medicines and supplements.

3.1 When last did anyone in your household use any wild products? (Tick one)

☐ Never ☐ More than a year ago ☐ This year

(If ‘Never’ or ‘More than a year ago’, proceed to section 4 Food Security.
If ‘This year’, continue to question 3.2.)

3.2 Does your household use wild products for any of these purposes?
(Tick as many as applicable, and select frequency per ticked category)

Purposes	Yes / No	Which products are used?	Where are they procured from?
Artifacts and Jewellery (Antlers, bone, hide, leather, seeds, shells)			
Baskets and Brooms (Grasses, palms, reeds)			
Boats and Carts (Wood)			
Construction and Furniture (Beams, flooring, poles, roofing, wood)			
Cooking and Heating (Fats, oils, wax, wood)			
Cosmetics (Aromatics, fats and oils, jelly and wax)			
Medicines			
Rituals			
Other (Please specify)			

3.3 When last did anyone in your household trade any wild products? (Tick one)

☐ Never ☐ More than a year ago ☐ This year

If ‘This year’, could you please provide details of which ones, where, when, quantities sold, and money earned?

4. Food Security

4.1 How often are these statements true for your household? (Tick one per category)

Statement	Never (Less than once a month)	At times (Once or twice a month)	Often (3 to 10 days a month)	Regularly (More than 10 days a month)
Everyone in our household has enough food e.g. Each member can fulfil their appetite				
We skip meals because we run out of food e.g. too busy to eat / power outage / need to buy food				

4.2 On average, how many items of food do you have in a meal or on a plate? (1-5)

4.3 Which of these sources does your household procure food from?

(Tick as many categories as applicable; then for each ticked category, select one quantity)

Which of these sources does your food come from?	Yes / No	How much of your household food is procured from here?			
		1-25%	26-50%	51-75%	76-100%
Market (multiple vendors / supermarket)					
Shop (single local trader)					
Farmer (grows and sells own crop)					
Our own farm / yard (we farm the land)					
Gathered (from fields / forest / garden)					

4.4 How would you rank these foods by the quantity used in your household?

Where 01 = most quantity eaten/most money spent on/most important,

And 05 = least quantity eaten/least money spent on/least important

Food	Rank
Fruits (Berries, citrus, melons)	
Grains (Cereals, flours)	
Meat (Eggs, fish, flesh, insects)	
Vegetables (Flowers, leaves, roots, stems)	
Packed processed foods (Cake, candy, chocolate, cookies, soda)	

5. Socioeconomic Information

5.1 Gender: 5.2 Age:

5.3 What was your last educational qualification?

5.4 How many members does your household comprise of? (Enter numbers per age category)

Under 15 ☐ 16-65 ☐ Over 66 ☐

5.5 Does anyone in the household receive social welfare grants? (If so, please list the grants)

5.6 How many members earn money regularly?

5.7 Which activities contribute to the household income regularly?

Activity contributing to household income	Who in the household is involved in this activity?

5.8 Which of these does your household own?

Asset	Yes (1) / No (0)
Donkeys/Horses	
Goats/Sheep	
Cattle	
Bicycle	
Motorbike	
Car	
Electricity connection	
Water on tap	
Gas for cooking	
Internet connection	
Radio	
Television	
Refrigerator	
Cell phone	
Computer	
Within the house	How many?
Rooms (used for sleeping)	
Toilets (with sewage disposal)	

Thank you for your time and contribution!

Table A1: List of variables and indices, their types, and distributions, used in analyses

Variable	**Type**	**Distribution**	**Mean**	**Std Deviation**
Number of WEF species used per household	Count	Non-normal	0.45	1.41
Number of wild food types used per household	Count	Non-normal	0.34	0.61
Number of NTFP items used per household	Count	Non-normal	1.55	1.38
Number of sources of food per household	Count	Non-normal	2.66	0.92
Household food security score	Ordinal	Non-normal	7.49	1.28
Respondent's rank for fruit	Ordinal	Non-normal	3.37	1.05
Household wealth quintile	Ordinal	Non-normal	1.80	0.77
Respondent education level	Ordinal	Non-normal	2.60	1.55
Respondent age	Continuous	Non-normal	42.03	17.02
Number of adults per household	Count	Non-normal	2.95	1.83
Number of children per household	Count	Non-normal	1.48	1.50
Number of earning members per household	Count	Non-normal	1.11	1.09
Number of grant holders per household	Count	Non-normal	1.46	1.70
Number of total members per household	Count	Non-normal	4.76	2.65
Number of senior citizens per household	Count	Non-normal	0.33	0.62
Average annual rainfall at site	Continuous	Normal	644.22	310.47
Average annual temperature at site	Continuous	Non-normal	17.80	2.78
Average human population at site	Continuous	Non-normal	727.83	882.08
Proportion of WEF users at site	Percentage	Non-normal	20.78	15.82
Proportion of wild food users at site	Percentage	Non-normal	26.33	26.79
Proportion of NTFP users at site	Percentage	Normal	73.11	13.54
Primary source of food in household	Nominal	NA	NA	NA
Respondent gender (Male/Female)	Nominal	NA	NA	NA
Type of site (Rural/Urban)	Nominal	NA	NA	NA
Biome	Nominal	NA	NA	NA

Table A2: Comparison between means of variables between urban and rural sites

Level	Variable	Rural (mean)	Urban (mean)	Wilcoxon test	
				W	p
Respondent	Age	Older (43.47±16.78)	Younger (40.41±17.18)	35319	0.02
	Education level	Lower (Secondary school ± 1.6)	Higher (Matric ± 1.4)	22108	<0.001
	Rank for importance of fruit in diet	Similar (3.37±1)		32758	0.43
	Female to Male ratio	Higher (3:1)	Lower (2:1)	NA	NA
Household	Number of adults in household	Similar (2.94±1.82)		34032	0.12
	Number of children in household	More (1.65±1.5)	Fewer (1.28±1.48)	36802	0.001
	Number of earning members in household	Fewer (0.93±1)	More (1.31±1.14)	25202	<0.001
	Number of grant receivers in household	More (1.79±1.71)	Fewer (1.08±1.61)	41265	<0.001
	Number of members in household	More (5.06±2.75)	Fewer (4.42±2.5)	36114	0.004
	Number of senior members in household	Similar (0.33±0.63)		32371	0.49
	Food security score	Lower (7.22±1.34)	Higher (7.79±1.12)	23738	<0.001
	Food source diversity	Higher (2.76±0.9)	Lower (2.55±0.9)	35365	0.01
	Wealth quintile	Lower (1.66±0.74)	Higher (1.97±0.78)	24372	<0.001
	Number of domesticated fruits used in household	Similar (1±1.48)		31825	0.83
	Number of NTFP items used in household	Higher (1.86±1.45)	Lower (1.2±1.2)	39965	<0.001
	Number of wild foods used in household	Higher (0.49±0.69)	Lower (0.17±0.45)	39758	<0.001
	Number of WEF species used in household	Similar (0.45±1.39)		31817	0.80

Chapter 4. Urban foraging: land management policy, perspectives, and potential[3]

Abstract

Gathering of uncultivated food from public spaces, also known as foraging, is observed in urban areas across the world. Motives for and responses to urban foraging vary with socio-economic contexts, but the literature focuses predominantly on the Global North. This study examines the existing urban land management structure and its approach to urban foraging in the eastern coastal region of South Africa. Through interviews with municipal officials in eight cities, I identify the different stakeholders and their roles and relationships in land management, with a focus on green spaces, planting, and foraging. I incorporate analyses of networks and environmental worldviews to determine barriers to and enablers of foraging in urban public spaces. The policy on urban public space management does not prohibit foraging, planting in public spaces includes some useful species, and land managers are amenable to the concept of foraging in public spaces. Lack of knowledge on wild indigenous species and sustainable offtake, ambiguous, coarse, or lacking policy, and normative views of pristine nature may hinder foraging. Overall, land managers perceive foraging as a favourable activity, a legitimate land use, with the potential for biodiversity conservation and land stewardship partnerships.

Keywords: land use management, open space, policy, urban biodiversity, urban foraging, wild edible fruits, wild foods

4.1. Introduction

Urban open space is a valuable resource globally, with over half of the world's population residing in cities, and an annual urbanisation rate of 1% in developing and middle-income nations (UNDESA 2018). In the face of densification and development, urban green space is a critical yet contested component of the urban landscape (Haaland and van den Bosch 2015, Kabisch et al. 2015). Urban green space constitutes predominantly undeveloped space within urban and peri-urban limits that supports multiple ecological and social processes (Kambites and Owen 2006). It includes vegetation surrounding managed structures such as roofs, power lines, and verges (Rupprecht and Byrne 2014, Wang et al. 2014), managed formal spaces such as public parks, gardens and forests (Wolch et al. 2014), unmanaged informal spaces such as vacant lots and edges (Rupprecht and Byrne 2014), as well as urban forests (Dobbs et al. 2014). It provides numerous ecosystem services such as macro- and micro-climate regulation and resilience (Dobbs et al. 2014, Wang et al. 2014), biodiversity

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conservation and connectivity (Bonthoux et al. 2014, Penone et al. 2012), and cultural and recreational value (Poe et al. 2014, Unt et al. 2014, Ribeiro et al. 2018).

A widely recognised but relatively understudied service of urban green space is the provisioning of natural resources such as medicinal herbs (Poe et al. 2013), wild foods and craft materials (Hurley et al. 2015), and fuelwood, for subsistence as well as cash income (Shackleton et al. 2017a). Foraging is the activity of collecting such resources from the natural environment (Shackleton et al. 2017b), that are not cultivated or farmed commercially. Urban foraging in developed nations tends to be linked to cultural traditions, place-making, and improved quality of living (Peckham et al. 2013, Hurley et al. 2015, Schunko et al. 2015) and in some cases, also with subversive ideological movements (Galt et al. 2014, Paddeu 2019 , Nyman 2019), but motivations for the same in developing nations are underreported. Foraging in developing country cities may contribute significantly to urban poverty alleviation (Ward and Shackleton 2016), contributing on average 20% of the household income among the urban poor (Kaoma and Shackleton 2015). Implicitly, the prevalence of foraging is contingent upon household access to green spaces (Cooper et al. 2018, Chakona and Shackleton 2019). Citizen access to urban green spaces may be constrained by uninformed planning (Kabisch and Haas 2014, Wolch et al. 2014), socioeconomic bias (Sister et al. 2010), historical legacy (Davenport et al. 2012), and ambiguous policy (Jay et al. 2012).

Urban foraging holds potential as a citizen stewardship strategy, by supporting devolved governance, informal green space co-management, and urban biodiversity conservation (Elands et al. 2019, Kowarik 2018, Threlfall and Kendal 2018, Buijs et al. 2019). However, the links between foraging and urban green space management remain unclear, as public engagement in urban green space management may be arbitrary, inconsistent, or unorganised (Molin and van den Bosch 2014, Mathers et al. 2015), and extractive use of formal public spaces is often deemed unlawful by policy (McLain et al. 2012, Charnley et al. 2018). Within the current decade, cities in developed nations have begun to formulate policies with the specific aim of promoting public edible landscapes (Hajzeri and Kwadwo 2019). The current literature on urban green spaces and foraging is predominantly from the Global North (Rupprecht and Byrne 2014, Kabisch et al. 2015, Botzat et al. 2016), and is lacking representation from Africa, where foraging is common and urban centres are fast growing (Haaland and van den Bosch 2015, Rupprecht et al. 2015, Shackleton et al. 2017b).

This study fills the gap in knowledge on the policy response to urban foraging in formal and informal urban green spaces in South Africa. My primary research questions were: (i) what are the different types of urban green spaces and the institutions and policies governing them? (ii) do these policies or institutions address the phenomenon of foraging; if yes, how, and if no, how would they? (iii) can foraging as an urban green space use also contribute to landscape stewardship, why, and how? And (iv) what are the potential enablers and barriers to foraging in urban green spaces? Through semi-structured interviews with urban land managers, I map the existing policies, practices, and partnerships in urban green space management, and ascertain if urban foraging is in conflict or concord with these. I use network analysis to identify the key stakeholders in urban green space management, and the relationships between them. I also use an environmental worldviews framework to explore the links between urban green space managers' normative views about nature and their level of agreement with foraging.

Network analysis is a technique from information science (Cumming et al. 2010) that has been used in conservation to identify key stakeholders (Mbaru and Barnes 2017, Hauck et al. 2016, Abrahams et al. 2019) and the flow of information and trust between them (Borg et al. 2015), land use change drivers (Boron et al. 2016), habitat trees (Rhodes et al. 2006), and conservation planning (Mills et al. 2014) and development (Farr et al. 2018). I use it to identify important urban land users and managers, and through them, the potential points of entry for planting and uptake of wild edible fruit species and forager-manager partnerships. Environmental worldviews are known to influence people's behaviour towards and use of natural resources (Harju-Autti and Heinikangas 2016, Wallhagen and Magnusson 2017), and may also influence decisions by policy-makers and land managers (Buijs and Elands 2013, Buijs and Lawrence 2013). I use an adaptation of the Future of Conservation framework (Sandbrook et al. 2019) to evaluate urban green space managers' perspectives on nature conservation, and assess if these influence their response (as barriers or enablers) to urban foraging.

4.1.1. Study Area

The study area, the Indian Ocean Coastal Belt (IOCB), is host to rich biodiversity (Mucina and Rutherford 2006) and dense human population, is undergoing rapid land cover change (Jewitt et al. 2015), and urban foraging is highly prevalent in this region (Chapter 3). I focus on the planting and foraging of wild edible fruit species, because they are (i) widely foraged globally (Hickey et al. 2016), within South Africa (Welcome and Van Wyk 2019), and in the study area (Chapter 3), (ii) commonly found in the wild as well as in human-dominated landscapes including agroforestry systems, home gardens, and urban green spaces (Schlesinger et al. 2015), (iii) significant contributors to nutrition and income across the socioeconomic and rural-urban gradient (Ward and Shackleton 2016), (iv) often resilient to climatic and harvesting pressures (Gaoue et al. 2016), and (v) potentially important to urban biodiversity, particularly frugivores and pollinators (Sardeshpande and Shackleton 2019). South Africa is among the most unequal economies in the world, with a quarter of its population living below the food poverty line (StatsSA 2017). Its history of racial segregation has resulted in uneven distribution of infrastructure, including urban green spaces (McConnachie and Shackleton 2010). This juxtaposition of food insecurity, unequal access to urban green space, and prevalence of foraging makes a compelling case for further investigation of the enablers of and barriers to improved food security and green space provisioning and management through urban foraging.

4.2. Methods

4.2.1. Site selection

The IOCB houses the metropolitan municipality of eThekwini, along with 10 other urban local municipalities in five districts (Figure 4.1), (Municipalities of South Africa 2018). The populations of these municipalities range from about 120,000 (KwaMbonambi) to 3.4 million (eThekwini) people (StatsSA 2011), with a mean population of 492,720 people. Community services, parks, and environment departments in all 11 municipalities were contacted by email. Where no response was received, the municipal offices were visited for an appointment to speak with relevant officials. Full length interviews were conducted in eight of the 11 municipalities, while officials were not available for interviews in the other three.

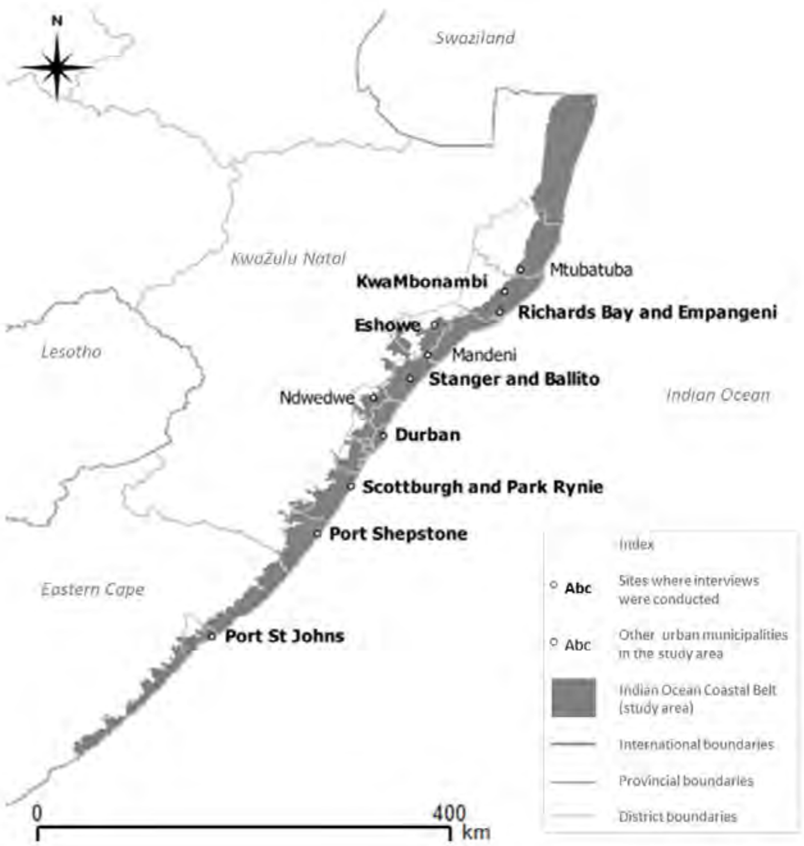

Figure 4.1: The Indian Ocean Coastal Belt biome (solid grey), urban municipalities within the biome, and municipalities where officials were interviewed (bold)

4.2.2. Semi-structured interviews

Key informants were initially identified within each municipality from municipal websites and contacted with a request for an interview. In municipalities with a designated parks department or environment department, parks managers and environmental managers were interviewed. In municipalities without designated parks or environment departments, officials in charge of tree planting and open space or environmental management within the community services department were interviewed. In the metropolitan municipality of eThekwini, I also interviewed a parks horticulturist and agroecology horticulturist as their role in managing open spaces was seen as pivotal by their colleagues in the parks and environment departments. A total of 15 key informant municipal officials were interviewed (Table 4.1). I consider this a representative sample based on the specificity of the research aims and questions, the strength of dialogue and density of information, and the case-based analyses of the qualitative data (Malterud et al. 2016), yielding sufficient information power.

Table 4.1: Details of the key informants interviewed

Local Municipality	Town/City	Parks Manager	Environmental Manager	Community Services	Total
uMfolozi	Kwambonambi	NA	NA	1	1
uMhlathuze	Richards Bay & Empangeni	1	1	1	3
uMlalazi	Eshowe	NA	NA	1	1
KwaDukuza	Stanger & Ballito	1	1	0	2
eThekwini	Durban	1	2	1	4
uMdoni	Scottburgh & Park Rynie	1	1	0	2
Ray Nkonyeni	Port Shepstone	1	0	0	1
Port St Johns	Port St Johns	NA	NA	1	1

Interviews with key informants were guided by the set of research questions (Appendix 1) about the scope and extent of formal and informal public open spaces under their administration; their mandate, management practices, and policies; and their opinion on foraging in public open spaces. Of the 15 key informants, 13 were asked to answer Likert scale questions about their environmental world views (the remaining two key informants deemed themselves unsuitable for comment as they managed broader mandates of community services). Interviews were conducted on an individual basis to avoid groupthink and collective answers. Interview length varied from 14 to 65 minutes, with a mean duration of 35 minutes. All interviews were recorded as audio files, and completely transcribed in MS Word. Respondents were labelled as CS (community services), EM (environmental manager), and PM (parks manager) for reporting purposes.

4.2.3. Data analysis

4.2.3.1. Qualitative analysis

Transcripts were coded for emergent themes manually in MS Excel. Information from interviews was complemented and triangulated with that from the Integrated Development Plans (IDPs) and Spatial Development Frameworks (SDFs) of respective municipalities as available. Specifically, searches were run for figures (number, budget, area, etc.) and policies about parks, conservation areas, and open spaces. These documents did not contain any information on management protocols.

4.2.3.2. Network analysis

The links between stakeholders were ascertained from the interviewee responses. Although no directed questions about stakeholder links were included in the initial interview guide, this information invariably and spontaneously surfaced in the interviews. Based on this data, a network was developed to identify the key actors and their connections to urban open spaces. Information from the interviews was used to map networks of stakeholders in urban open space management. Each group of actors involved in urban open space management was defined as a vertex or node, and the flow of management actions between these actors was considered an edge. The networks were directed and weighted (e.g. Fagiolo et al. 2010), and weights were based on the nature of transfers between stakeholders. Four types of management actions were identified, each regarded independent of the others, and assigned a weight (Table 4.2). The identification, independence, and weight of actions were *a posteriori* assumptions made by the author to conceptually represent the networks. As the aim of the analysis was to determine the degree of influence of actors on land management, direct management actions were assigned maximum weight, and devolved management rights, minimum weight.

Table 4.2: Types of management actions and weights assigned to them

Management actions	Weight
Approval or permission to use land (e.g. EIA approval)	1
Sharing of advice and expertise on land use management (e.g. landscaping advice)	2
Provision of management services (e.g. invasive alien control)	3
Sponsorship of plants, equipment, funding (e.g. offsets)	4

Networks were created and graphs plotted in R using the 'igraph' package. Degree centrality and authority and hub scores were calculated in R. Degree centrality is the absolute number of edges that a given vertex or node has with all other vertices or nodes within the network. An authority is a vertex or node with the most incoming edges, and a hub is a vertex or node with the most outgoing edges. Thus, degree centrality identifies the actors with the most connections, and authority and hub scores identify the actors that receive and provide maximum input in urban open space management, respectively.

4.2.3.3. Environmental worldviews

Holmes et al. (2017) developed a set of 28 Likert scale questions, based on the New Ecological Paradigm (Dunlap 2010), the Inclusion of Self in Nature (Wilhelm-Rechmann et al. 2014), the Two Main Ecological Values (Bogner 2018), and other frameworks, to conceptualise environmental worldviews of conservation workers. Sandbrook et al. (2019) classify these worldviews into four quadrants, each representing a different but not mutually exclusive approach to conservation:

(i) Critical Social Science (e.g. Spash 2015), leaning towards ethical anthropocentricism
(ii) Traditional Conservation (e.g. Miller et al. 2014), based on preservationism
(iii) New Conservation (e.g. Marvier and Kareiva 2014), tending towards utilitarianism
(iv) Market Biocentrism (e.g. Wilson 2016), advocating market-ecosystem segregation

In my adaptation of the Future of Conservation framework, the essence of 38 functional and normative assertions is distilled into seven normative statements, and respondents are asked to choose whether they agree, disagree, or feel neutrally about these statements. This compression reduces repetition (and potential respondent fatigue), breaks down complex conservation concepts into simple layperson terms, and avoids radical or abstract stances that respondents may not understand or may respond aversely to. The reduction in questions renders the scale susceptible to low internal validity, and increases the coarseness of response translation into worldview categories. However, I do not classify respondents into categories, but only identify their beliefs, and test for statistical differences between their worldviews and their opinion of foraging.

Environmental worldviews of interviewees were compared to their stance on urban foraging using a Chi-squared test with the null hypothesis: The interviewee's stance on foraging is independent of their environmental worldviews. I acknowledge that the assumption of a minimum expected frequency of five is violated by my dataset. Thus, due to the small sample size, the results of the test may be representative of divergent worldviews, but also a chance occurrence. Chi-squared tests were performed in R 3.6.0 (R Core Team 2015).

4.3. Results

4.3.1. The nature and number of open spaces

Of the 11 municipalities, four had formal open spaces, and four had conservation areas that are demarcated as such in town planning schemes (Table 4.3). Formal open spaces (parks and gardens) are characterised by landscaping features and amenities such as seating to engender public access and recreation. These are distinguished from informal open spaces, which lack improvement or demarcation, but are often used by the public for recreational purposes, and are viewed by municipalities as areas for future development and conversion to formal parks (CS2, PM3, CS3, PM5, EM3, CS4). Informal open spaces were identified and defined in the town planning schemes of eight out of the 11 municipalities. Some open spaces are demarcated for conservation purposes due to their strategic location (EM3), biodiversity (EM4), and ecosystem services (EM5). Such conservation areas are jointly managed by municipalities and citizens, and are mostly open for public use, subject to environmental considerations and at times user fees. Seven of the 11 municipalities host formally protected areas, although only Durban has protected areas administered by the municipality (the rest fall under provincial administration).

Out of the 11 municipalities, five had dedicated parks and environment departments to manage their open spaces, while the rest assigned this role to their respective community services departments. In Durban, the agroecology division played a significant role in management of all three types of open spaces (PM1, EM1, CS1). Parks departments in the different municipalities had between 100 and 300 staff members, and environment departments had between one and 25 staff members. Community services departments had between one and three staff members whose role related to open space management in the form of tree planting, waste management, or beach management. The agroecology division in Durban had seven staff members. The community services and agroecology departments engaged general workers from the government's Extended Public Works Programme (EPWP) when required, such as for planting and clean-up campaigns (PM4, CS1).

Table 4.3: The number and nature of open spaces across urban municipalities in the study area

Town/City Name	Formal Open Spaces	Informal Open Spaces	Protected Areas	Department In Charge
Mtubatuba[1]	0	4	2 [Provincial]	Community Services
KwaMbonambi[2]	0	3	0	Community Services
Richards Bay & Empangeni[3]	2	4 [Conservation]	0	Parks, Environment
Eshowe[4]	0	5	1 [Provincial]	Community Services
Stanger & Ballito[5]	0	5 [Conservation]	2 [Provincial]	Parks, Environment
Mandini	0	Undefined	2 [Provincial]	Community Services
Ndwedwe[6]	0	Undefined	0	Community Services
Durban[7]	12	10	7	Parks, Environment
Scottburgh & Park Rynie[8]	2	11 [Conservation]	0	Parks, Environment
Port Shepstone[9]	3	17	7 [Provincial]	Parks, Environment
Port St Johns[10]	1	Undefined	1 [Provincial]	Community Services

1 Mtubatuba SDF (2018); 2 Umfolozi Municipality (2015); 3 Umhlathuze SDF (2018); Umlalazi Municipality (2011); 5 Quayle and Pringle (2013); 6 Sishi, N (pers. comm.); 7 Govender (2018); 8 Umdoni IDP (2018); 9 Ray Nkonyeni IDP (2018); 10 Port St Johns IDP (2018).

4.3.2. Open space management: practices, policies, and planting

The suite of management practices used in open spaces ranged from plant trimming and biomass removal to restoration and carbon and biodiversity offset greening (Table 4.4). Parks and environment departments often work closely with the waste management section within the municipality (PM4, CS5, EM3, EM4). While plant trimming, biomass removal, and landscaping are mostly undertaken by parks departments and their community services counterparts, planting is often a joint undertaking by the parks and environment departments. Parks and community services departments are usually trained in mechanical invasive alien control methods such as trimming (PM2, PM4), but often enlist specialist teams from the environment department or the district administration for chemical control or intensive removal (CS3, PM5). In areas where sensitive ecosystems are faced with high development pressures, the environment departments engage with developers and town planners to protect and restore open spaces. In Durban, the Botanic Gardens and the agroecology division promote permaculture practices.

Table 4.4: Management practices and departments undertaking them

City Name	Trimming & Biomass Removal	Planting	Invasive Alien control	Awareness & Education	EIA, Planning, Protection	Compliance, Offsets, Restoration
Mtubatuba	Community Services	Community Services	NA	Community Services	NA	NA
KwaMbonambi	Community Services	Community Services	Community Services	Community Services	NA	NA
Richards Bay & Empangeni	Parks	Parks + Environment	Parks + Environment	Community Services	Environment	Environment
Eshowe	Community Services	Community Services	NA	NA	NA	NA
Stanger & Ballito	Parks	Parks + Environment	Parks + Environment	Environment	Environment	Environment
Durban	Parks	Parks	Environment	Parks + Environment	Environment	Environment
Scottburgh & Park Rynie	Parks	Parks + Environment	Parks + Environment	NA	Environment	Environment
Port Shepstone	Parks	Parks + Environment	Environment	NA	Environment	NA
Port St Johns	Community Services	Community Services	Community Services	NA	NA	NA

Conservation areas are characterised by a focus on the conservation of ecosystem integrity and services, thereby subject to well-defined rules on the kinds of uses that the public can and cannot undertake within them. Only the formal parks and gardens in Durban have clearly defined rules and policies for the kind of activities and uses permitted inside them. These tie in with the larger framework of the Durban Metropolitan Open Space System (DMOSS) that governs land use throughout the municipality in formal, informal, and protected open spaces (EM1, EM2, CS1, PM1). Other municipalities with similar policies around informal open space use are uMhlathuze's Environmental Services Management Plan (ESMP) (EM5), KwaDukuza's Biodiversity and Open Spaces Map (BOSMap) (EM3), and uMdoni's Tree Policy (EM4). These policies help the municipalities to prioritise land for conservation, development, and a spectrum of intermediate land uses. In Durban, the Botanic Gardens and Silverglen Nature Reserve are two examples of specific use policies. The Durban Botanic Gardens allows visitors to extract biological material, usually for research purposes, only with the recorded authorisation of the administration (PM1). The nursery at Silverglen Nature Reserve offers its visitors and traditional healers the opportunity to extract biological material such as tree bark, generally for personal or professional use (PM2, Oxland, J. pers. comm.).

While the DMOSS does not explicitly address the harvest of wild fruits or animals as a source of food, it does refer to the removal of bark from trees for medicinal use. Such use is generally permissible so long as it is done without inflicting significant damage to the plant (EM2, EM1). Similarly, the ESMP does not mention the use of wild fruits or food, but does acknowledge the use of natural resources such as reeds from urban open spaces, and incorporates such use as an ecosystem service that contributes to the biodiversity economy, thereby advocating sustainable use (EM5). The BOSMap considers more widely the sensitivity of ecosystems and their services, not delving into specific small-scale uses such as wild food foraging (EM3). The Tree Policy similarly advises on priority ecosystems and species, not focusing on the details of natural resource extraction (EM4). The existing policies on open space use are either ambivalent or encouraging of natural resource extraction provided it is sustainably done.

Planting of trees is actively undertaken by most municipalities during Arbour Week in September. Municipalities with parks and environment departments have internal budgets allocated to planting, although officials admitted it was difficult to provide a figure for how much of the budget was spent on planting or how many trees were planted (Table 4.5). In smaller municipalities, planting was undertaken incidentally, such as when a new housing development required greening (CS3), or when private entities initiated offset greening (EM4). Most municipalities supplement their internal planting budget with sponsorship from the Department of Agriculture, Forestry and Fisheries (DAFF) and the Department of Economic Development, Tourism, and Environmental Affairs (EDTEA). Where restoration or offset planting is undertaken, the developers and occasionally, NGOs like Wildland Conservation Trust (WCT), sponsor the purchase of plants. Planting is generally done in low income housing yards, schools, and newly developed sidewalks and amenities. In Eshowe, trees planted by the municipality in public open spaces were reportedly stolen within a week (CS2), so the officials decided to plant in household yards rather than openly accessible spaces. In some cases, verges and sidewalks in low income housing neighbourhoods may be too narrow and already occupied by water and electricity infrastructure (PM2), prompting planting inside yards rather than along the road. The sponsors and location of the planting often influence the choice of species planted, although Arbour Week plantings commonly consist of one (horticultural, domesticated) fruit tree and one indigenous shade tree per household.

Table 4.5: Factors influencing planting in different municipalities in the study area

Town/City Name	List of prescribed planting species	Annual planting frequency	Budget sources	Target location	Species selection criteria
Mtubatuba	None	Unknown	Unknown	Unknown	Unknown
KwaMbonambi	None	Incidental	Infrastructure, EDTEA, WCT	Small town rehabilitation, sidewalks	Guidance & sponsorship from EDTEA, WCT
Richards Bay & Empangeni	None	Once (Arbour Week)	R600,000* Internal, DAFF, EDTEA	Low income housing yards, open spaces, restoration	Indigenous, drought resistant, shade; fruit, vegetables
Eshowe	None	Once (Arbour Week)	R30,000 Finance, DAFF, EPIP	Low income housing yards, schools	Fruit, shade, indigenous, succulents; guidance & sponsorship from DAFF, EPIP

Stanger & Ballito	Yes	Monthly (Annual total 400 plants)	R200,000 Internal, DAFF, EDTEA	Low income housing yards, schools, open spaces, restoration	What suits the area; indigenous, fruit; non-aggressive growth and fruiting; medium maturity size; non-messy trees; history
Durban	Yes	Unknown	R416,00,000*	Low income housing amenities, open spaces, schools, restoration	Sponsorship from WCT +
Scottburgh & Park Rynie	Yes	Incidental	Internal, DAFF, EDTEA	Low income housing amenities, restoration	Guidance & sponsorship from DAFF, EDTEA
Port Shepstone	None	Incidental	R600,000* Internal	Low income housing amenities, open spaces, schools	Indigenous, ornamentals, guidance & sponsorship from DAFF, EDTEA
Port St Johns	None	Unknown	R20,000 Internal	Unknown	Unknown

* these are budgets for Parks development and maintenance, of which plantings are one part

DAFF: Department of Agriculture, Forestry and Fisheries, EDTEA: Department of Economic Development, Tourism, and Environmental Affairs, WCT: Wildlands Conservation Trust

The species lists from the parks departments contained a number of medicinal species, as well as *Trichelia dregeana*, a commonly occurring species whose arils are often consumed as a delicacy after soaking in water. However, each species list had only two wild edible fruit species, namely

Harpephyllum caffrum (appeared in two lists), *Diospyros whyteana* (one list), and *Ficus sur* (one list). The agroecology species list did not contain any wild edible fruit species. There was also a recurring perception among interviewees that edible fruit species were either not wild or not indigenous, and that commonly occurring plant species in open spaces were either invasive alien guavas or not fruit bearing.

'Personally I wouldn't [encourage people to forage] because it is very difficult to differentiate between indigenous and alien fruits…Fruits from alien plants are poisonous'

- CS3

'Guava is alien, mango and pear are exotic. The waterberry (Syzygium spp.)*… I haven't seen fruits on it. You get a black-purple fruit* (Flacourtia indica)*… but that tree is not indigenous.'*

- EM4

'We've been getting a lot of comments from new developers… about can we plant fruit trees along the sidewalks in our developments. And our main issue with that is that so many of the fruit trees are not indigenous. Meaning that they use a lot more water… and we're going to be water scarce in the future so there's serious issues with that.'

- EM1

However, on further discussion, most interviewees recollected examples of indigenous wild plant species that bear edible fruit. There is scope for the inclusion of more wild edible fruit species in plantings, and municipal officials are open to the prospect of such. Lack of information coupled with budget restrictions may be the only obstacle in the uptake of wild edible fruit species planting.

4.3.3. Open space management: stakeholder engagement and partnerships

Community services departments often undertake awareness and cleanliness campaigns to educate and engage citizens in waste management (CS5, CS3). Parks and environment departments partner with citizen bodies such as church and neighbourhood groups, conservancies, and urban improvement precincts as well as individual land owners to facilitate joint land management. Citizen groups may report on service delivery and illegal activities within their area, or organise as committees, non-profit organisations, or body corporates that facilitate the maintenance of public spaces, parks, or nature reserves through fundraising and vigilance with assistance from the municipality. In some cases, citizens and municipalities co-manage some public or private open spaces with the aim of conserving the biodiversity therein, although such areas are not formally developed or protected (see Table 4.3). Interviewees mentioned examples of 10 such partnerships in three municipalities, namely Durban (4), Scottburgh and Park Rynie (2), and Stanger and Ballito

(4). Active public involvement in open space management exists in some municipalities, but is most established and evolved in Durban, the largest urban centre in the IOCB.

A branch of Durban's environment department is dedicated to developing biodiversity stewardship partnerships with citizens. These partnerships offer land owners a suite of incentives in exchange for sustainable management of their land. These range from land zoning and environmental impact assessments for development, invasive alien control and vegetation burning in open spaces, to maintenance, management, marketing, and tax breaks in exchange for conservation servitudes. Through these partnerships and restoration programmes, the department has also developed citizen capacity in invasive alien control and management burning in some areas. The agroecology division in Durban focuses solely on citizen partnerships and capacity building. Interested citizens or groups approach the division seeking assistance in setting up their small-scale food production systems. The division helps them develop a co-operative, constitution, business plan, a memorandum of understanding with land owners, and linkages with fresh produce markets. They impart training in bio-intensive permaculture farming, and provide support in the form of seeds, saplings, and machinery. The Durban Botanic Gardens also hosts thematic programmes to educate the public about biodiversity and botanical heritage.

Environment departments in four municipalities undertake restoration and offset greening in partnership with developers. ESKOM, King Shaka International Airport, Tongaat Hulett Developers, TransNet, property developers, and sand mining companies were some of the examples cited. Strategic Environmental Assessments and Environmental Impact Assessments mandatory for development authorisation often stipulate compensatory greening, and municipalities team up with the DAFF, EDTEA, or NGOs to advise on the nature of restoration. Often such offset and restoration projects generate local biodiversity-based livelihoods such as *Papyrus* reed enterprise (EM5), and nursery and gardening enterprise (EM1). All interviewees involved in the execution of restoration projects agreed that including wild edible fruit species in such greening is feasible and holds potential for foraged fruit based livelihoods.

'We have mining houses… and I think urban foraging is one of those elements they're gonna have to consider… [in] their rehabilitation efforts.'

- EM5

4.3.4. Network analysis

Up to 10 different stakeholder groups were identified (Table 4.6), although the number varied depending upon the size of the municipality. For example, whereas the municipality engaged with individual land-owner citizens as well as groups of citizens such as neighbourhood committees in

Durban, medium-sized municipalities interacted with citizen groups, but seldom with individual citizens, and such citizen groups were not mentioned by interviewees in smaller municipalities. Therefore, three networks were constructed, one each for a metropolitan municipality (Ethekwini), medium-sized urban municipalities (KwaDukuza, Ray Nkonyeni, Umhlathuze, Umdoni), and small urban municipalities (KwaMbonambi, Mtubatuba, Port St Johns, Umlazi). The networks were graphically plotted (Figure 4.2) to represent degree centrality (Table 4.6) of stakeholders in urban open space management.

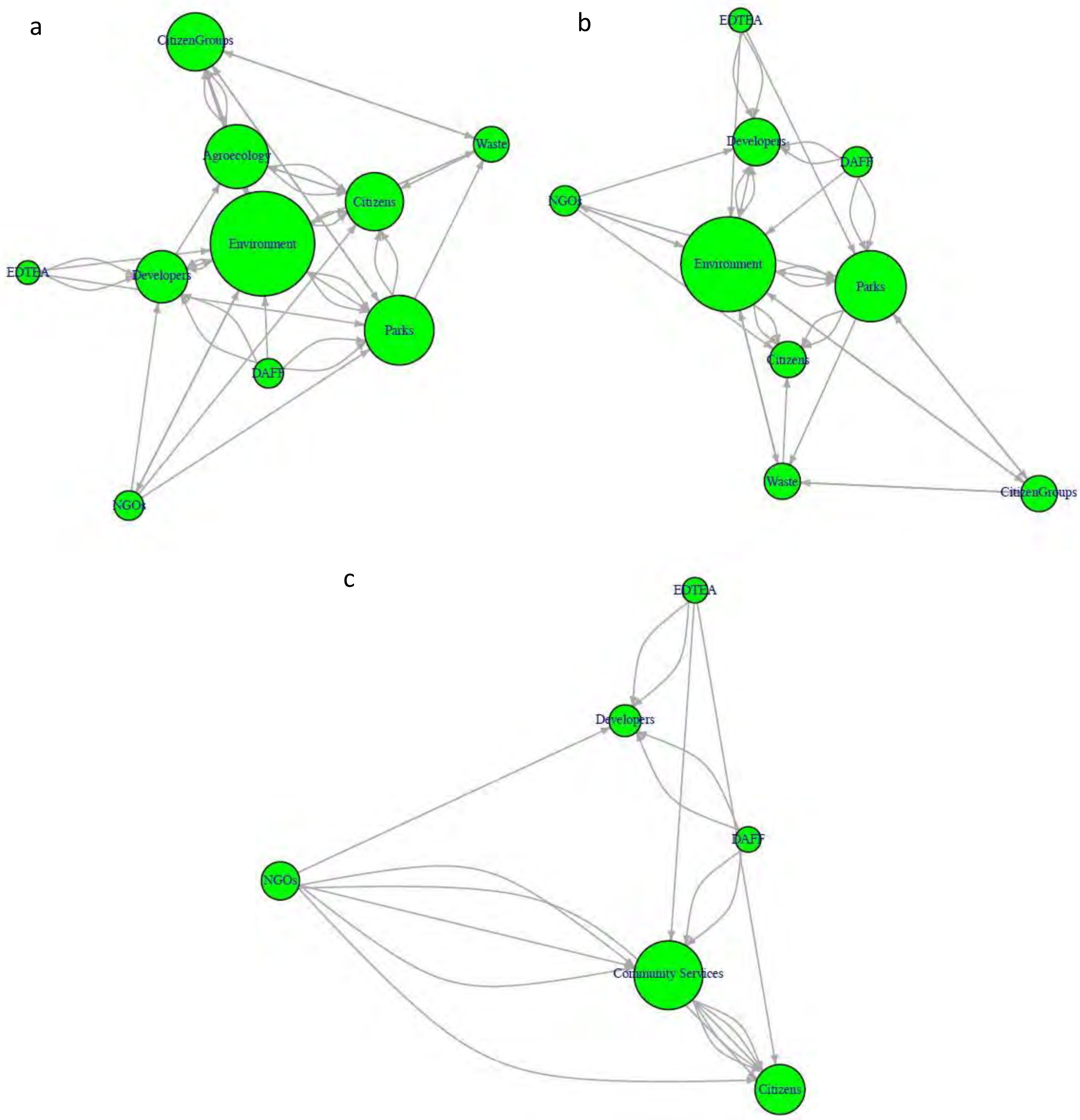

Figure 4.2: Network diagrams of stakeholders in open space management in: (a) metropolitan, (b) medium, (c) small urban municipalities

While the environment and parks departments were central to open space management in the metropolitan and medium-sized municipalities, the community services department, that handled both these functions (albeit on much smaller scales) and waste management was central in the small municipalities (Table 4.6). The agroecology department in the metropolitan municipality also had a high degree centrality. Citizens were more central than developers and NGOs in the metropolitan and small municipalities, but developers were more central than citizens, who in turn were more central than NGOs in medium-sized municipalities. The DAFF and EDTEA were the least central entities in all three networks, as they only provide inputs to the local administration and private sector, but do not rely on them for any transfers.

Table 4.6: Degree centrality, and authority and hub scores of different stakeholders in different sized urban municipalities

Stakeholder categories	Vertices or Nodes	Metropolis			Medium-sized towns			Small towns		
		Deg	Auth	Hub	Deg	Auth	Hub	Deg	Auth	Hub
Non-administrative	Citizens	10	1	0	6	0.55	0	8	1	0
	Citizen Groups	10	0.82	0.25	6	0.32	0.46	-	-	-
Local administration	Environment	18	0.52	0.73	16	0.64	1	11	0.84	0.66
	Parks	12	0.61	0.54	12	1	0.47			
	Waste	6	0.27	0.29	6	0.36	0.27			
	Agroecology	11	0.07	1	-	-	-	-	-	-
Provincial administration	DAFF	5	0	0.35	5	0	0.70	4	0	0.34
	EDTEA	4	0	0.31	4	0	0.62	4	0	0.48
Private sector	Developers	9	0.30	0.12	8	0.50	0.20	5	0.30	0
	NGOs	5	0.09	0.43	5	0.12	0.58	6	0	1

Deg: Degree centrality (total number of incoming and outgoing connections of stakeholder)
Auth: Authority score (rank of stakeholder relative to stakeholder with most outgoing connections)
Hub: Hub score (rank of stakeholder relative to stakeholder with most incoming connections)

Citizens and citizen groups were the authorities in the metropolitan municipality, receiving approvals, advice, management services, and sponsored plants from most other stakeholders (Table

4.6). The agroecology and environment departments in the metropolis were hubs that provided approvals, advice, services, and resources to citizens, the parks department, developers, and NGOs. In medium-sized municipalities, the parks departments were the authorities and the environment departments were the hubs, while citizens were the authorities and NGOs the hubs in smaller municipalities. The DAFF and EDTEA were hubs in medium-sized municipalities, often advising private sector stakeholders on restoration projects and sponsoring plants for parks and citizens.

4.3.5. Open space management: challenges

Illegal dumping was the single largest challenge in open space management cited by interviewees (7). Criminal and illegal activities such as drug use, sand mining, theft, and vandalism were also cited (7) as challenges, followed by invasive alien control (5). Illegal settlement by new urban immigrants, land fragmentation by agriculture, development, and land claims, land use conflicts between conservation and other development and recreational uses, and a shortage of staff were equally cited (4) challenges. Restricted budgets and lack of policy also figured on the list (Figure 4.3).

‘Some say people are dumping because they are not aware. But I ask, if they are not aware, why don’t they dump right in front of the road? Why do they dump at night or during weekends? They know what they’re doing is wrong. It’s not a matter of awareness, it’s a matter of people being lazy. There’s no sense of responsibility. And contradictory to popular belief, all races are dumping. You catch them dumping, you’re like I thought you knew better! Just because people with money can afford [to live in upmarket suburbs] doesn’t mean they have that sense of responsibility.’

- CS5

‘Close to 2030 we will make sure that all our suburbs have parks in order to eliminate open spaces. Because people go to these spaces to [illegally] dump [waste], the kids are busy with drugs. So once we develop those parks, it will assist us to reduce illegal dumping and [provide] recreation [opportunities] so [children] don’t pay attention to unnecessary things.’

- PM5

‘We don’t have big companies which contribute in terms of paying rate. We rely only on government budget which comes in the form of equitable share. So in budget we are restricted… and unfortunately due to limited budget, we are failing to fulfil our vision objective.’

- CS2

'I don't know why the municipality is keeping so much property. Because to maintain those [open spaces] is costly and time consuming. If you're looking at certain areas within the municipality, there's no place to plant a tree. And it gives us more work because the trees are falling, we've got to trim them.'

- PM4

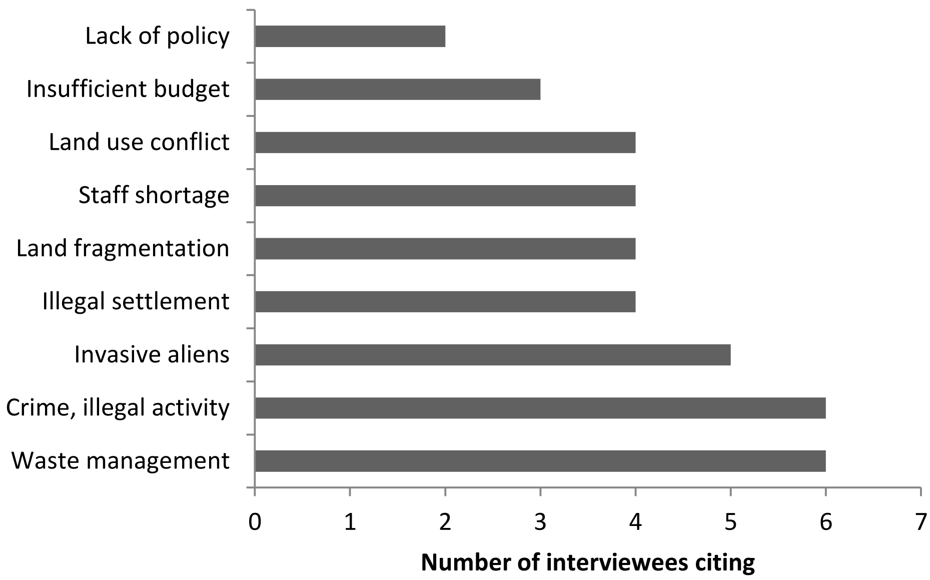

Figure 4.3: Challenges faced by urban open space managers across municipalities (n=15)

Besides these oft-cited challenges, some interviewees also highlighted issues stemming from the apartheid legacy. At the turn of the 20th century, the Land Acts of South Africa dispossessed native peoples of their land, and displaced them into segregated, settlements with very poor living conditions and infrastructure (Letsoalo and Thupana 2013). With the abolition of apartheid in 1994, land was opened up to the economically underprivileged natives, in the form of government-sponsored low-cost housing in urban areas (Goebel 2007), and land in trusts governed by traditional chiefs in rural and peri-urban areas (Mazibuko 2014). Open spaces in low-cost housing schemes have historically been under-provisioned (Goebel 2007, Donaldson et al. 2013, Shackleton et al. 2017a), and recent attempts at greening have in some cases been constrained by limited open space (PM2), or used exotic species (EM4). In the wider context of present-day open space management, traditional land claims and trusts may at times challenge or dispute land zoning for biodiversity conservation or public recreation (EM2, EM5). Particularly in Durban, where 44% of the land falls under the Ingonyama Trust, securing land for conservation is difficult due to differing priorities of the local municipality and the trust board (EM2).

'[The] spatial representation of nature reserves in Durban... it's a very centralised representation. [A]ll the group areas people were shifted on to the periphery of the city where there were no opportunities. And then you get a new post-apartheid city where no one's taking nature experiences to people. They're just still at the central model... So when we try to work on the communal land, try to make inroads with the chiefs there, coming in and saying well we want a model where we want you to secure a portion of the land exclusively for conservation, and we don't want people to use it, that model will never work in that context. We just wouldn't get buy-in. So you have to have a different approach… an approach where it's resource use. But in a way where hopefully those resources are being utilised in a manner that actually that's sustainable. And people can see some benefits flowing from them.'

- EM2

Lastly, some of the interviewees mentioned that it can be challenging to acquire, block, or retain suitable land for conservation, food production, and recreation in the face of other high-yielding economic uses like commercial or residential infrastructure (also see Environmental Worldviews).

'[O]ur biggest challenge here is land. Because more people want to [build] buildings now. Property developers [are] investing and pushing for houses. Plus they're getting more monies. [For the] same land here, if they can pick up property for half a million or a million rand, why [would they] waste time [allowing people] to do small [permaculture] agriculture [on their land]?'

- CS1

The municipalities face common challenges of waste, crime, and invasive alien species management that may be aggravated by the lack of financial or human resources and adequate policy responses. In addition, they acknowledge the need for improved planting in low-cost housing areas, and more inclusive use-based conservation models in traditional areas. Foraging has the potential to increase public use of open spaces, strengthening management capacity through citizen partnerships, and contributing to biodiversity enrichment in low-cost housing areas and conservation in traditional areas.

4.3.6. Foraging

Of the 15 interviewees, 12 reported to having observed some instance or evidence of foraging within their municipality, and 10 of these instances were of wild edible fruit. Medicinal bark removal (4), *Papyrus* reed harvest (1), and mushroom picking (1) were the non-fruit foraging instances reported. *Carissa* (4), *Eugenia* (1), *Passiflora* (2), *Psidium* (2), and *Syzygium* (2) were the wild species interviewees reported having seen foraged. Instances of informal vendors of these species were reported by four interviewees.

Twelve of the 15 interviewees were in favour of foraging, and three were concerned about its implications, namely foraging threatening vulnerable species (2), encouraging propagation of invasive alien species (2), and being a health hazard for the uninformed (2), which in turn would be a liability for the municipality or management.

'I don't know if I would encourage people to [forage] because you see I will say I'm encouraging people to take those fruits… and then the whole species [is] gone. So I think those species somehow need some kind of protection… if they are available in public spaces… like if you do require to take some fruit… there must be some sort of permission from the municipality… so that it is not free for all.'

- PM3

'In my opinion… people would eat fruits from trees that they know. Like your mango, pear, or guava. If there's an indigenous tree, they wouldn't know whether you can eat the fruit… or not, whether it could it be poisonous.'

- EM4

'[Foraging can be] dangerous, especially for the growing children, because they're not really aware. It's not like our fathers that grew up on farms and they know these [edible] fruits... You know old people are very knowledgeable of indigenous things. [Un]like us.'

- CS3

In protected and formal open spaces, foraging may be restricted to certain areas or species, and this information is usually provided on signboards or at the administrative offices of these spaces. For example, although foraging in the Durban Botanic Gardens is legal, the rules require that anybody extracting any plant material from the Gardens seeks permission from the management. In informal open spaces, this is generally not the case, unless the space is private.

'The foraging probably does happen without our knowing about it because it's probably done without permission. We would encourage people to ask permission first, and that's where they fill out, or we fill out a form for them.'

- PM1

'So to my mind, people coming and removing fruit from those [common] trees [in nature reserves], they do it in any case, informally. Would you want to formalise it? I don't know if it's necessary, but there's no one stopping them and I don't think there's a problem with them doing that.'

- EM2

'If you're taking from mother nature, it's a good thing. My problem is against stealing [laughs]. [Foraging] is not stealing, because it's an open space. Although it belongs to the municipality, it's an open space. [People] coming to your property, jump[ing] over your fence, that is stealing.'

- PM4

Three of the 12 interviewees in favour of foraging said it would augment food supply and security. In terms of managing open spaces, those in favour of foraging said it would aid or complement the function of their departments. Interviewees asserted that foragers could partner with the municipality to aid biomass and waste removal (6), and reduce crime by promoting regular, responsible use of open spaces (3). Foraging could also assist biodiversity conservation by promoting the sustainable use of natural resources (3), encouraging the dispersal and planting of indigenous species (3), attracting indigenous animal and bird species (2), and adding human benefits to nature conservation (2). Lastly, it could play a role in encouraging awareness, education, learning, and research about diverse food species (1) and preserving and propagating cultural relationships between plants and people (1).

'I don't have a problem with [foraging]. Makes our life easier [laughs] because they're removing what… we [would] have to remove otherwise. It helps the distribution of seeds, it also helps with our maintenance. And it's nature. People should be able to pick up what's there.'

- PM2

'You know whilst we might say as parks officials we're not going to plant that because it's going to drop messy fruit. Well in actual fact that fruit that's really what people want. So I think there's a good opportunity at looking at edible landscapes and… foraged foods and promoting that.'

- PM1

'[I would] definitely [encourage foraging]. Because the municipality's hands are stretched as is. There wouldn't be a problem because I grew up eating wild fruits anyway… there's nobody that's managing those [informal] open spaces.'

- EM3

Even among those who favoured foraging, estimation of sustainable yield and adoption of appropriate harvest practices was a precondition (4), although they felt that fruit foraging was likely to be less damaging than harvesting of other plant parts. There was also the concern that increased food availability could potentially support larger populations of vervet monkeys, which are reportedly a nuisance in Durban (1). There was no significant difference between the stances of interviewees from different departments (χ^2= 1.47, p=0.49).

'We would want to try and think about the sustainability of the activity… [And wild edible fruits] to me is a lot more inviting as a space to interact with people… [be]cause… collect[ing] bark for example is clearly a much more destructive activity generally. [We ideally want to know] what is it that people want, what kind of demand is there for that, what is the supply of those resources per protected area, and what would be a sustainable offtake? And then you could have a monitoring programme to think about whether or not we've got the science right.'

- EM2

All interviewees were amenable to the concept of developing products, supply chains, and ecotourism with foraged fruit. The most frequently cited potential benefit of commercial foraging was the creation of employment opportunities, contributing to poverty alleviation, and local economic development (7). Additionally, some proposed that commercial foraging could potentially augment the function of their departments, by realising economic benefits and sustainable resource use in open spaces and conservation areas (5); and by providing favourable indigenous, resilient, and low input alternatives to agriculture, which is a major land use conflict in open space and conservation area management (4). Further, some also noted that commercial foraging could contribute to the culture, knowledge, and uptake of diverse food species (3).

'So I think [there is] value in educating the public about weeds which are really nutritional… it [could] be a case of learning about a particular tree and what it can be used for and then encouraging the planting of a particular tree species. So we could use this [garden] as a public educational platform to promote the idea. Could we have a park in a district… that allows foraging and we actually plant for foraging?'

- PM1

'I don't know if [indigenous fruits] is what people are looking at when they say [agriculture]… but if we think about it in a transformative way, because we don't have to do things like we did in the past. We can't say all we're going to plant here are apple trees and orange trees. We could be planting those various [indigenous fruit] species.'

-EM1

All interviewees concurred that with sustainable practices, commercial foraging would not pose ecological problems. Formalising harvest and sale of foraged fruit through transparent, regulated supply chains would potentially deter unsustainable offtake according to some (3), and could also encourage domestication and cultivation of new species if the demand was high enough (3).

'I don't think [commercial foraging] is risky because that will be [the] same as going to agriculture. If there is a demand for those kind of fruits, then your nurseries will just come in making sure that the product is cultivated, and it's opportunity.'

- PM3

'Now you might have been getting say a tonne [of fruit] a year, now you've gotta share your tonne, and there's half a tonne each. And now somebody else sees it, and there's three or four people. Then… is it possible to cultivate these fruits? If there's that kind of demand, would it not be easier and better to take it to people? [O]nce [wild edible fruits] are all growing around the… homesteads, that would be a lot easier, with the transport costs as well. Now everybody's got access to their own resource. So maybe you take a little bit out the forest, naturally, but also maybe the more long-term sustainable solution would be to take those trees to people.'

- EM2

Resource allocation in terms of who was eligible to forage in certain areas or from certain trees was recognised as a possible issue (2), but was countered by the observation that wild edible fruit bearing species are fairly common and not ecologically threatened (3). The Durban agroecology division works around resource allocation within citizen groups by encouraging them to create and adhere to a constitution (CS1), and this form of devolved commercial foraging rights may prove useful in urban neighbourhoods or private open spaces.

In the case of intensive foraging in parks or dedicated foraging gardens, the attractiveness of the space may be compromised by foraging (PM1), but design considerations such as designated foraging areas and companion planting could potentially alleviate this issue. Wild foods may be considered as inferior to conventional mass-produced foods, despite their nutritional value, and their relative vitality and productivity in unmanaged landscapes (2).

'The Valley Trust… released a poster comparing cabbage to local weeds and things like blackjacks and amaranthus, and the nutritional value [of these wild foods] far superseded cabbage. So I think that's the value… in educating the public about weeds which are really nutritional. And growing cabbages, takes a long time to grow a cabbage… and all the pests... And this whole thing of weedy plants being seen as inferior or poor people's food. So the whole connotation that weeds are for poor people. Because again that's where they were trying to promote the value of weeds and foraged foods.'

- PM1

'You know weed is in the eye of the beholder… a forager would take this [weed] as fantastic but most people would see those as weeds.'

- EM2

The novelty and seasonality of wild edible fruits were seen as market risks: while they could be a selling point, unfamiliarity and unavailability could also hinder popularity (3). Introducing supply chains to formal markets such as stores and restaurants could help increase exposure and 'legitimacy' of wild edible fruits (1), and bridge seasonal gaps in traditional produce (1).

Foraging in urban open spaces is not generally considered illegal unless explicitly stated at the location. Whereas there are some specific concerns, the consensus is that foraging would be beneficial overall to achieving the objectives of all stakeholders.

4.3.7. Environmental worldviews

There was a significant difference between the environmental worldviews of interviewees who were pro-foraging and those cautious about encouraging it in public spaces (χ^2= 95.77, p<0.001). Notably, those interviewees that were concerned about the implications of urban foraging tended to favour conservation for nature's sake rather than for human benefit, and tended to believe that pristine nature untouched by humans does exist. Overall, these two statements evoked the most divided responses.

'Nature is socially constructed. It's not real.'

- PM1

'There are some places where I personally I feel like that the hand of humans should be actually very limited or almost nothing. I think that's really important.'

- EM2

All interviewees agreed that the well-being of people is important to nature conservation (Figure 4.4). Some interviewees expressed the importance of traditional land claims (3) and development rights (3) in urban land use planning in relation to this statement. Twelve of 13 interviewees agreed with partnering with markets and fair trade with a view to conserving nature. Such a partnership was seen as a source of employment opportunities by some (2), and others recognised it as an expression of the value of the ecosystem services that their departments worked towards conserving (4). All but one of the interviewees believed that both the wealthy and the poor should benefit from nature conservation, although it was acknowledged that the rich often benefitted more than the poor (3). Disagreement with this statement (1) echoed the sentiment that even though the rich have larger environmental footprints, they already enjoy more access to nature, and therefore should not hold the same priority as the poor as beneficiaries of nature conservation. While most interviewees believed using economic incentives in nature conservation was not risky, two of them believed it could pose a risk due to uncertainties in the flows and yields of ecosystem services and their sometimes abstract nature.

'We have no tangible way of saying this is how this wetland is benefiting X, Y, and Z person on the ground. We can say generally… this is how it may protect us from climate impacts or… provide water. But when you put down a development on paper saying I'm gonna employ this many people for this period of time, it's going to result in this much economic development, there's no way we can compete with that. As much as it's important to speak the same language as economists and developers, it is difficult, a risk, because we could come out on the wrong side of that.'

- EM1

'We have to ensure that… if we are proclaiming areas for nature conservation, areas for obstructing economic use… that they do in fact yield the economic benefits that other forms of the economy do. So that's where I see the risk. And you know with nature, you aren't in complete control. There's uncertainties.'

- EM5

Similarly, while most strongly agreed that for nature conservation to better succeed, the emotional separation between people and nature needs to be reduced, two interviewees had a more neutral stance, saying that while emotional connection was important, people's socio-economic backgrounds and priorities also influenced nature conservation. Some interviewees identified awareness and education as a means of establishing and strengthening this connection (3).

'There is the potential, if you're poor or if you don't have the means, yes, then surely you could be completely disconnected [from nature] because you can't get to it. But if you're wealthy enough, people seek these opportunities in any case. I think [emotional connection to nature] is definitely important. I don't know if it's completely required. I think it definitely helps. I mean people will make decisions about pandas or tigers or California rednecks even if you haven't seen one.'

- EM2

'Education plays an important role. Some people… don't know the importance of a tree, because nobody told them, that it's not that you mustn't cut a tree, that you get whatever you get from it. Sometimes people need to be educated in order to preserve their environment.'

- PM4

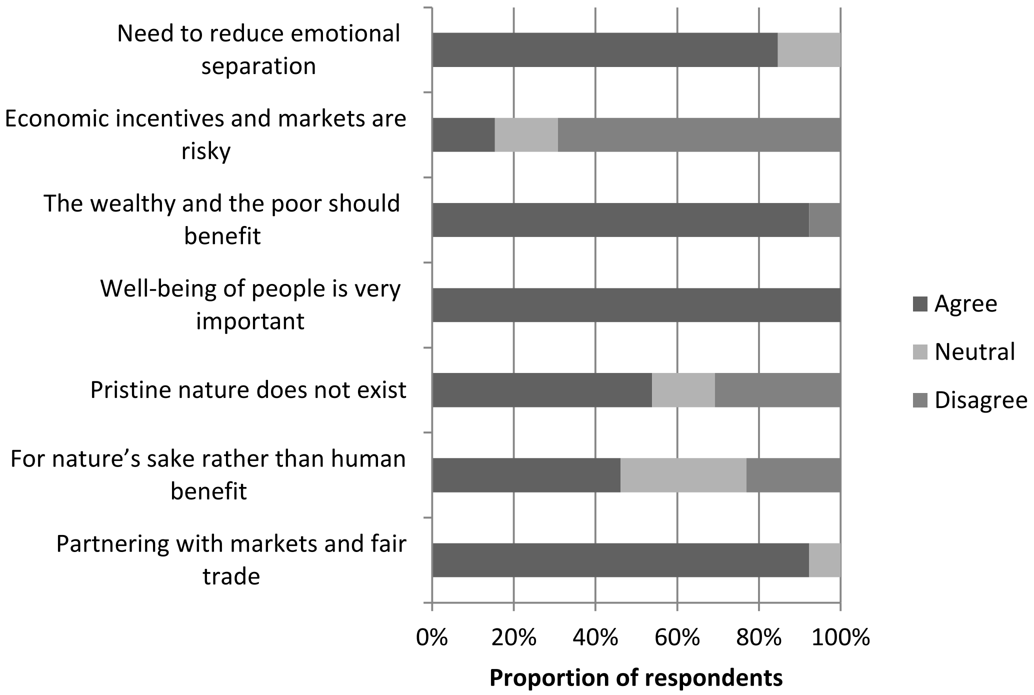

Figure 4.4: Responses of urban open space managers to the environmental worldview statements Likert scale (n=13)

4.4. Discussion

The urban municipalities within the IOCB range from small towns to major economic hubs and include the metropolis of Durban. While smaller towns have few to no formal green spaces, larger municipalities have formal parks and gardens as well as departments dedicated to the maintenance of these. Smaller municipalities typically manage their informal spaces as a mandate of community services, with budgets and staff in common with waste management and infrastructure development, and often have no specific policy to inform land use or greening decisions (also see Gwedla and Shackleton 2015). In economic hubs with various land use pressures, municipalities have incorporated open space mapping systems such as the DMOSS (Roberts 1994, Davids et al. 2016, Ethekwini website 2019), BOSMAP (Quayle and Pringle 2013), and the ESMP (Umhlathuze SDF 2018) to prioritise conservation and development. Environment departments in these hubs coordinate collaboration across various stakeholders including developers, town planners, district and provincial departments, NGOs, and citizens with the explicit aim of sustainable land use management, including conservation and restoration (Ethekwini website 2018a, b, c, Ethekwini SDF 2018, pp.122-125, Govender 2018, Ray Nkonyeni IDP 2018, Umdoni IDP 2018, Umhlathuze SDF 2018).

4.4.1. Policy and protocol

Foraging in urban open spaces covered in the IOCB is regarded as legal unless otherwise notified at the site. Some sites require foragers to seek permission from the owners or managers of the space, and this is generally conveyed to the public through signboards. Some public spaces such as the permaculture garden at the Durban Botanic Gardens (Mattson 2013) and Silverglen Nature Reserve (Crouch and Edwards 2004) are specifically designed with the aim of spreading awareness and propagating resources for sustainable harvesting of indigenous plant resources. In the wider context of urban open space management, foraging is not specifically mentioned or addressed as an activity or an ecosystem service occurring in these spaces, but the broad policy governing these spaces promotes sustainable use of natural resources therein. The policy in coastal KwaZulu Natal is therefore at the very least cognizant of the extractive use of urban open spaces, which is a stark difference from examples in the literature where policy categorically prohibits such use (McLain et al. 2012, Charnley et al. 2018). However, such policy mechanisms exist in only three of the eight municipalities, even though foraging has been observed by interviewees in the eight municipalities. This absence, ambiguity, and in some cases, coarseness of policy has been identified as a challenge by land managers. The lawfulness of foraging may be a concern for foraging and non-foraging citizens with an interest in foraging, and spreading awareness about sustainable foraging may unlock the potential for citizen engagement in land stewardship. Examples of such citizen engagement include co-production of green spaces in Berlin, funding of citizen-led green space interventions in Utrecht, and semi-autonomous governance of green spaces in Amsterdam and Milan, all along side recreational or extractive use of these green spaces (Buijs et al. 2019).

4.4.2. Planning and planting

Planting in urban open spaces is undertaken with a clear emphasis on indigenous and useful species, particularly plants bearing parts of medicinal value. The concept of wild edible fruits is however novel to most urban land managers, and less than a handful of such species are currently included in plantings. In Durban, wild edible fruits may prove particularly useful to the environment department, which seeks use-based conservation strategies in protected and traditional areas, and for the agroecology division that seeks low-input resilient food species. Thus, planting indigenous wild edible species for foraging could provide a win-win solution for biodiversity conservation and food production, which may conventionally be perceived as being conflicting land uses (Phalan et al. 2011, Wilhelm and Smith 2018). Urban parks are often host to high species richness, although a considerable portion of their species may be exotic (Nielsen et al. 2014, Champness et al. 2019). The medium-sized and small municipalities could benefit from incorporating indigenous edible species in planning their upcoming green infrastructure to be multifunctional (Hansen et al. 2019). Providing households with indigenous fruit tree species also has the potential to perpetuate traditional knowledge and prevent the extinction of experience of biocultural diversity (Elands et al. 2019).

Decisions on planting are influenced by various stakeholders in different contexts. In Durban, the agroecology, environment, and parks departments are the main providers of plants and planting-related funding. In the medium-sized municipalities, these are supplied by the environment department, the DAFF, and the EDTEA, and in the small municipalities, they are supplied by NGOs, the community services department, and the EDTEA. Informing these providers about the potential of wild edible fruits and the target areas for their planting would improve outcomes for all stakeholders. In the metropolitan and medium-sized municipalities, the environment and parks departments are the main mobilisers in open space management, whereas in small municipalities, the community services department and NGOs play a more central role (Section 3.4). These stakeholders will play a crucial role in disseminating awareness about sustainable foraging and the additional roles foragers could play in assisting the local administration.

4.4.3. Partnership potential

All municipalities face challenges with waste management and illegal activities in open spaces, as well as shortage of staff and budgets to manage these spaces, echoed by Gwedla and Shackleton (2015) in the Eastern Cape. Foragers could fill this gap directly by being voluntary monitors and reporters of these issues. Existing citizen collaborations could be bolstered by foragers, who are regular and active users of open spaces, hold diverse knowledge about, and values for, these spaces, but may not have a legitimate voice or representation in local governance (Buijs et al. 2019, Paddeu 2019, Kowarik 2018). Land managers are optimistic about exploring the potential of foragers as active partners in land use management. They identified a number of ways in which foraging fits favourably into their land use frameworks and the wider goals of the local and national administration. With appropriate consideration to local context and stakeholder objectives (Molin and van den Bosch 2014, Mathers et al. 2015), municipalities can form mosaic governance partnerships to better achieve specific goals (Buijs et al. 2019).

Recognising the social and economic value of foraging grounds could build a case for improved collaborative stewardship of existing informal green spaces, and for enrichment of existing green and degraded spaces with useful species. Clear and detailed evidence of the economic contribution (e.g. Kaoma and Shackleton 2015, Shackleton et al. 2017a) as well as cultural connotations (e.g. Poe et al. 2014, Kowarik 2018, Ribeiro et al. 2018, Nyman 2019) is required to help ascertain these values, and also to identify priority areas (e.g. Sister et al. 2010, Jay et al. 2012) for planting, conservation, and restoration. Quantification of some of these values and justification of land use decisions based on them can be difficult especially when competing with economic development (Section 3.7). Formalising and commercialising certain foraged products may be a way of representing tangible yields from green spaces, although this may in some cases conflict with the anti-capitalistic ideology of certain foragers (Galt et al. 2014, Paddeu 2019, Nyman 2019). More information on foragers' perspectives and motives is required in order to develop partnerships and co-operative enterprises as applicable.

4.4.4. Perceptions

Urban land managers are amenable to the concept and activity of foraging contingent upon adherence to use of common species and sustainable harvest practices and quantities based on scientific evidence. Wild edible fruit foraging is perceived as a more viable alternative to other forms of potentially more damaging extraction (e.g. debarking, lopping). This is empirically true (Gaoue et al. 2016, Ruwanza and Shackleton 2017), but different species respond differently to varying degrees of harvest (Sardeshpande and Shackleton 2019), and therefore all stakeholders should be equipped with knowledge on best practices including low-impact harvest and the quantities that may be safely harvested for each species. In some cases, locals who have used the species over generations may already possess appropriate traditional knowledge about sustainable harvest (Thomas et al. 2017). Further considerations related to foraging include designing foraging spaces and tenure systems to minimise overexploitation and user conflicts, for what are essentially common-pool resources, and leveraging the unfamiliar and variable nature of wild foraged fruits to increase uptake by casual users as well as market buyers.

The environmental worldviews results indicate that land managers' normative perceptions of pristine nature and its conservation may influence their decision to plant and advocate for foraging (Section 3.7). The construct of pristine nature and its conservation by excluding humans is a major polarising point among conservation workers worldwide (Sandbrook et al. 2019). However, although land managers had different positions on the concept of pristine nature and conserving its intrinsic value, they all conceded that with appropriate measures, casual, cultural, and commercial foraging could be sustainable. This is in consonance with findings from a global survey in which conservation workers in Africa favoured people-centric and capital-based conservation (Sandbrook et al. 2019).

4.5. Conclusions

Foraging is a permissible activity in most urban open spaces in the study area, with tacit support from policy and land managers. Lack of information about wild indigenous edible species and their sustainable harvest is the main barrier to planting of foraging-friendly species. Planting for foraging in urban open spaces as well as home gardens has the potential to provide multiple benefits for all stakeholders, including fulfilling biodiversity conservation and food security objectives.

Foraging could be considered an ecosystem service adding use value to urban green spaces in the context of urban development and restoration planning. Foraging for small-scale commercial purposes could also create sustainable livelihoods, provided adequate information on and adherance to sustainable harvest practices and quantities for different species and spaces. The desirability of such participatory, use-, and market-based form of natural resource conservation varies with policy and land managers' individual perceptions of nature.

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Appendix 1

1. Open spaces

1.1. What is the area covered by open spaces in the municipality? What types of open spaces does the municipality have (informal, formal, developed/improved, specialised, conservation areas)? By whom are these open spaces managed?

1.2. What are the management practices undertaken in these open spaces? Are there policies addressing the nature of public use of these spaces?

1.3. What are the challenges faced by the municipality in managing these spaces? Are there proactive efforts towards engaging the public in overcoming these challenges?

2. Planting

2.1. What is the average frequency and volume of planting within the municipality? What are the target areas for such planting? What are the criteria for selection of species to plant?

3. Foraging

3.1. Does foraging occur in the municipality? Have the officials observed such activity? Do they believe it occurs? Who forages where and for what?

3.2. Would the municipality encourage foraging in open spaces? Would they encourage commercial scale foraging? Why?

4. Environmental Worldviews: To what extent do you agree with the following statements?

Statement	Agree	Neutral	Disagree
Nature can be conserved by partnering with markets and fair trade.			
Nature should be protected for nature's sake rather than human benefit.			
Pristine nature untouched by human influence does not exist.			
The well-being of people is very important in conserving nature.			
Both the wealthy and the poor should benefit from nature conservation.			
Using economic incentives and markets in nature conservation is risky.			
We need to reduce the emotional separation between people and nature.			

Chapter 5. Fruits in the city: the nature, nurture, and future of urban foraging

Abstract

Urban foraging is a widespread global informal phenomenon that has been documented in the Global North more than other parts of the world. In this study, I interviewed 80 urban foragers in four cities in the eastern coastal region of South Africa, with an aim to understand the nature of urban foraging in a developing nation context. I asked foragers about their initiation into foraging, their motivations, logistics, yields, and associated activities, as well as descriptions of their foraging grounds, and if and how they had changed. I also asked them about their opinion of and interest in future scenarios where more people take up foraging, sell foraged products, and conduct foraging tours. I found that many foragers started foraging in their childhood, in the company of friends and family, and regarded it as a cultural and recreational activity. Foraging was mostly done within a five kilometre radius of home, on a weekly or fortnightly basis, and very few foragers processed or sold their foraged products. Forests and street sides were equally used by the foragers, and very few had been discouraged from foraging. Most foragers were enthusiastic about more people foraging, having designated spaces for foraging, and foraging-based businesses such as processed products and ecotourism. I recommend that policymakers and land managers recognise and encourage foraging as a potentially sustainable use for stewardship of urban green spaces. I also suggest harnessing foragers' knowledge of useful species and spaces to develop green spaces and foraging-based supply chains. I list the main wild edible fruit species used by foragers in the area, and recommend these species for planting in public spaces.

Keywords: biodiversity conservation, foraged food, land use change, urban ecosystems, urban foraging, wild edible fruits, wild food

5.1. Introduction

Urban foraging is the activity of citizens collecting resources from the urban environment (Shackleton et al. 2017a), that are not cultivated or farmed commercially. These resources include wild foods (Hurley et al. 2015), fuelwood, craft materials, and medicinal herbs (Poe et al. 2013), and may provide subsistence as well as cash income (Shackleton et al. 2017b). Foraged products may help improve food security (Chakona and Shackleton 2019), alleviate poverty (Schlesinger et al. 2015), and buffer against adversities (Dalu and Shackleton 2018) in urban households. Urban foraging may also hold cultural and recreational value (Peckham et al. 2013, Schulp et al. 2014, Hurley et al. 2015, Schunko et al. 2015), allowing citizens to engage in traditional practices and place-making. Wild foods often represent underutilised and resilient species, some of which can coexist in relatively disturbed and densely populated environments with humans (Termote et al.

2012, Zeidemann et al. 2014, Levang et al. 2015, Chakona and Shackleton 2019, Sardeshpande and Shackleton 2019). Foraging of wild foods can help perpetuate knowledge about such species and their propagation (e.g. Parra et al. 2012, Rist et al. 2016, Thomas et al. 2017) to enhance and supplement food availability in human-dominated landscapes. In addition to increasing food species and nutritional diversity, foraging can help in conserving ecosystems and wildlife (e.g. Shanley et al. 2012, Pacheco-Cobos et al. 2015, Novello et al. 2018), and in turn helping climate change adaptation and resilience (Woittiez et al. 2013, Mbow et al. 2014, Shackleton 2014, Vira et al. 2015, Balama et al. 2016, Leakey 2018) in cities, the epicentres of human development. Urban foraging may also provide opportunities for land stewardship partnerships between citizen foragers, governments, and private entities (Elands et al. 2019, Kowarik 2018, Threlfall and Kendal 2018, Buijs et al. 2019).

Although the potential for foraging-based management and conservation in urban green spaces has been identified, urban land use policy does not adequately address the key aspects of governance and tenure. For example, although public involvement is generally encouraged in urban green space management, its organisation and role is not often well-defined (Molin and van den Bosch 2014, Mathers et al. 2015); in some cases, extracting resources from public spaces may be regarded as an illegal activity (McLain et al. 2012, Charnley et al. 2018). In the last 10 years, some cities such as Bristol (UK), Vancouver and Victoria (Canada), and Berlin (Germany) have incorporated the explicit aim of promoting public edible landscapes in their urban green space management policies (Hajzeri and Kwadwo 2019). However, the species used in these landscapes are usually agricultural food species that do not necessarily contribute to biological, cultural, or nutritional diversity or climate resilience, and the spaces developed by municipalities may not offer the avenues for cultural, ideological, or recreational expression sought by some foragers (Galt et al. 2014, Paddeu 2019, Nyman 2019). Motivations for urban foraging vary with socio-economic, geographical and political context, and although urban foraging is observed across the globe (Shackleton et al. 2017a), most of the scientific literature about it is based on observations from the Global North (Rupprecht and Byrne 2014, Schulp et al. 2014, Kabisch et al. 2015, Botzat et al. 2016).

The current state of knowledge on the use of urban green space for foraging lacks representation from Africa, even though foraging is prevalent and urban centres are rapidly growing on the continent (Haaland and van den Bosch 2015, Rupprecht et al. 2015, Shackleton et al. 2017a, UNDESA 2018). Urban green space includes managed formal spaces like public parks, gardens, forests (Wolch et al. 2014, Dobbs et al. 2014), vegetation on structures such as buildings and verges (Rupprecht and Byrne 2014, Wang et al. 2014), as well as unmanaged informal spaces such as vacant lots and edges (Rupprecht and Byrne 2014). The opportunity to forage is dependent on the availability of and access to such green spaces (Cooper et al. 2018, Chakona and Shackleton 2019). The distribution of urban green spaces may be uneven, often to the disadvantage of low income neighbourhoods, due to socioeconomic discrimination (Sister et al. 2010), historical inequalities (Davenport et al. 2012), lacking or non-specific policy (Jay et al. 2012), or indiscriminate development (Kabisch and Haas 2014, Wolch et al. 2014). South Africa, with its high socioeconomic inequality, food poverty (StatsSA 2017), and past racial segregation, has striking deficiencies in public urban green spaces and trees in low income housing areas (McConnachie and Shackleton 2010, Noble and Wright 2013, Gwedla and Shackleton 2015). However, foraging is very common across the rural-urban continuum (Chapter 3), and therefore, it is important to identify the species and spaces that are used by foragers to inform better development and conservation of urban green spaces that could serve the multiple functions enumerated above.

This study uses qualitative analysis to determine the flow of knowledge between foragers, their motivations for foraging, their preferences and descriptions of the spaces and activities associated with foraging, and their visions for the future of foraging. I also describe the time and effort foragers invest, some of the main species they use, and their yields from foraging. The research questions are: (i) who forages, and how is information about foraging (spaces and species) transmitted? (ii) why do people forage, and what other activities are undertaken alongside foraging? (iii) what are the frequencies, logistics and yields of foraging? (iv) where do people forage, and why? (v) how do foragers envision the future of foraging? The study area is the Indian Ocean Coastal Belt (IOCB), a relatively small biome with high human population density and high biodiversity (Mucina and Rutherford 2006). The study area is experiencing rapid changes in land cover and land use (Jewitt et al. 2015), and urban foraging is common in this area (Chapter 3). I lay particular emphasis on foraging of wild edible fruit species, because they are the most commonly foraged item globally (Hickey et al. 2016), nationally (Welcome and Van Wyk 2019), and regionally (Chapter 3); occur in a variety of landscapes (Schlesinger et al. 2015), providing important nutrition and income across the socioeconomic spectrum (Ward and Shackleton 2016); are often resilient to climatic extremes and harvesting (Gaoue et al. 2016), and important to urban biodiversity (Sardeshpande and Shackleton 2019).

5.2. Methods

Adult individuals in urban townships were opportunistically approached in a door-to-door survey to enquire about their foraging activities if any. No prior criteria (position in household, age, gender) were used to select respondents. Consenting forager respondents were interviewed about their foraging practices and preferences based on the research questions (Appendix 1). Key questions included their household composition (number of adult, child, employed, and foraging members), their introduction to and company while foraging, the frequency of and time spent foraging, the various items foraged and activities undertaken alongside foraging, descriptions of their foraging grounds, and their normative views on the future of foraging, including local enterprises centred on foraging, with a specific focus on wild edible fruits. A booklet of 51 common wild edible fruit species was used to facilitate identification by respondents with the help of pictures of fruits, flowers, leaves, and morphometrics and local names (Chapter 3). A total of 80 forager respondents were interviewed in four cities (mean 20±1.6) (Figure 5.1). The semi-structured interviews were conducted in English as well as isiZulu with the help of a field assistant according to the respondents' preference. All interviews were recorded as audio files with verbal consent from the respondents, and transcribed by the researcher at a later stage. Data were entered into MS Excel for analyses, namely descriptive statistics, and manual coding based on emergent themes. Inferential statistics (Kruskal-Wallis anovas and Spearman rank correlations) were performed in R 3.2.3 (R Core Team 2015). Data were anonymised, and for the purpose of reporting, respondents were identified by alphanumeric representations of their municipality, neighbourhood, and interview number; for example, the third respondent from the neighbourhood of Msinsi in Mtubatuba would be MTMS3.

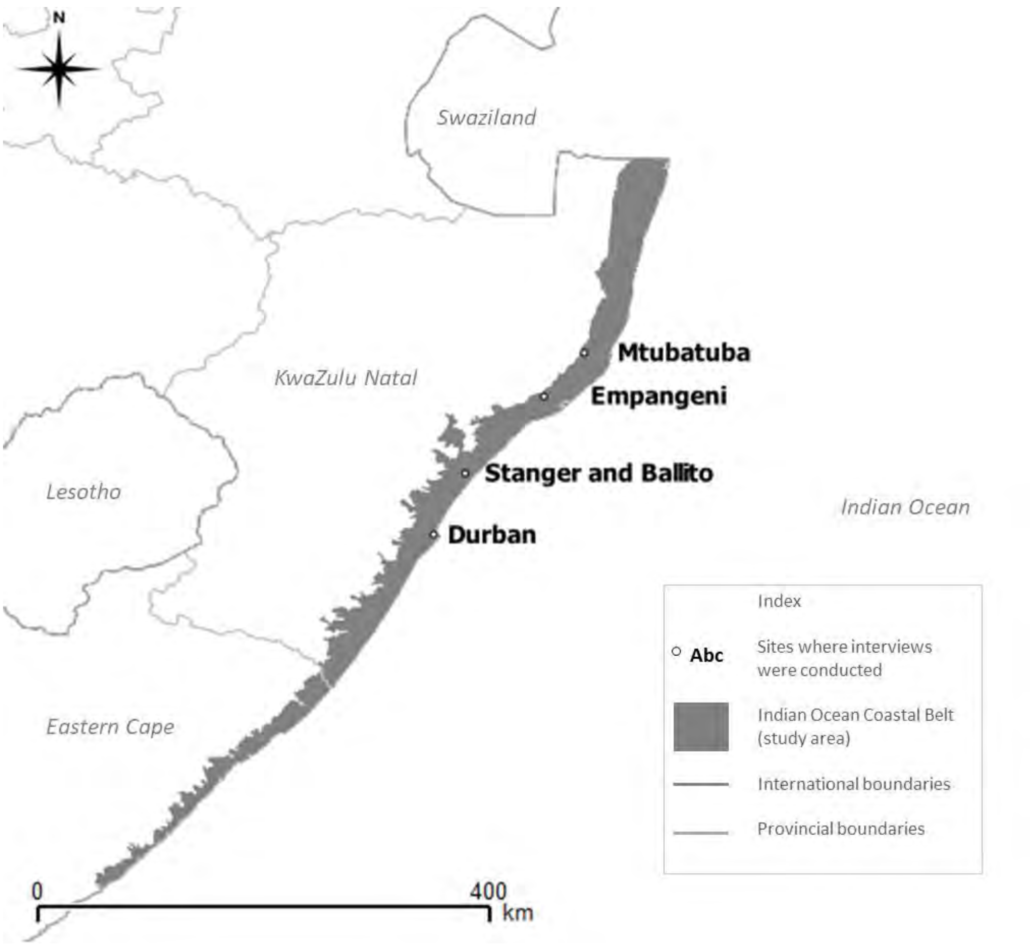

Figure 5.1: Location of study area and sites

5.3. Results

The mean respondent age was 36 years (±14.4), and about a two-thirds of the respondents were female (n=51), and a third were male (n=29). The average size of the respondents' households was six members (±3.7), with a mean of two children (±2), one earning member (±1), and three foraging members (±2.5). On average, seven species of wild edible fruit were foraged per household (±5). About three-quarters of the respondents (n=59) had foraged within the last 12 months, while fewer respondents had foraged within the last five years (n=10), within the last 10 years (n=5), and over a decade ago (n=6). The number of foragers in the household had a strong positive correlation to the number of children (r=0.87), and a moderate positive correlation to the total number of members (r=0.42) in the household. However, the number of children, foragers, or members in the household did not have any correlation with the diversity of WEF species foraged. The number of employed members in the household had a weak negative correlation to the number of WEF species foraged (r=-0.15).

A total of 49 wild edible fruit species from 35 genera were foraged by respondents (Table 5.1), with a majority of respondents (n=67) using guava (*Psidium guajava*), an alien species. Waterberries, an indigenous species known locally as umdoni (*Syzygium cordatum*), were used by more than half of all respondents (n=42), followed by passionfruit or granadilla (*Passiflora edulis*), an alien species, which was used by half of all respondents (n=39). The 10 most frequently cited species were used by at least a third of all respondents. Four of these top 10 species were aliens, and of the 49 species used by respondents, a total of 13 were aliens. Other indigenous species in the top 10 included the wild date palm (*Phoenix reclinata*, vernacular isundu), *Vangueria infausta* (vernacular amaviyo), *Ximenia caffra* (vernacular amathunduluka), Suriname cherry (*Eugenia uniflora*), and *Ficus sur* (vernacular amakhiwane).

Table 5.1: List of wild edible fruit species used by foragers (*alien species)

#	Species	Users (n)	% of users	#	Species	Users (n)	% of users
1	*Psidium guajava* L.*	67	86	26	*Rubus ellipticus* Sm.*	4	5
2	*Syzygium cordatum* Hochst.	42	54	27	*Carissa edulis* Vahl	3	4
3	*Passiflora edulis* Sims*	39	50	28	*Carissa macrocarpa* (Eckl.) A.DC.	3	4
4	*Rubus cuneifolius* Pursh*	38	49	29	*Diospyros lycioides* Desf.	3	4
5	*Phoenix reclinata* Jacq.	35	45	30	*Hylocereus undatus* Britton & Rose*	3	4

6	*Syzygium cumini* (L.) Skeels *	32	41	31	*Cordia caffra* Sond.	2	3
7	*Vangueria infausta* Burch	30	39	32	*Cucumis africanus* L.f.	2	3
8	*Ximenia caffra* Sond.	30	39	33	*Diospyros whyteana* (Hiern) F.White	2	3
9	*Eugenia uniflora* L.	26	33	34	*Dovyalis caffra* Sim	2	3
10	*Ficus sur* L.	26	33	35	*Englerophytum natalense* (Sond.) T.D.Penn	2	3
11	*Strychnos spinosa* Lam.	23	30	36	*Ficus craterostoma* Warb. ex Mildbr. & Burret	2	3
12	*Opuntia ficus-indica* (L.) Mill. *	22	28	37	*Grewia bicolor* Juss.	2	3
13	*Harpephyllum caffrum* Bernh.	19	24	38	*Grewia flavescens* Juss.	2	3
14	*Hyphaene coriacea* Gaertn	12	15	39	*Grewia occidentalis* L.	2	3
15	*Carissa bispinosa* Desf.	11	14	40	*Opuntia engelmanii* Salm-Dyck*	2	3
16	*Eriobotrya japonica* (Thunb.) Lindl.*	10	13	41	*Rhoicissus tridentate* Planch.	2	3
17	*Psidium cattleianum* Sabine*	10	13	42	*Syzygium guinense* DC.	2	3
18	*Annona senegalensis* Pers	9	12	43	*Berchmia discolour*	1	1
19	*Sclerocarya birrea* Hochst.	9	12	44	*Berchmia zeyheri* (Sond.) Grubov	1	1
20	*Rubus niveus* Thunb.*	8	10	45	*Diospyros mespiliformis* Hochst ex A.DC.	1	1
21	*Strychnos madagascariensis* Poir.	7	9	46	*Mimusops zeyheri* Sond.	1	1
22	*Osyris compressa* A.DC.	6	8	47	*Parinari curatellifolia* Planch. ex Benth.	1	1
23	*Tabernaemontana elegans* Stapf	5	6	48	*Solanum betaceum* Cav.*	1	1
24	*Coccinia sessilifolia* (Sond.) Cogn.	4	5	49	*Syzygium jambos* (L.) Alston*	1	1
25	*Cucumis metuliferus* Naudin	4	5				

5.3.1. Initiation, knowledge, and company in foraging

Over half of the respondents (n=44) could not recollect the age at which they began foraging, but stated that they were young children. Of those respondents who could provide an estimated age, most said they were between six and 10 years old (n=21), while some were as young as two to five years old (n=7), between 11 and 15 years old (n=6), and as old as 16 to 20 years of age (n=2). Less than half of the respondents (n=34) could recollect how they were introduced to places and plants from which they could forage. Friends were the most frequently cited source of this information (n=14), followed by family members including parents (n=9), grandparents (n=5), other adults (n=3), and siblings (1). Some respondents used the words custom, hobby, and lifestyle (n=1 each) to indicate the integral role foraging had in their lives. Two respondents said they acquired knowledge of foraging by exploring on their own. Over half of the respondents (n=43) said they foraged with their friends, and about a third of the respondents (n=26) said they also foraged with family members, while some respondents also foraged solitarily (n=10).

'[Foraging is] a lifestyle. I've learned it from neighbours and friends.'

- DBCD2

Some respondents spontaneously provided additional information about some of the wild edible fruit species they used. For example, the indigenous waterberry *Syzygium cordatum* was associated with the coastal forest (n=3), and the alien waterberry *Syzygium cumini* was associated with rivers (n=3). Further, two respondents also asserted that *S. cordatum* 'belonged to the black man' and *S. cumini* 'belonged to the white man'. The monkey orange (*Strychnos spinosa*) was reported by two respondents to be used as a laxative and purgative. Two respondents also reported that *Tabernaemontana elegans*, known in isiZulu as monkey's scrotum, is used for medicinal purposes.

5.3.2. Associated activities

Foraging for wild edible fruits was often done in conjunction with fuelwood gathering (n=21), fishing (n=14), hunting, swimming (n=10 each), and in some instances, fetching water (n=4), and tending livestock (n=3). Consequently, over a quarter of all respondents said they collected fuelwood (n=21) and wild herbs (n=21) while foraging, and also brought home fish (n=14), bushmeat (n=10), wild honey (n=5), and water (n=4) from these outings. Some respondents engaged in foraging when visiting their homesteads on the outskirts of the city, or in smaller towns and villages (n=10), whereas some foraged during their transit to and from their workplace (n=7), school (n=7), or miscellaneous places around the neighbourhood, such as houses of friends and neighbours, or gardens and shops (n=6).

'Sometimes I take the cattle to the bush. Maybe I will spend the whole day there. I will become a bird, because I will eat fruits there.'

- MTKM5

Foraging for and eating wild edible fruits was the most commonly cited aspect of foraging that respondents enjoyed (n=32). Other highlights of the foraging experience included allied activities (n=18) such as climbing trees, fishing, playing, and swimming, the company of friends (n=7), watching wildlife (n=4), and fond memories (n=3). The perceptions of wild edible fruits as being fresh (n=11), healthy (n=10), free (n=3), and unique (i.e. not available in stores, n=1) were also mentioned by respondents as aspects of foraging that they enjoy. Among the things that foragers did not enjoy about foraging, about a third (n=26) cited threats from wildlife, mainly snakes (n=23) and insects (5). Other aspects included unpleasant experiences such as the boredom of foraging alone, unwelcome foraging by non-resident individuals in the area, eating rotting or insect-infested fruit, and fights and injuries while playing with friends (n=2 each).

'I remember painting our hands red with wild mulberries and making juice from them… swimming in a dam reservoir, which is a highlight of the experience. Foraging for me is freedom.'

- DBMP2

Respondents who had last foraged a year ago or longer ago were asked why they had stopped, and if they would resume foraging. A commonly cited reason was that they had outgrown the activity (n=8). Respondents also said that they could no longer find wild edible fruits to forage in their vicinity (n=8) due to tree felling for residential or road infrastructure development (n=5), or invasive alien control (in the case of guavas, n=2). Some respondents (n=4) said they had moved residence from other places to the cities, and did not know where to forage here. Lifestyle changes such as being employed or having family members employed also resulted in reduced time for foraging in the case of some respondents (n=3).

'It wasn't just picking fruits. When I would go to pick fruits, I was looking for something different... We just wanted something close to nature. None of us have the time now because we are all working… and most of the fruits that we used to pick don't grow here anymore. People cut them down for different reasons. Most people used to have fruit trees right in front of their doors. Like we used to have one but we cut it as well… because it looks untidy.'

- DBKM1

On whether they would resume foraging, most respondents (n=28) said that they would, provided they found suitable plants and places to forage at, with the knowledge that it was legal to do so. The five respondents who said they would not forage again perceived foraging as a childhood activity that they no longer had enthusiasm for. Two respondents also noted the lack of enthusiasm in the current generation of children towards playing outdoors, and subsequently, foraging.

'These children, they don't go to bushes now, they only watch TV. They don't even pick the peaches [in the yard]'

- KDSK7

5.3.3. Foraging practices and patterns

The distance between foragers' homes and their foraging grounds was highly variable, with a mean of 8.4 km (±20). Many of the respondents foraged within a one kilometre radius of their home (n=37), and almost as many foraged within a five kilometre radius of their home (n=33). Very few respondents foraged in places that were up to 10 km (n=3), 20 km (n=2), 50 km (n=2), or 100 km (n=3) away from their homes. I consider respondents foraging beyond the radius of 10km from their urban homes to be city dwellers who forage outside the city. Most respondents walked to their foraging grounds (n=71), and very few necessarily used some form of transportation to get there (n=9). The distance travelled for foraging was moderately positively correlated to the amount of time spent foraging (r=0.43, p>0.001), the quantity of forage (r=0.25, p=0.03), and the diversity of WEF species foraged (r=0.34, p=0.002), and had no relation to the frequency of foraging or the foragers'age.

Most respondents, but under half of all interviewed, said they foraged one to three days a week (n=35). A fifth of the respondents said they foraged opportunistically during fruiting season, between a cumulative of three to thirty days a year (n=16). Some respondents foraged regularly, between four to seven days of the week (n=10), whereas others foraged once or twice a year (n=8), a fortnight (n=5), or month (n=4). The frequency of foraging had no relationship to the age or household demographics of foragers, the time spent or distance travelled by foragers, or the quantity or diversity of WEF species foraged.

About a third of the respondents said a single foraging session lasted up to 30 minutes (n=25), with a fifth of all respondents spending about five minutes foraging at a time (n=16), usually in transit. Over a quarter of all respondents reported spending about an hour per foraging session (n=22). A quarter of all respondents spent between two and seven hours per foraging instance (n=20), and the remainder said they spent an entire day when foraging (n=11). Two respondents who foraged over 30 years ago could not recollect the frequency of and time spent foraging.

About a third of all respondents (n=25) estimated that they collected about a bagful of fruits (the equivalent of 1.5 kg, 2 l, or 10 to 20 orange-sized fruits) on average per foraging session. A quarter of all respondents (n=20) collected about half a bagful (750 g, 1 l, or under 10 orange-sized fruits) per foraging session. Fewer respondents collected up to 3 bags (4 kg, 5 l, or up to 50 orange-sized fruits, n=5) or 10 bags (15 kg, 20 l, up to 200 orange-sized fruits, n=4) per foraging session. Other respondents foraged incidentally and opportunistically, and could not provide an estimate of the quantity of fruits they foraged. The quantity of WEFs foraged was positively correlated to the time spent foraging (r=0.52, p>0.001), the distance travelled (r=0.25, p=0.03). The quantity of WEFs foraged had no relationship with the diversity of WEF species foraged, household demographics, or the frequency of foraging.

A fifth of all respondents (n=17) said they processed the foraged fruits into products such as juices (n=13), jams (n=3), curds, popsicles, sweets, and wines (n=1 each). Guava (*Psiudium guajava*) was the most commonly cited fruit foragers processed (n=8), followed by granadilla (*Passiflora edulis*, n=4), and date palm (*Phoenix reclinata*, n=2). Some foragers (n=1 each) also processed prickly pears (*Opuntia ficus-indica*), marulas (*Sclerocarya birrea*), monkey oranges (*Strychnos spinosa*), and waterberries (*Syzygium* sp.). None of the respondents who processed fruits sold any of the fruits, and only one respondent sold the processed product, namely granadilla and guava popsicles, for 50 cents apiece.

Just over a tenth (n=9) of all respondents said they sold the fruits they foraged. Three of these respondents sold fruits in the past, as children, at street markets, to make money to pay for snacks and school lunches. One of the respondents said the children in their household presently did this, and one respondent presently sold fruits regularly door to door. Three respondents said they presently sold some of their foraged fruits at street markets occasionally. The frequency of sale was either weekly (n=4), seasonal (n=2), or opportunistic (n=3). Quantities of fruit sold ranged from a bagful to 10 bagsful (1.5 kg to 15 kg, n=2 each). Guavas (n=5), granadillas (n=2), waterberries (n=2), and date palm fruits (n=1) were the fruits sold by respondents. Prices for guavas were 50 cents apiece (n=3), and weekly turnover from fruit sales was estimated at R100 (n=3).

5.3.4. Foraging grounds

Over a third of the respondents said they foraged in wild forested areas (n=31) and on the streets in their neighbourhoods (n=30). About a quarter of the respondents said they foraged in vacant lots in their neighbourhoods (n=21). Fewer respondents foraged along river banks (n=8), in the natural vegetation around their allotted garden patches (n=6), on the premises of establishments such as schools and industrial areas (n=5), and on abandoned farmland (n=4). A fifth of the respondents reported to foraging in more than one place (n=18). Rivers (n=14), valleys (n=6), the beach, and hills (n=1 each) were the natural landmarks mentioned in relation to foraging grounds. Human-made landmarks included premises or surroundings of public establishments such as schools (n=7), police stations (n=4), malls (n=2), an airstrip, bridge, church, dam, fuel station, graveyard, industrial area, and shop (n=1 each); and managed landscapes such as residential areas (n=4), roads (n=7), and plantations (n=2). A majority of the respondents (n=60) held that at least one of the places they foraged on was public land, with free and open access for all. A fifth of the respondents said at least one of the places they foraged in was private (n=16). Fewer respondents foraged in communal areas (n=9) and land that had been converted from formerly abandoned to currently private, or vice versa (n=5). Most of the respondents (n=75) had never been told not to forage in the places they forage in. Those respondents that had been asked not to forage (n=5) by communal land occupants said they continue to forage in the absence of these owners.

A majority of the respondents (n=55) commented on some form of biodiversity they encountered at their foraging grounds. About half of all respondents (n=41) said they saw birds, and about a third said they saw mammals (n=28) such as buck, hogs, and monkeys, and reptiles (n=24), mainly snakes. Some respondents reported insects (n=7) such as bees, butterflies, and worms, and livestock (n=6) including cows and goats. Five respondents said they did not notice much biodiversity around their foraging grounds. Over half of all respondents (n=45) mentioned that there were other people foraging where they foraged, particularly children (n=10). Eight respondents said there were 'many' people foraging where they foraged.

Under a third of all respondents (n=23) said they had noticed changes in the places where they foraged, and some said they had observed no changes (n=13). The felling of trees was the most commonly reported change (n=12), in some instances, for development of houses and roads (n=4), or logging for firewood (n=2). Land use transformation (n=10) included building of houses (n=6), and roads (n=1), and gumtree plantation (n=1) on previously forested communal lands, but also the conversion of privately owned premises to communal garden patches (n=2). Waste management was also mentioned (n=7), with more instances of increased littering (n=5) than those of reduced littering (n=2). Changes in biodiversity included the appearance of invasive species (n=2) on water and land, and the eradication of alien guava trees (n=2), and a reduction in wild animals (n=1). Three respondents noted the uncertainty and irregularity of tree fruiting linked to seasonal weather changes. Other changes observed by respondents were the drying up of water bodies (n=2), fewer human visitors, and reduced safety (n=1 each).

'So the [place] where we used to pick fruits has been developed into houses, people are living there. So there are no longer bushes there where used to be fruits. And then the river where we used to fetch water, now it's dry. There are a lot of changes. [As children, we would] climb trees, eating fruits. We were never hungry, we were always full of fruits. And would swim along there when we were picking fruits. So it was fantastic! I really miss it. (laughs)'

- UHEM15

5.3.5. Normative futures for foraging

A majority of the respondents (n=68) discussed their views on the potential and implications of increased foraging. In response to the question 'Should more people forage?' most respondents (n=61) answered yes. Of the respondents who did not favour more people foraging at their foraging grounds, some cited the threat to foragers from wildlife (n=2) and from thieves (n=2), and others believed that increased foraging would threaten the supply of fruits to those who currently forage (n=2), including wildlife (n=1), and may exacerbate logging for firewood (n=1). More than half of the respondents were in unconditional support of more people foraging (n=49), but 12 respondents said that they would be happy to share their foraging grounds with more people provided they were residents of the proximal neighbourhoods or communities.

'[People] should [forage for wild edible fruits]. I mean they're free! I think there are too little people picking them. (Laughs). It's therapeutic as well. I would.'

- UHEM14

Respondents were asked if they approved of setting up small local businesses that supplied foraged fruit and processed products to shops or restaurants, and if they personally would be interested in being part of such an enterprise. Half of all the respondents (n=40) said they approved and expressed interest in selling foraged fruit and processed products. Fewer respondents said they approved, but would not like to be involved in such business (n=10). Respondents who did not approve of the business proposition (n=11) cited the same reasons as those who did not favour more people foraging, as well as the risk of commercial foraging creating resource allocation conflicts in communal areas (n=4).

Respondents were also asked if they approved of setting up a local ecotourism enterprise that allowed tourists to forage on their grounds for a limited time alongside viewing wildlife and recreation activities, and if they would personally like to be involved in such an enterprise. About half of all respondents (n=39) approved and expressed interest in taking out guided tours, and 14 respondents approved, but were not interested in being involved. Those respondents who disapproved of the ecotourism proposition (n=11) cited the same reasons as those who didn't favour more people foraging, as well as that they did not think foraging would interest tourists (n=4).

'Tourism. Yes absolutely especially if you look at the reputation that KwaMashu has no one thinks about it as a place you can go and do things. Everyone knows about the hijackings and all the dangerous stuff. It would be great to have something that changes people's perspective of the place. I don't think I've ever seen a tourist here. It would be nice to have something like that with a community could just go and enjoy themselves. And to get back that part of themselves, picking fruits. No one has done that in a while. It'd be fun to have something like that. I think that [business] shows a quality we would like to see, an entrepreneurial quality. I would be very impressed. I would buy stuff like that.'

- DBKM1

Of the respondents that were approving of and interested in being involved in the processed product or ecotourism businesses, 11 said (without being prompted) that they would like to undergo technical training to be able to provide saleable products or ecotours. Three respondents said (unprompted) that they would like to use their knowledge to make alcohol, desserts, and juice from foraged fruits. Three other respondents (unprompted) identified existing tourist attractions (golf club, monument, river mouth) in the vicinity of their foraging grounds, and suggested that foraging could be marketed to them. One respondent noted that such businesses would help keep the knowledge about wild foraged foods alive and propagate it.

Four respondents spontaneously suggested that the municipality should plant more wild edible fruit trees in public spaces such as along roadsides, playgrounds, and parks. The proposition of a park dedicated for foraging was discussed with 21 respondents, all of whom said they would forage in such a designated foraging park. However, two of these respondents acknowledged that there might arise issues related to resource allocation, and three respondents said users would have to be educated about sustainable harvest practices, including propagating species in high demand.

'Stealing might be a problem. It counts as stealing because you can't just take [fruit] whenever, you have to wait for it to bear. The trees have a certain process that they go through. I don't think that people around here know when to and not to pick, and you would end up where we are right now where we don't have any [fruit trees] anymore because we had them and people didn't necessarily know when to pick them. The municipality can try. When they do open up a park like that, you invite everyone over for the opening and tell them the rules or an educational talk to tell them how to go about preserving everything. That would be helpful.'

- DBKM1

5.4. Discussion

Foraging mostly began in childhood, and friends and family were equally important in transmission of knowledge about species and spaces for foraging. Foraging was viewed as a cultural and recreational activity integral to the respondents' upbringing, resonating with findings from other parts of the world (Peckham et al. 2013, Schulp et al. 2014, Hurley et al. 2015, Schunko et al. 2015, Landor-Yamagata et al. 2018). Names and traits that foragers attribute to certain species (e.g. *Syzygium* in this case) may carry tacit information about the nature of the species, such as their alien or indigenous status, and their affinity for resources in an ecosystem. Foragers' knowledge, preferences, and practices may be used as a baseline for the conservation, design, and development of foraging spaces (Rupprecht and Byrne 2014, Hansen et al. 2019), policies on tenure and resource allocation (Wynberg and van Niekerk 2014, Wynberg 2017), and monitoring and propagation programmes (Parra et al. 2012, Thomas et al. 2017, Novello et al. 2018). Commonly known edible alien species such as *Psidium* and *Syzygium* are prominent in forager baskets and bags, but my findings indicate that 36 indigenous species are also in use (Table 5.1), and could be further promoted. Foraging is a conduit for the intergenerational transfer of traditional and subversive knowledge about ecosystems, biodiversity, and alternative food systems. It is therefore critical to protect and promote this activity as part of biocultural heritage (Cocks et al. 2016, Buijs et al. 2019, Elands et al. 2019), particularly as such knowledge is likely to provide valuable alternatives for climate change resilience (Mbow et al. 2014, Shackleton 2014, Vira et al. 2015, Leakey 2018).

5.4.1. Where and why

Most foragers in the sample walked between one and five kilometres to forage, and about a fifth of them foraged opportunistically or incidentally en route to various places. This finding is different from findings from studies in the Global North, where more foragers tend to travel further afield to forage (Synk et al. 2017, Landor-Yamagata et al. 2018). Most foragers foraged between a few times a week to a few times a month, and spent between an hour and a day doing so, collecting between half and one bagful of fruits on average. Processing of fruits was uncommon, and the sale of fruits even less so. Very few foragers mentioned supplementation of household subsistence or income as a motivation for foraging. For the few foragers who sold their forage, the estimated mean contribution of cash income from sales of foraged wild edible fruits was about R400 a month, similar to findings from other researchers in South Africa (Kaoma and Shackleton 2015, Ward and Shackleton 2016), and the equivalent of a child welfare grant provided by the government of South Africa (SASSA 2019). Foraging for wild edible fruits was commonly accompanied by foraging for wild herbs, and collecting fuelwood. The act of foraging and eating the fruit itself was the main highlight of the foragers' experience, followed by recreational aspects such as playing, family bonding, bushmeat hunting, fishing, and swimming. Inherently, landscape attributes such as wildlife and water bodies were closely linked to the foraging experience. Birds and mammals were observed by foragers in the spaces they forage in, indicating that urban foraging grounds harbour wildlife. Foraging provides a valuable interface between human resource extraction and biodiversity conservation, and this interaction could be leveraged to promote better management, monitoring, and planting to further both causes (e.g. Threlfall and Kendal 2018, Hansen et al. 2019).

5.4.2. Streets, sylvan, and social spaces

Almost equal proportions of foragers foraged in forests as on street verges, and a considerable number also foraged in vacant lots. These findings are similar to other studies from the Global North (Synk et al. 2017, Charnley et al. 2018) in demonstrating that foraging occurs in fragmented and disturbed green spaces as much as in relatively intact forests. However, the marked difference in my findings is that none of the respondents reported to using any formal green spaces such as parks or gardens in their vicinity. The findings also highlight that street verges are an aspect of urban green infrastructure that could be better planned to optimise delivery of ecosystem services (Botzat et al. 2016, Säumel et al. 2016). Although none of the respondents expressed concerns over environmental pollution, the literature suggests that edible leaves and mushrooms along verges of busy roads are more prone to lead accumulation than those in residential areas (Amato-Lourenco et al. 2020, Kokkoris et al. 2019). Planting for foraging in residential areas will not only reduce the risk of contamination, but also improve access to resources within the typical foraging distance of 1-5km from home. Tree felling and development of housing under the Reconstruction and Development Programme (RDP) were the main changes reported by foragers at their foraging grounds. The planning and execution of the RDP has until recently lacked green infrastructure (McConnachie and Shackleton 2010, Noble and Wright 2013), and may in some cases use unsuitable alien ornamental species (Chapter 4), a phenomenon also observed globally in formally managed green spaces (Nielsen et al. 2014, Champness et al. 2019). The findings offer evidence of demand for, and recommendations towards the inclusion of wild edible fruit species in green spaces in the RDP as well as new housing developments (Table 5.1, Chapter 4).

5.4.3. Challenges, changes, and continuity

Very few foragers in the sample had been barred or restricted from foraging by rules or land managers, and this is reflected in the non-specific open space use policies in the study area (Chapter 4) that favour use-based biodiversity conservation. Other researchers have observed similar relationships between foragers and land managers (Landor-Yamagata et al. 2018) as well as the prohibition of foraging in public open spaces (McLain et al. 2012, Charnley et al. 2018). The main deterrent to foraging was a perceived threat from snakes. The unavailability of species or spaces for foraging was the main reason past foragers cited for having ceased to forage. A very small number cited their age and lack of enthusiasm as a reason for not foraging anymore. A majority of the respondents were in favour of more people foraging in the spaces they forage in, and the designation of gardens or parks dedicated to foraging. Past foragers were also keen to resume foraging provided they found spaces to forage in. Some municipalities globally (Hajzeri and Kwadwo 2019) as well as within the study area (Chapter 4) encourage and facilitate planting and harvesting of traditional food species by citizens in their open spaces. I recommend that municipalities incorporate wild edible fruit species into their public spaces as well as experiment with different set-ups of neighbourhood community food forests where wild indigenous species are propagated for in-situ foraging (e.g. Crouch and Edwards 2004, Mattson 2013). Such initiatives will highlight areas that need attention, e.g. access, allocation, education, and capacity building for land stewardship, biodiversity monitoring, and sustainable harvest estimation.

5.4.4. Future for foraging?

With respect to foraging-related business, about a third of all the foragers approved of such enterprises, and about half of all the foragers expressed interest in these enterprises. A fifth of all the foragers took a proactive approach towards these enterprises, either seeking capacity development, or offering to add value to them with their local knowledge. The potential for foraging-based business, particularly ecotourism, is currently under-explored in the study area, unlike in the Global North (e.g. Reyes-Garcia et al. 2015, Landor-Yamagata et al. 2018, Fuste-Forne 2019). Urban green space managers are also amenable to small-scale commercial foraging, provided sustainable practices are followed (Chapter 4). I therefore propose that foragers, land owners and managers, and potential buyers of foraged products (such as restaurants, shops, and ecotourism businesses) share information on the possible species, spaces, and yields that can contribute to building novel foraging-based supply chains. Sustainability standards and certifications (e.g. Morgan and Timoshyna 2016, Ting et al. 2016) may link foraging to biodiversity conservation goals, ensure equitable access and benefit distribution, and promote the visibility and value of foraged products on the market (see Bride et al. 2015, Sardeshpande and Shackleton 2019).

5.5. Conclusions

Urban foraging is a recreational activity initiated in childhood and often continuing into adulthood. Knowledge about foraging spaces and species is usually transmitted through family and friends. Wilderness areas and neighbourhood streets are equally important ecosystems for urban foraging. Whereas wilderness areas offer further opportunities for recreation such as hunting and swimming, neighbourhood streets and public premises offer the convenience of foraging in transit to work.

Formal green spaces are not used by foragers for foraging. However, the concept of designated foraging gardens and parks appeals to foragers. Many foragers would like to see more people foraging, and are amenable to engaging in small-scale enterprise based on foraging. Given the availability of information on sustainable practices and market demand, these enterprises could entail selling forage, prcessed products, and ecotourism experiences.

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Appendix I: Question guide for Forager Interviews and or Participant Information Interactions

What is your age? How many adults, children, and earning members does your household comprise of? What are the occupations of employed members?

Who in the household forages? When, how and why did you and or they start foraging? How did you and or they find out where and what to forage? Who do you and or they forage with?

When last did you forage? Why have you not foraged within the last year (if applicable)? Would you like to resume foraging? If there were a dedicated space for foraging, would you use it?

Where do you forage? How do you travel between home and this/these place(s)? How did you locate this/these place(s)? How long have you foraged here? Has this/these place(s) changed over the course of your experience?

Are the foraging grounds owned and or managed by specific entities? Have you ever been told not to forage at a particular place? By whom? What do you do in such a situation?

What do you forage for? Do you do anything else when foraging? What do you do with your foraged wild edible fruits? How much (volume/weight) do you typically forage in one session? How often do you forage?

What do you like and or dislike about foraging at present? Have there been changes in the way/places you forage? Would you like to see changes? Do you see any wildlife in the area where you forage?

How do you feel about more people foraging? How do you feel about people making and selling foraged products on the market? How do you feel about people taking tourists on foraging outings? Would you be interested in either of the activities?

Chapter 6. Conclusion

In this chapter, I summarise the key findings from the thesis and link them to the research questions, as well as to national and global commitments and policies on biodiversity conservation and sustainable development. Based on the findings of the thesis, I synthesise four possible future pathways, and identify the pros and cons, and key stakeholders in achieving these scenarios. I assess these four potential pathways against the design principles for community-based natural resource management (Cox et al. 2010). Lastly, I list specific actions for stakeholders to further their agendas of sustainable resource utilisation and urban green space management through partnerships.

6.1. Key findings

6.1.1. WEFs are uniquely ubiquitous and useful

The literature and my findings posit that WEFs are a widely occurring subset of natural resources with multiple uses in diverse contexts. They are unique in that they bridge the range of NTFPs with food and non-food uses, the gaps between wild and domesticated foods, and are used by people across the socio-economic spectrum (Chapter 3). This may in part be due to their presence along the gradient of wild to developed landscapes, and the variety of uses they offer. Although some WEF species require specific ecological conditions to grow and fruit (e.g. Brokamp et al. 2011, Isaza et al. 2017), a number of WEF species are found growing on fallow or otherwise unproductive land, as well as in heavily used and modified agricultural and urban areas (Mandle and Ticktin 2013, Lankoande et al. 2017). The ubiquitous habitat range of WEFs as a group may be attributed to their resilience to environmental pressures, and their dispersal by animal and human users. Some WEF species act as keystone species in their ecosystems, providing food and refuge to wild birds, insects, and mammals, some of which may be charismatic or flagship species themselves (Shackleton et al. 2018, Sardeshpande and Shackleton 2019, Zietsman et al. 2019). Notwithstanding, the literature on WEFs is limited to the ecological or economic aspects of a handful of species (Sardeshpande and Shackleton 2019). Over half of the large-fruited used WEF species occurring in South Africa have more than one use for humans, including the provision of medicinal extracts, fuel, and fibre (Chapter 3). Besides being a source of nutrition, WEFs also form an important part of natural resource users' experience of culture and nature (Chapter 5).

6.1.2. WEF use can contribute to multiple objectives of biodiversity conservation and sustainable development

The second problem statement of this thesis sought to determine the synergies that exist and can be established between the use of WEFs and biodiversity conservation and sustainable development. Through my methodological framing, I approached this problem based on four themes, namely (i) food security, access, and diversity, (ii) ecological functions and biodiversity conservation, (iii) land use policy and stewardship, and (iv) the potential for sustainable livelihoods. I found a number of ways in which WEF use can contribute to some of the specific Aichi Targets of the Convention on Biological Diversity (CBD), and the Sustainable Development Goals (SDG) (Table 6.1).

6.1.2.1. WEFs and food security

WEFs are likely some of the most easily accessible wild natural resources as they are among the most widely used NTFPs globally and regionally (Hickey et al. 2016, Welcome and Van Wyk 2019), and within the study area, where they are often sourced from within household yards (Chapter 3) and neighbourhood streets (Chapter 5). Nevertheless, only a fifth of the respondents in the nationwide sample used WEFs, and my studies failed to find any links, causal or otherwise, between WEF use and household food security or wealth (Chapter 3). Instead, I found that households that used WEFs had more diverse sources of food, and inferentially, higher dietary diversity. Users of WEFs also cited the perceived health benefits such as the fresh and nutritious nature of WEFs as a motivation for foraging for them (Chapter 5), rather than any significant contribution to the household economy. Indeed, WEFs are a source of important and high quality micronutrients, and many of them possess medicinal properties (Broegaard et al. 2017, Bvenura and Sivakumar 2017, de Oliveira Beltrame et al. 2018). Planting, propagating, and popularising WEF species in public spaces would complement government initiatives to improve access to and consumption of nutrients to combat malnourishment, such as the Integrated Food Security and Nutrition Programme and the Natural Resources Management Programme (DAFF 2019). I found that households with domesticated fruit species in their yards were more likely to also use WEFs (Chapter 3), and that local municipalities in small and medium-sized towns often donate saplings of domesticated fruit species to households (Chapter 4). Therefore, I suggest that planting WEF species alongside domesticated fruit species would be an effective introduction to increase awareness, acceptance, and uptake of lesser-known WEF species.

Table 6.1: Synergies between WEF use and CBD Aichi targets and SDGs (CBD Aichi Targets https://www.cbd.int/sp/targets/, SDGs https://sdgtool.com/ accessed on 29/11/2019)

Objectives & outcomes	Findings	Reference	CBD/SDG Targets
Food Security	➢ WEFs may provide food and income in times of environmental and socioeconomic shock ➢ Use of WEFs is linked to household dietary diversity (but not absolute food security) ➢ Planting and use of WEF species ties in with local and national policy and initiatives to improve food security	Chapter 2 Chapter 3 Chapter 4	CBD A2 CBD A3 CBD B7 CBD C13 SDG 2
Biodiversity Conservation	➢ WEF species are valuable genetic resources owing to their resilience and ecosystem services ➢ A diversity of WEF species are used across South Africa, and there is scope for increasing uptake of indigenous species ➢ Planting and use of WEF species answers to local and national policy on mainstreaming the biodiversity economy and landscape conservation, but may pose risks to core objectives of strict conservation areas	Chapter 2 Chapter 3 Chapter 4	CBD A1 CBD A3 CBD B7 CBD C13 SDG 2.4 SDG 2.5
Landscape Stewardship	➢ Promoting use of WEF species has the potential to enrich ecosystem services in public spaces, and aid land use policy to achieve sustainable use and co-management of urban spaces, given consideration to humanmade infrastructure and location ➢ WEF users frequent a range of natural and modified ecosystems, and are willing to help co-manage these and potential new foraging areas ➢ WEF users have an intimate knowledge of, and value for, WEF species and ecosystems they forage in	Chapter 4 Chapter 5	CBD B7 CBD C11 CBD D14 CBD D15 CBD E SDG 9 SDG 11 SDG 13 SDG 15 SDG 17
Sustainable Livelihoods	➢ Planting and use of WEF species ties in to local and national policy on creating sustainable livelihoods within the biodiversity economy ➢ WEF users are interested in, and willing to trade their foraged produce or foraging experience and knowledge through fair trade products and ecotourism	Chapter 4 Chapter 5	SDG 1.5 SDG 4.7 SDG 8.4 SDG 8.9 SDG 12

6.1.2.2. The role of WEFs in biodiversity conservation

WEF species represent a set of relatively underutilised food species that can be used in agroforestry, or in some cases also be domesticated and cultivated as climate resilient crops (Leakey 2018, Sardeshpande and Shackleton 2019). Currently, some of the most widely used WEF species are exotic (Chapter 3, Chapter 5). There is also a common misconception among land managers that edible fruit bearing species are rarely indigenous, and that subsequently, planting for foraging may encourage the spread of alien species (Chapter 4). I have provided land managers with a list of indigenous and alien WEF species uses across South Africa, and suggest that planting of indigenous WEF species in public spaces will increase their availability, visibility, and consequently, their use and propagation. Many WEF species nourish and depend upon a diversity of indigenous pollinators and dispersers (Shanley et al. 2012, Venter and Witkowski 2013, Sekar and Sukumar 2015, Shackleton et al. 2018), and particularly in urban ecosystems, can provide habitat as well as passageways for wildlife as a conduit between larger green spaces (Champness et al. 2019, Zietsman et al. 2019, Chapter 4). Thus, not only are WEFs an important genetic resource, but they also prominently provision and support other biodiversity, often across the climate, development, and disturbance gradient (e.g. Mabhaudhi et al. 2016, Mabhaudhi et al. 2017). Planting and promoting use of WEF species would therefore feed into local and national commitments to sustainable greening, biodiversity and habitat protection, and climate change resilience (PAGE 2017). When planting WEF species for wildlife as well as human consumption, an important consideration would be the estimation of optimum yield for humans, as to fulfil their functions in the ecosystem, a proportion of fruits will have to be reserved for wildlife (Chapter 4). Further, information on viable yield will have to be communicated and adhered to along with sustainable harvesting practices (such as plucking rather than lopping, and at the appropriate time of year), in order to ensure plant vitality. Some of this knowledge already exists in foraging communities (Thomas et al. 2017, Chapter 5), and in some cases, research is required to estimate sustainable offtake (Chapter 4).

6.1.2.3. Extending WEF use to natural resource management and landscape stewardship

WEFs are a subset of a gamut of natural resources, and therefore the learnings from their use and management can potentially be applied to other types of natural resource and land management, with due consideration to context. Besides their supporting and provisioning functions, by virtue of being most species trees and shrubs, WEF species also offer regulating functions such as carbon and water sequestration, nutrient cycling, and soil stabilisation. However, these very functions may work to the disservice of humanmade infrastructure such as water and electric supply lines in urban areas (Chapter 4). Integrating ecosystem services into urban infrastructure will require strategic partnerships across different departments and systematic planning to make urban green infrastructure multifunctional (Artmann et al. 2019, Hansen et al. 2019). Promoting use of WEFs in public spaces will call for specific action from different stakeholders, particularly the local government, to institute tenure rights, devolved governance systems, and collaborations for co-management of foraging spaces with different actors. The South African National Environmental Management: Biodiversity Act (2004) makes provisions for sustainable use-based management and conservation of biological resources and ecosystems, and for equitable access and sharing of benefits arising out of such use. Formalising the otherwise casual practice of foraging through regulations is likely to allow for the dissemination and enforcement of sustainable harvesting practices, and afford protection to the open spaces in which WEF species are foraged. Such formalisation could be initiated by recognising these spaces in local land use mapping and policy (e.g. Quayle and Pringle 2013, Umhlathuze SDF 2018, Ethekwini website 2019). I identified three pathways through which promoting WEF use could enhance landscape stewardship collaborations (Section 6.3), and designating certain areas for foraging emerged as the most favoured pathway, rather than greening existing humanmade infrastructure, or opening up conservation areas to foraging. This preference may be a reflection of a certain set of land managers' worldviews of nature and its conservation, which often idealise pristine nature, and view human activity as detrimental to conservation (Sandbrook et al. 2019, Chapter 4). Ultimately, the dichotomy between protection of and production in natural landscapes is often resolved to the scale and context of the area in consideration (Artmann et al. 2019, Mell and Clement 2019).

6.1.2.4. The potential for sustainable livelihoods using WEFs

Although WEFs were used by a significant proportion of the nationwide sample and all respondents in the regional sample, a very small fraction of these respondents traded in WEFs or products derived from them (Chapter 3, Chapter 5). My studies found that land managers as well as WEF users were enthusiastic about developing livelihoods around sustainable use of WEFs (Chapter 4, Chapter 5). I specifically proposed the concepts of value addition to WEFs through processed food products and foraging ecotourism. South Africa is a source of high value biodiversity-linked processed products on the global market (e.g. Wynberg and van Niekerk 2014, Wynberg 2017), but has relatively limited local markets and supply chains for fresh foraged wild products to urban areas (see Reyes-Garcia et al. 2015, Landor-Yamagata et al. 2018, Fuste-Forne 2019). The proposed supply chains reflect the objectives of the South African National Biodiversity Economy Strategy (2015) that enables and facilitates sustainable livelihoods through the use of biodiversity resources. As mentioned above, there is a need for improved exchange of information on appropriate resilient species and sustainable harvest and offtake, as well as institution of suitable governance mechanisms as prerequisites to initiating enterprises based on WEF use. Besides using government guidelines and capacity building, such enterprises may also benefit from access to high value markets through standardisation and certification processes (Morgan and Timoshyna 2016, Ting et al. 2016). The existing stakeholder networks involved in managing the urban commons and their related enterprises (Chapter 4) indicate a good foundation for the development of such supply chains.

6.1.3. WEF foraging is a confluence of culture and conservation

Foraging for WEFs has significant cultural connotations within my study sample (Chapter 5), as well as in forager communities globally (Peckham et al. 2013, Schulp et al. 2014, Hurley et al. 2015, Schunko et al. 2015, Landor-Yamagata et al. 2018). Foragers assert that they value the free and communal access to resources, knowledge transmission through friends and family, social cohesion, lifestyle choices, and recreational opportunities associated with foraging. Thus, foraging offers people the possibility of maintaining a measure of food sovereignty (Grey and Patel 2015, Augstburger et al. 2019), and exercising their traditional and ecological knowledge and management systems (Kremen and Merenlender 2018). These alternative and traditional food systems often embed adaptation and resilience strategies by virtue of being practised over generations in their specific local and cultural contexts (Mabhaudhi et al. 2016, Walsh-Dilley et al. 2016). Whereas industrial agriculture places emphasis on food production, traditional food systems tend to incorporate more nuances such as social structures and ecological processes in the procurement of food (Mabhaudhi et al. 2017, Nyman 2019, Bergius and Buseth 2019), of which foraging is an example. These diverse and devolved integrated food systems provide alternative pathways for sustainable development, particularly in the Global South, where they persist but risk being replaced by industrial agriculture (Mabhaudhi et al. 2017, Kremen and Merenlender 2018, Augstburger et al. 2019, Bergius and Buseth 2019). Efforts to protect and propagate traditional food systems include the valorisation of underutilised species (de Oliveira Beltrame et al. 2018, Gregory et al. 2019) and the recognition of cultural values of biodiversity (Gavin et al. 2018, Brown and Murtha 2019). Foraging is an embodiment of both of these actions, and I propose leveraging it for the conservation of species, landscapes, and ecosystem services in different contexts through different pathways in the following section.

6.2. Future directions

Results from Chapters 4 and 5 reveal the nature of urban foraging, specifically, the species that are foraged, the spaces that foraging occurs in, and the policy and management implications or lack thereof, of foraging. Using this information, I propose four pathways through which the activity of foraging could help conserve not only WEF species and the culture associated with them, but also the landscapes they are foraged from. I then compare the four pathways using the design principles for community-based natural resource management (Cox et al. 2010).

6.2.1. Planting wild edible fruit trees in residential areas (yards, complexes)

In some small and medium-sized municipalities (but not metropolitan municipalities like Durban), households under the reconstruction and development programme (RDP) receive one (domesticated) fruit tree sapling and one indigenous tree sapling per household during Arbour Week. These saplings are supplied to the households by the Community Services or Environment departments of the local municipality. The procurement of these saplings usually involves recommendations, sponsorships, or budget allotments from the provincial Department of Agriculture, Fisheries, and Forestry (DAFF), and the Department of Economic Development, Tourism, and Environmental Affairs (EDTEA). The DAFF, EDTEA, and local municipalities could begin providing wild edible fruit tree saplings to households. In all municipalities, developers of new and upcoming private housing schemes seek clearance and advice from the local municipality (Chapter 4) on the greening of their premises. Such developers can also be similarly advised by the Community Services or Environment departments to use wild edible fruit tree species. These saplings will mature and bear fruit within five to ten years.

The potential barrier to the adoption of wild edible fruit tree species is the perception of fruit and leaf litter being 'messy' and difficult to maintain (see also Shackleton and Mograbi 2020). In the past, trees within household yards have been felled in order to reduce maintenance and biomass removal efforts. In some cases, the lack of space in RDP developments has constrained tree plantation (similar to Gwedla and Shackleton 2015). Roots and branches of some trees may also grow aggressively and damage water or electrical supply lines. Therefore, the species selected for planting in residential areas have to be relatively low-maintenance and low-shedding, small to medium-sized, with docile, compact root and branch growth in order to facilitate uptake. The foreseeable benefits of planting wild edible fruit trees in residential areas include the provision of undisputed and well-defined access to household or local residents, thereby reducing the risk of conflicts of resource allocation. This is also perceived as a way of ensuring sustainable and steady wild fruit supply to residents in contrast to unpredictable and variable supply of wild fruits from untended open spaces.

Planting of wild edible fruit tree species in residential areas will aid the stewardship of land in private or communal ownership, and provide easy access to and reliable supply of wild edible fruits. However, it will not contribute to landscape or ecosystem-level management and stewardship, nor will it promote multi-stakeholder cooperation. Foragers rated the recreational value of foraging highly (Chapter 5), and planting wild edible fruits within residential areas will provide limited opportunities for landscape-level recreational activities associated with foraging. Nevertheless, this pathway is favourable for the promotion and propagation of the culture and knowledge of alternative and traditional indigenous foods. Planting for foraging in residential areas is a feasible pathway for small and medium-sized municipalities, with the Community Services and Parks departments respectively being the main actors in executing the necessary actions. It has limited potential in the metropolitan municipality of Durban.

6.2.2. Foraging in peripheral green infrastructure (verges, edges)

A number of foragers reported to picking wild edible fruits, and at times wild herbs and spinaches, from the edges of roads and sidewalks, often when walking to work or neighbourhood destinations (Chapter 5). However, in the lists of plant species procured and planted by the local municipalities, only three species of wild edible fruits were found (Chapter 4). Inferentially, the trees from which wild edible fruits are foraged were planted in the past, by private or non-municipality planters, or grew there incidentally. The DAFF, EDTEA, and local municipalities could therefore include more species of wild edible fruit trees in their plantings in these spaces. The premises of public offices such as police stations and schools were also commonly mentioned as sites where wild edible fruits were foraged. Some municipalities encourage the planting of agricultural food-bearing species in peripheral open spaces such as verges and school premises to augment urban and sustainable food production. In such cases, the municipality supplies seeds and seedlings, manure, soil, and helps build citizen capacity in organic intensive farming. Municipalities engaged in such capacity development can potentially include wild edible fruit species in their seeds and seedlings supply. Some foragers and municipal officials also suggested planting of wild edible fruit trees on the periphery of public spaces such as playgrounds and parks.

Foreseeable risks in planting for and foraging in peripheral green infrastructure include over-extraction, allocation disputes, logging, and theft (see also Richardson and Shackleton 2014). Free and open access to wild edible fruit trees may attract high numbers of foragers or high volumes of harvest (possibly for commercial purposes), affecting the vitality of the trees, and potentially creating high disturbance in their surroundings. In the absence of regulations and ownership, there might arise issues of who forages, and how much is foraged. Trees from peripheral green spaces are logged in some places, often for fuelwood, and therefore, woody species of wild edible fruit may be threatened by such use. In some cases, (domesticated) fruit species saplings as well as valuable ornamental species planted by the municipality in peripheral green spaces have been stolen. With these considerations, the species selected for planting in peripheral green spaces have to be relatively heavy-bearing and resilient to harvest and disturbance. Further, where such species are planted, information on fruiting seasons and instructions on sustainable use will have to be displayed explicitly. Local resident associations may volunteer to take responsibility of the wild edible fruit trees in their neighbourhood to ensure sustainable harvest and prevent logging or theft.

Structural and spatial contexts would also play an important role in planting for foraging. Similar to the first pathway, planting along verges of humanmade infrastructure such as walkways and embankments would require the roots to be compact so as to not impact the infrastructure, and the branches to be routinely maintained to prevent physical and visual obstruction, especially along roads. Planting for foraging would be appropriate in areas with relatively low or slow vehicular traffic and high pedestrian traffic, to minimise hazards. Relatively secure and peopled public premises with adult supervision, such as hospitals, police stations and schools, would be suited to planting for foraging, so as to reduce the risk of mishaps related to children and crime, as signage may not be accessible to or heeded by all users. Bearing these specifications, planting for foraging along peripheral green infrastructure is likely to aid collaboration between various stakeholders towards maintaining this infrastructure and augmenting its functionality. Besides providing food, it may also help prevent erosion, provide transit corridors for biodiversity, improve waste management, and increase social cohesion (Du Toit et al. 2018).

Planting and foraging of wild edible fruit trees in peripheral green infrastructure will ensure free and open access to fruit for all. In addition to improving food availability, it will also increase visibility and subsequently awareness of sustainable wild food foraging. There are however a number of limiting factors from social, structural, and spatial standpoints, which need to be factored into decisions on which species to plant, and where to plant. Such a scenario has the potential to bring together local neighbourhoods for landscape stewardship, not only from a resource management perspective, but also towards better waste and infrastructure management, and potentially neighbourhood and biodiversity monitoring. The key collaborators would be the Community Services and Parks departments in the municipality, managers of public premises, and representatives of the communities where such planting is done. This pathway is feasible in all levels of municipalities, but is likely to be more effective where staff from each stakeholder group can monitor the infrastructure routinely (e.g. Roman et al. 2017).

6.2.3. Foraging in consolidated and dedicated green spaces (parks, gardens)

Planting for and promoting foraging in designated green spaces, namely parks and gardens, was considered a favourable pathway by foragers as well as green space managers (Chapters 4 and 5). The distinctive feature of such designated spaces was the incorporation of rules and regulations for sustainable and equitable foraging. The knowledge that foraging in such spaces is legitimate, regulated, and encouraged would attract foragers (Chapter 5). Designated areas would ensure that ecosystem disturbances and any potential damage from foraging is contained within the area, rather than distributed across green spaces of varying degrees of biodiversity value. Important questions raised during preliminary discussions included the lack of information on suitable species, sustainable quantities and methods of harvesting, the potential threat to ecosystems from associated activities such as debarking, logging, and littering, and potential disputes over tenure and allocation. In order to address these issues, the creation of foraging gardens and parks would require collaborations between multiple stakeholders. European cities that promote citizen-led green space governance (Buijs et al. 2019) and public food gardens (Hajzeri and Kwadwo 2019) could prove a useful starting point for the development of foraging parks.

Questions of suitable species and methods and quantities of harvesting can be answered by some of the research preceding this chapter (Chapters 2 and 3), as well as other research specific to species that has already been published, or may be initiated based on information gaps identified herein. The design and landscaping of such spaces to optimise efficient production, recreation, and aesthetic value can be aided by the technical expertise of Parks departments. The rules and regulations in dedicated foraging gardens and parks would have to include prohibition of destructive and disruptive practices such as debarking and littering. However, regulations applying to tenure and allocation were not clear, and will have to be discussed with the main stakeholders, namely foragers, green space managers (Parks, Environment, and Community Services managers), local residents and associations, and any landowners who agree to lease their land for such a purpose. The Agroecology department of the Durban municipality helps citizens create and operate food gardens or small urban farms in open spaces, and their guidelines for such co-operative farming would be a useful starting point for the formulation of rules and regulations for foraging gardens and parks.

Similar to foraging in peripheral green spaces, foraging in dedicated green spaces would allow for co-management and stewardship of landscapes of provisioning and cultural value in the urban biosphere. It will also increase the accessibility, visibility, and legitimacy of traditional, alternative, and resilient food species. In contrast with planting in private or peripheral spaces, planting for and foraging in consolidated and designated spaces will necessitate the incorporation of explicit rules and engagement of the community in maintaining these spaces, thereby facilitating information exchanges and building communities of practice. Planting for foraging in dedicated green spaces is particular suited to large municipalities like Durban which have distinct green spaces, often with well-defined mandates, and personnel allocated to their management and maintenance, as well as high through traffic.

6.2.4. Foraging in conservation areas (reserves, restoration, offset developments)

Planting for and foraging in conservation areas was seen as a possible but not entirely desirable pathway by land managers. Conservation areas constitute different types of natural landscapes that offer varying degrees of protection to the biodiversity they host. Examples of these areas include protected areas or parks which preserve relatively pristine or highly valuable ecosystems and species, where only low impact recreational activities are permitted. Restoration and offset landscapes involve reconstruction or enrichment of specific ecosystems to enhance their functions, or to offset biodiversity impacts from developments elsewhere. In some cases, such conservation areas may be specifically targeted to provide biodiversity-based livelihoods through extractive use of indigenous or alien species. The motive behind all conservation areas is to protect and provide ecosystem services, be it cultural and supporting services in protected areas, or provisioning and regulating services in restoration and offset landscapes. Land managers as well as foragers recognised that foraging represents the utilisation of the cultural and provisioning ecosystem services of conservation areas.

Foraging in protected areas could be a potential source of ecosystem disturbance and subsequently degradation. Specifically, activities such as debarking, hunting, littering, logging, and overharvesting may possibly co-occur with extractive use, and would be unfavourable for biodiversity conservation in protected areas. Uninformed or indiscriminate foraging in protected areas may harm both harvested as well as unharvested vulnerable species, and may promote the spread of useful alien species such as guava. Further, the possibility of disputes over access to and allocation of resources was also flagged in such a scenario. On the other hand, planting for and promoting foraging in restoration and offset landscapes, particularly those linked to livelihoods, was seen as a favourable pathway by land managers. Planting for and promoting foraging in buffer zones between human habitation and protected areas would also be feasible. Land managers affirmed that foraging and livelihoods linked to it (such as local craft food supply chains and ecotourism enterprises) could be incorporated as an additional incentive into conservation areas.

Considerations for this scenario are similar to those for foraging in consolidated green spaces, namely the constitution of agreements between users regarding foraging access and allocation, and communication of and adherence to sustainable harvest quantities and practices. In the case of setting up commercial foraging-based livelihoods, additional precautions will be required. These could include self-regulatory or third-party standards and certifications to ensure sustainable and responsible harvest and improve visibility and market value of foraged products. Foraging in conservation areas has the potential to both aggravate and ameliorate land use conflict. Planting for foraging in conservation areas has limited potential due to the strict rules and regulations that foraging might contravene.

6.2.5. Comparison of pathways for community-based natural resource management

I compare the four pathways against the design principles for community-based natural resource management (Cox et al. 2010). The third pathway, namely planting of special parks and gardens for foraging, emerges as the most feasible pathway. This pathway has the most well-defined commons boundaries, incorporates all design principles, and poses very little risk to conservation and development objectives (Table 6.2). The second most feasible pathway is planting for foraging along verges and other peripheral green infrastructure. Such planting could be well-governed by nested enterprises, but could potentially endanger other species or infrastructure in the landscape. Although planting for foraging in private residential areas involves minimal risk, it is not practicable in all contexts, and has limited potential to contribute to multiple objectives. Planting for foraging in conservation areas has equal opportunities and risks, thus proving to be the least favoured pathway. This outcome also reflects some land managers' views of conservation goals being compromised by human use of landscapes, and thus, a link between CPR theory and the critique of fortress conservation (Chapter 4, Cox et al. 2016). Planting of special parks and gardens for foraging also presents the optimum combination of ease of access, governance, collaboration, and livelihood potential. Overall, the Parks department emerges as the key stakeholder for the implementation of the first three pathways.

The pathways developed and discussed in this section do not include foraging in informal urban green spaces such as vacant lots, where a significant amount of foraging also occurs (Rupprecht and Byrne 2014, Synk et al. 2017, Charnley et al. 2018, Chapter 5). However, I propose that some of these spaces could be accorded the status of foraging parks, and enriched with further planting of species of wild edible fruits as well as edible and medicinal herbs, which are often foraged in conjunction (Chapter 5). The formalisation of such spaces may provide protection to the biodiversity they contain as well as aid sustainable foraging and landscape management. However, such formalisation also risks alienating foragers who value the unregulated and open access nature of these spaces and their activities therein (Galt et al. 2014, Paddeu 2019, Nyman 2019, Chapter 5). Nevertheless, recognising the biocultural value of these informal spaces and the ecosystem services they provide is likely to protect these areas from indiscriminate infrastructure development. Incorporating foraging parks and gardens will allow foragers to continue or resume their cultural and recreational activities (Chapter 5) and also allow land managers to better prioritise and conserve these areas (Chapter 4).

Table 6.2: Summary and comparison of the four pathways, with respect to the design principles, outcomes, and key stakeholders

Factors	Planting in:	**Homes**	**Verges**	**Gardens**	**Reserves**
Design principles	**User boundaries**	Clear	Unclear	Variable	Clear
	Resource boundaries	Clear	Unclear	Clear	Variable
	Congruence with local conditions	Not applicable	Possible	Likely to be upheld	Possible
	Appropriation and provision	Possible	Difficult to regulate	Likely to be upheld	Difficult to regulate
	Collective-choice arrangements	Not applicable	Possible	Likely to be upheld	May be compromised
	Monitoring users	Not applicable	Difficult to regulate	Possible	Difficult to regulate
	Monitoring the resource	Possible	Possible	Possible	Possible
	Graduated sanctions	Not applicable	Difficult to enforce	Likely to be upheld	Possible
	Conflict-resolution mechanisms	Not applicable	Difficult to regulate	Likely to be upheld	Difficult to regulate
	Minimal recognition of rights to organize	Not applicable	Possible	Likely to be upheld	May be compromised
	Nested enterprises	Not applicable	Likely to be upheld	Likely to be upheld	Possible
Pathway outcomes	**Access**	Undisputed	Public, disputable	Public, disputable	Restricted
	Governance	Private	Municipal	Municipal / public	Municipal / provincial
	Sustainability	Likely to be upheld	Difficult to enforce	Possible to enforce	Possible to enforce
	Collaboration	Not applicable	Possible	Possible	Possible
	Livelihoods	Possible	Difficult to regulate	Possible	Difficult to regulate

Executing actors	**Plant supply**	Parks	Parks	Parks	Environment
	Plant and area maintenance	Parks, Citizens	Parks, Community Services, Citizens	Parks, Citizens	Environment
	Governance	Citizens	Parks, Community Services, Citizens	Parks, Citizens	Environment, Citizens

While the literature acknowledges the use of urban infrastructure by biodiversity and the potential to enhance its functionality to achieve multiple goals (Rupprecht et al. 2015, Botzat et al. 2016, Säumel et al. 2016, Buijs et al. 2019, Elands et al. 2019), I find that managers of such infrastructure have their reservations about such uses. I suggest that the solution lies in finding synergies between infrastructure management and the ecosystem services as well as community services that foraging can preserve and provide respectively. Specific considerations in this regard include planting appropriate species, mobilising leaders and volunteers from within the community to monitor and report changes, and promoting collaboration between stakeholders. However, I acknowledge that while public participation and cross-department collaboration are recommended and aspired to by policymakers, achieving these goals can be arduous due to varied interests and willingness (Molin and van den Bosch 2014, Mathers et al. 2015), as also expressed by the infrastructure managers.

6.3. Further research and development

Based on my findings, I make the following recommendations towards strengthening synergies between WEF use and biodiversity conservation and sustainable development:

1. Improving access to existing information on the occurrence, ecology, and use of WEF species for foragers and land managers. The list of prominent foraging WEF species has been shared with land managers in the study area. Some further information on range, morphology, and uses is available with the researcher, and in-depth species profiles are available with the South African National Biodiversity Institute (SANBI, http://pza.sanbi.org/).
2. Research on optimal harvest practices and yield of WEF species and dissemination of this information to relevant stakeholders. Various academic articles, botanical records, certification standards, and indigenous knowledge describe sustainable harvest practices that can be tested and used for different species depending on the intensity of their fruiting and harvest demand.

3. Establishing partnerships between Parks, Environment, and Community Services departments within municipalities, and where possible, with NGOs and citizen groups to organise the planting and maintenance of WEF species.
4. Planting of WEF species in household yards, around public infrastructure, and in designated areas where applicable and possible to increase awareness and use. The plants and areas can then be monitored for plant survival, yield, vitality, and associated biodiversity. Public infrastructure and designated areas can also be testing grounds for effectiveness and implications of varying degrees of resource access and governance.
5. Linking users, relevant departments in the administration, and prospective buyers to develop sustainable supply chains based on WEF foraging.

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