Evaluating detection efforts and management of alien and invasive species by citizens in Western Cape, South Africa

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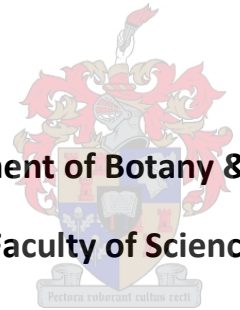
Thesis presented in partial fulfilment of the requirements for the degree of Master of Science



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Abstract

Invasive alien species (IAS) are a growing threat globally and cause a variety of ecological, economic and social impacts. People play a key role in introducing IAS and facilitating their spread but also in implementing and supporting management. Research and management of IAS traditionally focuses on biological dimensions and on state operated large scale control initiatives, with little emphasis on the social dimensions. Citizens can, however, contribute to prevention, detection, eradication and containment of IAS and getting an understanding of the extent of knowledge, perceptions and involvement in IAS management is important.

I evaluate the motivations and contributions of individual volunteers and groups to the control of IAS in South Africa's Western Cape province. I use two different online questionnaires, one for volunteer group co-ordinators and the other for individual volunteers involved in the control of invasive alien plant species (IAPS). In total, I identify 52 volunteer groups, most of which were motivated to take action by the rapid expansion of IAPS in their local areas, and their perceived need to maintain pristine fynbos. I estimate that half of these groups that participated in the survey clear nearly 5 300 ha of land with estimated labour costs of ZAR 5.1 million annually (equivalent to USD 0.32 million) when aligned with formal state management cost estimates. Most volunteer groups work on Australian *Acacia* species, raising their own funds to facilitate their work. Further, many groups affirm that they require support from governmental conservation organisations, for manpower to remove biomass and bigger plants, tools, training for new members and to comply with legislation on herbicide use. The majority of volunteers (82%) detect and report invasive species to relevant authorities, citizen science platforms and to their team leaders, while only 16% of volunteers said that they have never reported IAPS. Volunteers themselves gain fulfilment and build their social capital by meeting and interacting with new people and preserving native biodiversity. The contribution of these volunteer groups to IAPS management is important, but there is the need for better co-ordination and engagement between volunteer groups and mandated authorities working on science, policy and management.

I also administered questionnaires to citizens in eight small towns in the Berg River Catchment in Western Cape, South Africa, where volunteer groups are largely

absent aiming to assess their knowledge and perceptions of IAS. Overall, 262 respondents participated in the survey. More than half of the respondents 65% (n = 171) explicitly did not know the meaning of IAS, and 10% (n = 25) were unsure. Many respondents perceive IAS as beneficial. Using a logistic regression, I find that the minority of respondents who understand the concept of IAS were men with higher education levels, living in areas where IAS density is higher. Knowledge of IAS is found to be a pre-requisite for citizens engaging in reporting and removing IAS, and for them to get involved in volunteer programmes aimed at controlling IAS. I conclude that the citizens remain largely unaware of IAS and their impacts, in the Western Cape. However, once informed, some respondents 53% (n = 139) showed interest and willingness to learn more about IAS and their impacts regardless of their current level of knowledge. This suggests the need for better education campaigns which might help to facilitate support of IAS management efforts by the public in the future.

I conclude that there is a need to promote a broad public understanding of IAS in South Africa and help to facilitate ongoing citizen initiatives. The state support of volunteers could be used as a potential vehicle to promote awareness on IAS more generally. Creation of new volunteer groups in the Berg River Catchment may represent a potential way to increase citizen knowledge, co-ordinate awareness and reporting and management of IAS. This thesis highlights the importance of the social dimensions in invasion science and the need for better engagement between different stakeholders to improve reporting, policy and management surrounding biological invasions in South Africa.

Opsomming

Uitheemse indringerspesies hou 'n toenemende bedreiging in vir ekosisteme wêreldwyd en het 'n verskeidenheid ekologiese, ekonomiese en sosiale gevolge. Die mens speel 'n sleutelrol in die bekendstelling en en verspreiding van indringerspesies, maar is ook verantwoordelik vir die implementering en ondersteuning van die bestuur van indringerspesies. Navorsing en bestuur van indringerspesies fokus tradisioneel op die biologiese aspekte en op grootskaalse indringerbeheerprojekte wat deur die staat aangevoer word. Daar word egtermin klem op die sosiale aspekte van indringerspesies gelê. Burgers kan egter ‘n bydra tot die voorkoming, opsporing, uitwissing en beperking van indringerspesies lewer, en 'n begrip kry van die omvang van kennis, persepsies en betrokkenheid by die bestuur van indringers.

In hoofstuk 2 van hierdie tesis evalueer ek die motivering en bydrae van individuele vrywilligers en groepe tot die bestuur van indringerspesies in Suid-Afrika se Wes-Kaapprovinsie. Die data is versamel met behulp van twee aanlyn vraelyste, een gemik op koördineerders van vrywilligergroepe en die ander een wat gerig is aan individuele vrywilligers wat betrokke is by die bestuur van indringerspesies. In totaal het ek 52 vrywilligergroepe geïdentifiseer waarvandie meerderheid tot aksie gemotiveer is deur die vinnige verspreiding van indringerplantspesies in hul plaaslike gebiede, en hul klaarblyklike behoefte om ongerepte fynbos in stand te hou. Ek beraam dat die helfte van die groepe wat aan die opname deelgeneem het, ongeveer 5 300 ha skoonmaak met ‘n geraamde arbeidskoste van ZAR 5.1 miljoen per jaar (gelykstaande aan USD 0.32 miljoen) as dit vergelyk word met formele staatsbestuur kosteberamings. Die meeste vrywilligergroepe fokus op Australiese Akasia-spesies en samel hul eie fondse in om hul werk moontlik te maak. Baie groepe het ook bevestig dat hulle ondersteuning van regeringsbewaringsorganisasies benodig hoofsaaklik vir mannekrag vir die verwydering van biomassa en groter plante, gereedskap, opleiding vir nuwe lede en om aan wetgewing ingevolge die gebruik van onkruiddoders te voldoen. Die meerderheid vrywilligers (82%) ontdek indringerspesies en meld dit aan byrelevante owerhede, sowel as burgerwetenskapplatforms en hul spanleiers, terwyl slegs 16% van vrywilligers gesê het dat hulle nog nooit 'n indringerspesie aangemeld het nie.

Vrywilligers kry vervulling en bou hul sosiale kapitaal deur bymekaarkomste en interaksie met nuwe mense, en die bewaringvan inheemse biodiversiteit. Die bydrae van hierdie vrywilligers tot die bestuur van indringerplantspesies is waardevol, maar daar is ‘n behoefte aan beter koördinering en samewerking tussen vrywilligers en die betrokke owerhede verantwoordelik virwetenskap, beleid en bestuur.

In hoofstuk 3 het ek vraelyste aan inwoners van agt (8) klein dorpies in die Bergrivier-opvangsgebied in die Wes-Kaap, Suid-Afrika, verskaf met die doel om die inwoners se kennis en persepsies van uitheemse indringerspesies te assesseer. Altesaam 262 respondente het aan die opname deelgeneem. Meer as die helfte van die respondente 65% (n = 171) het uitdruklik (aangedui dat hulle nie weet wat…) nie geweet wat die betekenis van uitheemse indringerspesies is nie en 10% (n = 25) was onseker. Heelwat respondente beskou uitheemste indringerspesies as voordelig. Met behulp van 'n logaritmiese regressie het ek gevind dat die minderheid van respondente wat die konsep van uitheemse indringerspesies verstaan, mans is met hoë opleidingsvlakke wat woonagtig is in areas met ‘n hoë digtheid van indringerspesies. Benewens opleidingsvlak, is geslag en die digtheid van indringerspesies bevind as die beste veranderlikes wat kennis van uitheemse indringerspesies verduidelik. Kennis van uitheemse indringerspesies blyk om 'n voorvereiste te wees vir burgers wat betrokke is by die verslagdoening en verwydering van uitheemse indringerspesies, en vir hul betrokkenheid by vrywillige programme wat daarop gemik is om indringerspesies te beheer. Ek kom tot die gevolgtrekking dat die burgers grootliks onbewus bly van uitheemse indringerspesies en die impak daarvan in die Wes-Kaap. Na respondente wel ingelig is, het 53% (n = 139) van die respondent getoon dat hulle belangstel en bereid is om meer oor indringerspesies en hul impak te leer, ongeag hul huidige kennis. Dit dui op ‘n behoefte aan beter s bewusmakingsveldtogte wat ondersteuning kan bied aan indringerbestuursprojekte wat deur die publiek gedryf word.

Ek kom tot die gevolgtrekking dat daar 'n behoefte is om die publiek se kennis oor uitheemse indringerspesies in Suid-Afrika te verbeter en om bestaande burgerlike inisiatiewe te ondersteun. Die resultate van hierdie tesis beklemtoon die belangrikheid van die sosiale aspekte van indringerwetenskap en die behoefte aan

beter samewerking tussen verskillende belanghebbendes om sodoende die navorsing, beleid en bestuur van biologiese indringers in Suid-Afrika te bevorder.

Ingcamango

Izityalo ezingezozalapha (Invasive alien species - IAS) zisisisongelo esikhulu ehlabathini lonke yaye zinegalelo kokusingqongileyo, kuqoqosho nasekuhlaleni. Abantu banegalelo eliphambili kubukho bezi zityalo zingezozalapha nasekukhuthazeni ukunwenwa kwazo kodwa nasekufezekiseni nasekuxhaseni ukulawulwa kwazo. Uphando nolawulo lwe-IAS ngokwemveli lugxininisa kwiinkalo zebhayoloji nakumaphulo amakhulu olawulo aqhutywa ngurhulumente, yaye akujoliswa kangako kwiinkalo zokuhlala. Noko ke, abantu banokuba negalelo ekukhuseleni, ekuboneni, ekutshabalaliseni, nasekugcineni i-IAS nokuqonda umkhamo wolwazi, iingcamango nokubandakanyeka ekulawulweni kwee-IAS kubalulekile.

Ndihlola izikhuthazo namagalelo amatsha-ntliziyo namaqela ekulawulweni kwee-IAS kwiphondo laseNtshona Koloni eMzantsi Afrika. Ndisebenzisa amaxwebhu emibuzo amabini awahlukeneyo, elinye lelabanxibelelanisi beqela lamatsha-ntliziyo elinye lelamatsha-ntliziyo ngamanye abandakanyeke ekulawulweni kwezityalo ezingezozalapha ezikhula inkani (IAPS). Lilonke, ndibona amaqela amatsha-ntliziyo angama-52, amaninzi kuwo awakhuthazwa ukuba athathe inyathelo ekukhuleni okukhawulezileyo kwe-IAPS kwiindawo ahlala kuzo, nemfuneko ayibonayo yokulondoloza i-*fynbos* ekumgangatho ophezulu. Ndiqikelela ukuba isiqingatha sala maqela aye anenxaxheba kolu phando aye ageca phantse ihektare ezingama-5300 msebenzi lowo oxabisa iiRandi zaseMzantsi Afrika ezizigidi ezi-5.1 ngonyaka (imali elingana ne-0.32 yezigidi zeeDola zaseMelika (USD) xa ingqamana noqikelelo lolawulo lwemeko eqhelekileyo. Amaqela amaninzi amatsha-ntliziyo asebenza ngesityalo esiyi- *Acacia* sase-Ostreliya, ezinyusela iingxowamali zawo ukuze aqhube umsebenzi wawo. Ngaphezu koko, amaqela amaninzi ayavuma ukuba afuna inkxaso kwimibutho yolondolozo karhulumente, yokuhlawula abantu abaza kususa ibhayomesi nezityalo ezikhulu, izixhobo, ukuqeqesha amalungu amatsha nokwenza ngokuvumelana nomthetho ongokusetyenziswa kwezi zibulali zityalo eziyingozi. Uninzi lwamatsha-ntliziyo (82%) aye abhaqe aze axele izityalo ezikhula inkani kumagunya afanelekileyo, kumaqonga ezenzululwazi abahlali nakwiinkokeli zamaqela, ngoxa i-16% kuphela yamatsha-ntliziyo isithi ayizange ixele nge-IAPS. Amatsha-ntliziyo ngokwawo afumana ulwaneliseko aze akhulise ubudlelwane bawo

noluntu ngokuhlanganisana nokufakan’ imilomo nabantu abatsha nokulondoloza imvelo. Igalelo lala maqela amatsha-ntliziyo kulawulo lwe-IAPS lixabisekile, kodwa kukho imfuneko yokuququzelelwa okukuko nokufakan’ imilomo phakathi kwamaqela amatsha-ntliziyo namagunya afanelekileyo asebenza ngezenzululwazi, umgaqo-nkqubo nolawulo.

Kanti ndiye ndanikezela ngamaxwebhu emibuzo kubahlali beedolophu ezincinci ezisibhozo ngakwiChibi leBerg River kwiNtshona Koloni, eMzantsi Afrika, apho amaqela amatsha-ntliziyo enqabe kakhulu ngelokuzama ukuhlola ulwazi neembono zawo ngee-IAS. Bebonke, bangama-262 ababuzwa abaye banenxaxheba kolu phando. Bangaphezu kwesiqingatha ababuzwa 65% (n = 171) abaye ngokuphandle bachaza ukuba abayazi intsingiselo ye-IAS, yaye abali-10% (n = 25) bebengaqinisekanga. Uninzi lwababuzwa bacinga ukuba i-IAS iyinzuzo. Ndisebenzisa ubalo lwegrafu ndiye ndafumanisa ukuba igcudwana lababuzwa abayiqondayo ingcamango ye-IAS ngamadoda afunde kakhulu, nahlala kwindawo ezininzi kuyo ii-IAS. Ulwazi ngee-IAS kufunyaniswe ukuba lubalulekile kubemi abanenxaxheba ekuxeleni nasekususeni i-IAS, yaye nokuba babandakanyeke kwiinkqubo zobutsha-ntliziyo ezijoliswe ekulawuleni i-IAS. Ndifikelela kwisigqibo sokuba abahlali abaninzi abakazazi ii-IAS negalelo lazo, eNtshona Koloni. Kodwa ke, bathe bakufundiswa, ababuzwa abamalunga nama-53% (n = 139) baye babonisa umdla nokukulungela ukufunda ngakumbi nge-IAS yaye negalelo labo kungakhathaliseki ukuba bazi kangakanani ngazo ngoku. Oku kubonisa imfuneko yamaphulo okufundisa abantu kakuhle anokunceda ekukhuthazeni inkxaso yemigudu yokulawulwa kwee-IAS ngabantu kwixesha elizayo.

Ndifikelela kwisigqibo sokuba kukho imfuneko yokukhuthaza ukuba abantu baqonde ngokubanzi ngee-IAS eMzantsi Afrika ukunceda ekukhuthazeni amaphulo aqhubekayo abahlali. Inkxaso karhulumente yamatsha-ntliziyo inokusetyenziswa njengendlela yokufundisa abantu ngokubanzi ngee-IAS. Ukuyilwa kwamaqela amatsha amatsha-ntliziyo kwiChibi leBerg River kunokumela indlela entsha yokukhulisa ulwazi lwabahlali, ukuququzelela ukwazisa nokuchaza nokulawula ii-IAS. Le ngxelo ingekaqinisekiswa ibalaselisa ukubaluleka koluntu kwizityalo ezikhula inkani nemfuneko yokufakan’ imilomo okukuko phakathi kwamaqela awahlukeneyo ukuphucula ukuxelwa, umgaqo-nkqubo nolawulo olungqonge izityalo ezikhula inkani eMzantsi Afrika.

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Figure 3.4: Number of respondents who knew the species in question were IAS or indigenous and the number who perceived each as beneficial or harmful. *Aloe arborescens* is indigenous to South Africa and the rest of the species are invasive species found in the study region. (Page 67).

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Chapter 1: General introduction

Alien species are organisms that are intentionally or unintentionally introduced into new areas by humans for various reasons (Blackburn et al. 2011; Richardson et al. 2011). For example, some alien species are deliberately introduced to new areas as garden ornamentals, and for timber and firewood, agricultural crops, animal fodder, hedge plants and for other purposes (Richardson et al. 2020). Invasive animals are introduced mainly for the pet trade, ornamental purposes and for the game-farming industry (Measey et al. 2020). Many are also introduced accidently, as contaminants on vehicles and traded goods. Some of the introduced alien species establish in the new environments, spread and become invasive (Richardson et al. 2000; Blackburn et al. 2011). Invasive alien species (IAS) can cause major negative environmental and socioeconomic impacts in new areas where they are introduced (Richardson 2011; Simberloff & Rejmánek 2011), including impacts on the economy, on human health and biodiversity (Pimentel et al. 2005; Holmes et al. 2009; Powell et al. 2013; Bacher et al. 2018). Factors such as climate change, growth in human population densities and both natural and man-made disturbances contribute to the increased magnitude of invasion in most ecosystems (Hulme 2009). Due to the relationship between people and introduction and spread of IAS, there is a need to involve and engage the public in their management (Bremner & Park 2007; Verbrugge et al. 2013; Adriaens et al. 2015; Novoa et al. 2017, 2018; Shackleton et al. 2019).

1.1. Management of invasive alien plants in South Africa

South Africa has a long history of IAS introductions with management records starting in 1913 (Richardson et al. 2020; van Wilgen et al. 2020). The costs to manage these IAS are often higher than the benefits of introducing them (Turpie et al 2004; Mudavanhu et al. 2017; Nkambule et al. 2017). Efforts to control IAS cost South Africa approximately ZAR 2 billion each year (USD 120 million) (van Wilgen et al. 2020). Furthermore, the country has strong legislation underpinning management of IAS, through the National Environmental Management: Biodiversity Act ([NEM:BA] Act 10 of 2004). The Working for Water (WfW) program launched by the South African government in 1995 (van Wilgen & Wannenburgh 2016) is a globally recognised and well-documented control initiative that conducts and coordinate IAS

management throughout the country (Richardson & van Wilgen 2004; van Wilgen et al. 2020). Working for Water programme has goals of controlling IAS (plants and animals) and providing job opportunities for poor people (van Wilgen & Wannenburgh 2016). Regarding invasive alien plant species (IAPS), WfW operates on land owned by public and private institutions, and uses a mixture of biological, chemical and manual control methods to clear IAPS (van Wilgen et al. 2020). In 2008, a national programme dedicated to biosecurity and the early detection, assessment and control of invasive introductions was established (Wilson et al. 2013). When IAS are discovered and their taxonomic identification affirmed, establishing the level of risk (Rejmánek & Pitcairn 2002) and eradication feasibility (Panetta 2015) are essential steps towards informing management actions under this programme. Most NGOs and volunteer “hack” groups have been controlling IAPS especially on private land (van Rensburg et al. 2017; van Wilgen et al. 2017; van Wilgen et al. 2020). However, there is no monitoring data to account for these efforts (van Wilgen et al. 2020) and there is a need to gather information on these control efforts to have a more holistic understanding of the situation. There have been estimates of effort to control IAPS in South Africa (e.g. van Wilgen et al 2020) but nonetheless, invasions are still spreading and that there needs to be more work done.

Of the nine South African terrestrial biomes, the Fynbos Biome within the Cape Floristic Region (CFR) in the Western Cape is regarded the most invaded by IAPS, in particular by the plant genera *Acacia*, *Hakea*, and *Pinus* (Richardson et al. 2020; van Wilgen et al. 2020). These species pose a serious threat to native biodiversity, as they alter ecosystem processes, reduce local species richness and can increase transpiration and lead to less quantities of annual water runoff (Le Maitre et al. 2020). The main drivers promoting the establishment and spread of IAPS in the Cape Floristic Region (CFR) are both natural (climate change and disturbance regimes) and socio-economic forces which emerge from human activities (Roura-Pascual et al. 2009). Most studies focusing on the management of IAPS control measures in South Africa have been carried out in the CFR (van Wilgen et al. 2020). Despite ongoing control efforts, IAPS remain the largest threat to biodiversity in the Fynbos Biome.

1.2. Involvement of citizens in the management of invasive alien plants in South Africa

The role of citizens and their engagement in the management of IAS is a key element of IAS management and should not be overlooked (Novoa et al. 2018; Shackleton et al. 2020). If funding has been secured and the management plan finalized the lack of stakeholder support might influence the success of control initiatives or prevent them totally (Gardener et al. 2010; Panetta 2009, 2015). Involving citizens in the management of IAS is especially important to reach a level of agreement among stakeholders regarding their management and to reduce conflicts of interest (Shackleton et al. 2019). Lack of knowledge and awareness about IAS among citizens can also lead to failure of their control initiatives. Collaborative research and management planning, involving various actors (including citizens), could help to better shape policy, and to effectively control biological invasions in the country (Adriaens et al. 2015; Novoa et al. 2018; Shackleton et al. 2019). Citizens should also be aware of efforts being made to control such IAS, and what role they can potentially play in helping to manage them (Byrne et al. 2020).

According to Shackleton et al. (2019), there are many ways of involving society in the management of IAS, such as through citizen science and volunteer initiatives to monitor and/ control them. Citizens can play a relevant role from assisting with detection of IAS to supporting local management (Fitzpatrick et al. 2009; Dechoum et al. 2019). In addition, citizens themselves can facilitate public awareness of environmental issues which can empower people to take local action (Dechoum et al. 2019). Involvement in IAS management also has personal benefits for volunteers such as gaining personal fulfilment and building their social capital (Measham & Barnett 2008; Geoghegan et al. 2016) and thus contribute to their psychological and physical well-being (Koss & Kingsley 2010; Molsher & Townstead 2016).

Despite the importance of human and social dimensions of invasion science, there are still major research gaps in this domain within South Africa (Shackleton et al. 2020). Elsewhere in the world research on IAS and involving citizen science and volunteering is growing (Bois et al. 2011; Adriaens et al. 2015; Pocock et al. 2017;

Pagès et al. 2019; Johnson et al. 2020), but in South Africa there has been less uptake, and there is no baseline understanding of what is taking place and why society is involved in such actions – representing a key knowledge gap that needs to be filled (Novoa et al. 2018; Dechoum et al. 2019).

There is also a growing wealth of research on people's perceptions of IAS, even in South Africa (Bravo-Vargas et al. 2019; Potgieter et al. 2019; Shackleton et al. 2019; Cordeiro et al. 2020; Höbart et al. 2020; Vaz et al. 2020). However, there are still gaps to be addressed with regards to assessing and understanding knowledge and perceptions regarding IAS. These particularly relate to research focusing on small towns and comparing invasion densities with peoples' knowledge and perceptions. The perceptions of IAS are better understood if cognisance is taken of the socio-ecological contexts among stakeholders. Factors such as species traits, residence time, reasons for introduction, rates of spread and densities of invasions, impacts on people as well as management and outreach efforts contribute to the comprehension of IAS by citizens (Shackleton et al. 2020). Each urban/rural area has different challenges that needs specific management approaches of IAS (Irlich et al. 2017). These approaches should be made to suite different locations, different views of stakeholder and social consequences of IAS management actions (Gaertner et al. 2016 and 2017).

1.3. Aims and objectives

The overall aim of this study was to evaluate citizens' knowledge of IAS and their motivations and contributions to managing them in Western Cape, South Africa. This was accomplished by:

Assessing motivations and contributions of individual volunteers and volunteer groups for the management of IAS in South Africa's Western Cape province (Chapter 2).

- identifying volunteer groups controlling IAPS in the Western Cape province of South Africa;
- understanding people's practices and contributions towards detecting and controlling IAPS;

- examining volunteer's motivations for controlling IAPS;
- identifying the challenges individual volunteers and groups face.

Assessing public knowledge and awareness of invasive alien species in small towns of South Africa's Western Cape province (Chapter 3).

- assessing the awareness of IAS by the general public;
- assessing local perceptions of the impacts associated with IAS;
- assessing if knowledge and awareness of invasive species is correlated with invasion density;
- assessing people's willingness to detect, report and support IAS management.

This thesis comprises two research chapters which are presented in the form of journal manuscripts. Chapter 2: "Motivations and contributions of volunteer groups for the management of invasive alien plants in South Africa's Western Cape province" was submitted to *Bothalia* (*African Biodiversity and Conservation*) in August 2020. Chapter 3: "Public knowledge and awareness of invasive alien species in small towns of South Africa's Western Cape province" is intended for submission to Koedoe. Chapter 4 provides the overall conclusions of the thesis in which all the main findings are highlighted, and future needs are discussed.

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Chapter 2: Motivations and contributions of volunteer groups in the management of invasive alien plants in South Africa's Western Cape province

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Abstract

Research and management of biological invasions traditionally focuses on state operated large scale control initiatives, with little emphasis on volunteers. Volunteering can, however, contribute to detection, eradication and containment of invasive alien plant species (IAPS). Understanding the extent of involvement of volunteers in IAPS management is important. Similarly, understanding volunteers' motivations to volunteering is important to improve the success of IAPS management. In this study we aimed to: 1) identify volunteer groups controlling IAPS in the Western Cape province of South Africa, 2) understand their practices and contributions towards detecting and controlling IAPS, 3) examine volunteer's motivations for controlling IAPS, and, 4) identify the challenges individual volunteers and groups face. Data were collected using online questionnaires, one directed at volunteer group co-ordinators, and the other directed to individual volunteers involved in the management of IAPS. In total, we identified 52 volunteer groups. We estimate that half of these groups that participated in the survey clear nearly 5 300 ha of land with estimated labour costs of ZAR 5.1 million (equivalent to USD 0.32 million) when aligned with formal state management cost estimates. Most volunteer groups raise their own funds to facilitate their work, however, many suggest support from government entities, landowners and non-governmental organisations would help. Most volunteers (82%) detect and report invasive species to their team leaders, citizen science platforms and relevant authorities. Volunteers themselves gain physical and psychological fulfilment and build social capital by meeting new people. Our findings point to the valuable contribution of these groups, but also the need for better co-ordination and engagement between volunteer groups and mandated authorities on science, policy and management.

Key words: Biological invasions, Citizen science, Hack groups, Invasive alien species, Management, Stakeholder engagement

2.1. Introduction

Globally, invasive alien species (IAS) pose a significant and accelerating cost to economies, societies and ecosystems around the world (Pimentel et al. 2005; Jeschke et al. 2014). Humans are responsible for the initial introduction of IAS and their management at later stages (Hulme et al. 2008; Faulkner et al. 2015; Novoa et al. 2018; Shackleton et al. 2019). The rate at which IAS spread and the difficulty of managing them, has resulted in the recognition of the need for collaborations in research and management which enhance the link between science, policy, management and citizens around the world (Novoa et al. 2017; Abrahams et al. 2019). These integrative management approaches should include citizens and volunteers to help improve the effectiveness of IAS management over the long-term (Novoa et al. 2018; Dechoum et al. 2019), and support conservation work in times of budgetary constraint (Pagès et al. 2019). In this context, we define volunteering as a non-paid activity conducted by citizens to benefit the environment which is “planned” and included in a more or less formalised organisational context (Penner 2002).

According to Shackleton et al. (2019), there are many ways of involving society in the management of IAS, such as through citizen science and volunteer initiatives to monitor and/or control IAS. Volunteers can make a significant contribution in the local management of IAS at a reasonable cost and their efforts can be sustained over time (Dechoum et al. 2019). Volunteer programs can also be helpful in increasing public awareness of environmental issues and encourage local people to join the groups (Dechoum et al. 2019; Groom et al. 2019). More experienced volunteers, or champions, can be very helpful in the early detection of new and satellite infestations. There are various examples of the benefits volunteers can have for IAS management. For example, Dechoum et al. (2019) show that management programs for invasive pines (*Pinus* spp.) involving volunteers were effective, and resulted in overall reduction in their abundance and distribution in southern Brazil. Similarly, Delaney et al. (2008) showed a significant contribution by volunteers in detecting the range expansion of Japanese shore crabs (*Hemigrapsus sanguineus*) in the United States of America. Thomas et al. (2017) demonstrated the value of using citizens to detect invasive animal species using active and passive surveillance in Australia. Considering the success of volunteers in facilitating IAS management elsewhere in the world, research needs to be undertaken to better

understand and document the role of volunteers in the management of IAS in South Africa - which remains a current knowledge gap.

South Africa has major problems with both plants and animal IAS (van Wilgen et al. 2020). Invasive alien plant species (IAPS), in particular, pose a major threat across most of the country and the efforts to control them cost approximately ZAR 2 billion each year (USD 120 million) (van Wilgen et al. 2020). If left unmanaged, the impacts of IAPS on South African ecosystems are likely to increase (Wilson et al. 2020). South Africa has a long history of managing IAPS dating back to 1913 (van Wilgen et al. 2020). The Working for Water (WfW) program launched by the South African government in 1995 (van Wilgen & Wannenburgh 2016) is a globally recognised and well-documented control initiative (Richardson & van Wilgen 2004; van Wilgen et al. 2012). The purpose of this public works programme is to control IAPS as well as create employment opportunities for disadvantaged people (van Wilgen & Wannenburgh 2016). WfW operates on public and private land, and uses a mixture of biological, chemical and manual control methods (van Wilgen et al. 2020). Furthermore, South Africa has strong legislation, the National Environmental Management: Biodiversity Act ([NEM: BA] Act 10 of 2004), that underpins the management of IAS.

There is, however, limited research and emphasis on volunteering or private control initiatives in the country (van Rensburg et al. 2017). Understanding the motivations and contributions of volunteers to manage IAS and developing strategies to maintain their enthusiasm and willingness to participate is important to improving successful IAS control. Emphasis should also be placed on understanding the barriers that can negatively affect volunteer participation to guide relevant adaptive responses and policy (Shackleton et al. 2016).

Therefore, this study aims to: 1) identify volunteer groups controlling IAPS in the Western Cape province of South Africa, 2) understand the practices and contributions of volunteer groups towards detecting and controlling IAPS, 3) examine volunteer motivations for managing IAPS and 4) identify the challenges or barriers that are faced by volunteers when managing IAPS.

2.2. Methods

2.2.1. Study site

The study was conducted in the Western Cape province which is located on the south-western coast of the South Africa's Cape Floristic Region (CFR) with a population of approximately 6.8 million people (StatsSA 2019). Almost all the province's urban population is concentrated in the city of Cape Town, which is also the country's legislative and provincial capital. The Western Cape experiences a Mediterranean climate with hot dry summers and cold rainy winters (Rebelo et al. 2006). The primary vegetation type of the Western Cape is 'fynbos': a highly diverse, evergreen, hard leafed shrubland growing in nutrient poor soils (Rebelo et al. 2006).

The Cape Floristic Region is recognised as a global biodiversity hotspot due to its high levels of plant endemism and diversity (Rebelo 2006). The region is also the most invaded terrestrial area in South Africa, especially by IAPS in the genera *Acacia*, *Hakea*, and *Pinus* (van Wilgen et al. 2020; Richardson et al. 2020), which pose a serious threat to the biodiversity, as they alter ecosystem processes and reduce local species richness (van Wilgen et al. 2008). The economic impacts caused by these IAPS in the region are also high (van Wilgen 2016), where historical costs for control over the past 20 years have amounted to ZAR 564 million (2015 values) (van Wilgen et al. 2016). These costs do not include control efforts of IAPS by private landowners and volunteers.

2.2.2. Identifying volunteer groups in the Western Cape

To identify and map existing volunteer groups in the Western Cape managing IAPS, an online search (Google) was conducted using the following terms in English, Isixhosa and Afrikaans "hack groups, volunteer groups, invasive alien species control, and friends' groups" in April 2019. Researchers, managers and other stakeholders in the conservation sector (e.g. the Botanical Society of South Africa (Botsoc), Custodians or Rare and Endangered Wildlife (CREW) and Environment Society of South Africa (WESSA) were also consulted and asked to report known volunteer groups in the Western Cape. A short document asking people to report known volunteer groups in the Western Cape was produced and shared on social media (Facebook) and independently shared by users with personal accounts and

groups. This yielded more results than other search efforts. Snowballing (word-of-mouth referrals) methodology was also used to source additional volunteer groups whereby in interviews we asked volunteer group leaders to identify other groups known to them.

2.2.3. Questionnaires

Two different online questionnaires were conducted using Google Forms. One was directed at volunteer groups and was completed by the group co-ordinators or group leaders and contained 30 questions (Appendix 2.1), and the other was directed at individual volunteers and had 26 questions (Appendix 2.2).

The volunteer group related questionnaire aimed to better understand how the whole group functions and contained different questions relating to: 1) how and when the group was formed; 2) the motivation behind forming the group; 3) how the group operates; 4) how they measure success in managing IAPS; 5) whether there is a group budget, the source of funding and what the budget is used for; 6) whether the groups require additional support from government entities, landowners and non-governmental organisations (NGO's); and 7) challenges faced by the groups.

The questionnaire directed at individuals who volunteered for groups controlling IAPS in the Western Cape was aimed at understanding the motivations, values, and practices of volunteers. This questionnaire covered themes such as: 1) how they joined the volunteer groups; 2) their initial reasons for participating in IAS management; 3) their current motivations to volunteer, 4) the primary positive experiences or benefits they get from volunteering, 5) how often they volunteer; 6) whether volunteering cost them anything financially; 7) whether they detect and report IAS; and 8) any challenges they faced as volunteers. The second section of this questionnaire captured the demographic profile of respondents such as age, location, education level and current or previous field of work.

Both questionnaires contained open and closed ended questions, each with an estimated completion time of around 15 minutes. The final questionnaires were piloted, and the responses from the pilot experiment were not used in the results. The questionnaire was advertised by intermittent posting from August 2019 to May 2020 via emails where participants could use the link to access the survey and

participate voluntarily online or an option to get in contact for a telephonic interview. Government entities and NGO's such as City of Cape Town Invasive Species Unit and WESSA assisted with the distribution of the survey link throughout their volunteer networks using a mixture of direct emails and social media posts. The online survey ran for ten months where most responses were collected with very few done by telephonic interview in the same period.

2.2.4. Data analysis

Most questions related to motivations and challenges were open-ended to avoid forced responses. There are several different ways of classifying motivations, but for the purpose of this study, motivations were grouped into a mixture of categories identified by Bruyere & Rappe (2007), Measham & Barnett (2008), and West et al. (2015). Our categories relate broadly, to different environmental values, socio-cultural values, personal well-being and educational values (Appendix 2.3). Responses were categorised post hoc and were assigned into different categories. Responses that were difficult to classify or that did not fall into any of the pre-determined categories were then assigned to the "other" category (e.g. "*the managing authority [name withheld] and other state environmental entities, including provincial and local structures, are not doing their job to conserve and protect the Lourens river riverine area")*.

2.2.5. Ethics

The necessary ethical clearance to conduct the research was obtained from the REC: Humanities at Stellenbosch University - Project number: 9578. All ethical standards were adhered to. An informed consent was obtained from all participants and anonymity was assured.

2.3. Results

2.3.1. Volunteer groups

We identified 52 volunteer groups (Appendix 2.4), of these, we received 26 completed responses from volunteer group co-ordinators and 56 responses from individual volunteer members. Most of the volunteer groups are concentrated within the city of Cape Town, with some groups in smaller towns scattered throughout in the rest of the province (Figure 2.1). The geographical spread of the groups has a

full coverage of the Western Cape (with the furthest distance between Knysna and near Clanwilliam being over 500 km, but some groups were less than 10km apart). The fynbos biome was more represented than other biomes and most groups were situated in and around larger towns and cities in the region.

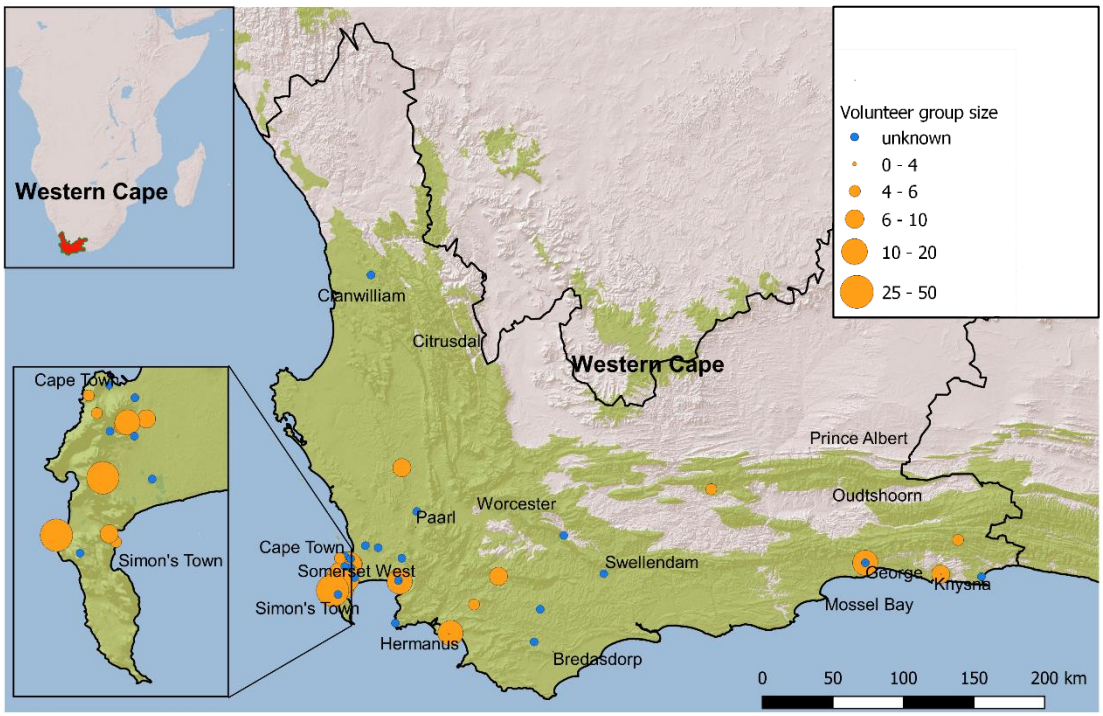

Figure 2.1. Identified volunteer groups (52) in Western Cape of South Africa. Groups that participated in the survey (26) are indicated by circles which also show group sizes (individual members per group). Groups that did not participate in the survey are indicated by blue circles. The green area on the map represents the fynbos biome.

The oldest volunteer groups were initiated as early as 1980. Many groups (43%) were triggered by the expansion of IAPS and members realising the need to stop their spread (Figure 2.2). For example, one group co-ordinator highlighted their motivation for starting the group as "*The overwhelming growth of alien invasive in the Pledge Nature Reserve after the June 2017 fires"*. The second most important motivation for the groups was the need to preserve nature and biodiversity (20%). For example, "*Elsies Peak was at that time a forest of invasive species. We wanted the fynbos back".* Moral obligation (14%) also played an important role in forming some volunteer groups, for example, one group's motivation was to "*To put back something to Nature"*, while another group leader said, "*We love and care for this*

place". This was followed by the need to preserve ecosystem services (11%). Other groups (6%) felt the need to get involved and protect important cultural and biodiversity sites. For example, *"Getting involved with the arboretum to formulate a draft management plan within the fynbos environment envisaged for the future. Focus on heritage, recreation and management"*. While some groups (6%) were initiated due to their desire to preserve environmental aesthetics.

The volunteer groups vary considerably in their size (maximum of 50 members and minimum of two members) with a mean of 12 members per group (Figure 2.1). Most groups meet once a week, mainly during spring, summer and autumn. The average distance that members of the groups travelled to the sites where they worked was 8.6 km with the maximum being 75 km and the minimum being 1 km. Half of the groups spent about three hours in the field controlling IAPS and the other half spent five or more hours when they met.

Most of the groups (60%) also conduct other social and environmental activities such as environmental education, drawing up land use plans, restoring indigenous species and participating in river clean-ups, with an average of 20% of their time spent on IAS control. To prioritise sites they work on, the groups' work is based on infestation densities, ease of plant identification and the terrain within their respective areas.

Almost all the groups concentrated their effort to control and reduce the spread and impact of invasive widespread woody trees such as: *Acacia saligna* (Port jackson), *Acacia mearnsii* (Black wattle), *Acacia longifolia* (Golden wattle) and *Acacia cyclops* (Rooikrans). Some groups also control emerging species with low population densities listed as category 1a on South Africa's NEM: BA Act such as *Spartina alterniflora* (Smooth cordgrass), *Lythrum salicaria* (Purple loosestrife) and *Melaleuca* species (Appendix 2.5). Almost all the groups use integrated control, combining manual removal and chemical control with herbicides at the site. However, only 16% of the groups indicated that they have qualified Pest Control Operators (PCO) in their groups. A PCO is someone who is trained and qualified to use herbicides to control IAPS.

Most groups (90%) indicated that they do not collect any data on their management implementation. The groups mostly rely on visual assessment to measure progress on their management interventions.

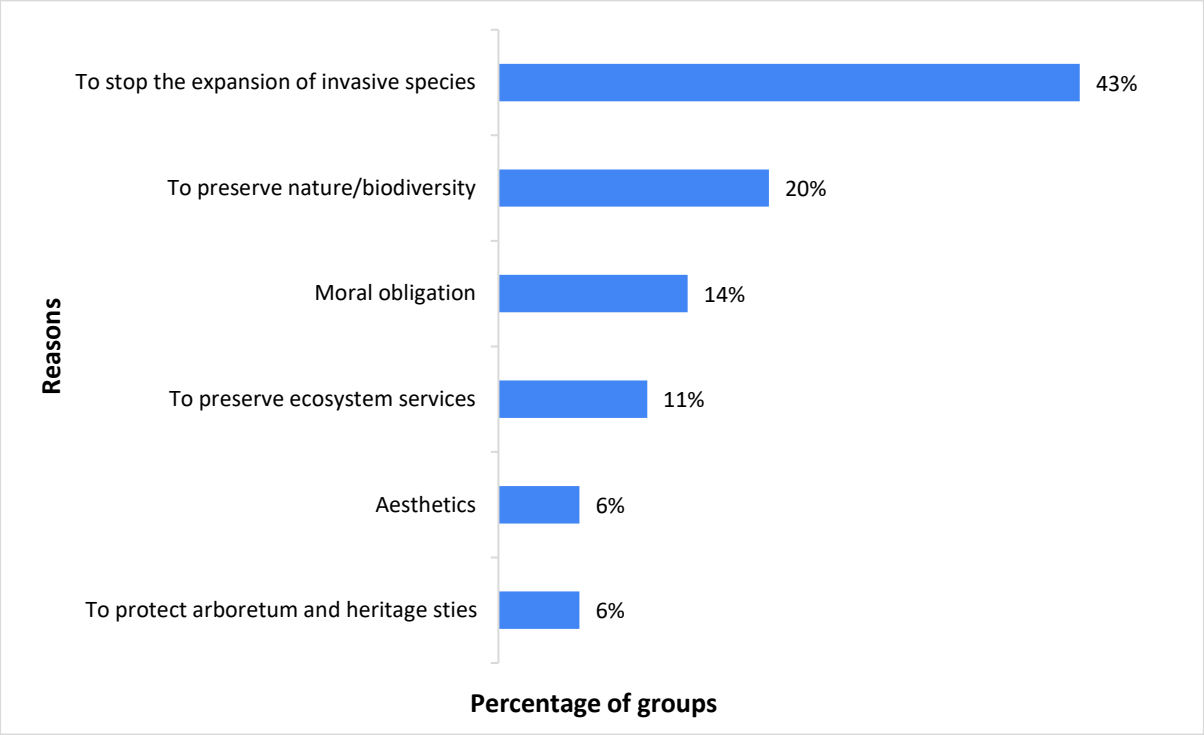

Figure 2.2. Motivations (n = 22) for forming volunteer groups that remove alien invasive plants in Western Cape, South Africa. This is a categorised representation of answers to open-ended questions.

2.3.2. Estimated value of contributions by volunteer groups

The majority (68%) of the groups are operating with no group budget, while the rest of the groups raised their own funds with a mean budget of ZAR 2 923 per month, equivalent to ZAR 26 307 per year (minimum ZAR 1 000 and maximum ZAR15 000 per month). Generally, there was no assistance from government entities, municipalities or NGO's, except for herbicide supply for some groups (46%). The money raised by groups was mainly for wages (for additional labour) and tools.

We used the data submitted by 26 volunteer groups that participated in the survey to estimate the equivalent total labour value contributed by these groups (26) to control IAPS in Western Cape drawing on WfW standards.

The estimate of the equivalent cost if it were done by WfW teams was calculated as: Number of hours worked by each group × number of volunteers × number weeks worked by the groups each year = the labour hours per group per year × by the general worker wage rate used by the WfW program. The totals for all 26 groups were added together and resulted in = = ZAR 5,106,241 (equivalent to USD 0.32 million). In considering all groups this number is probably closer to 10 million ZAR per annum.

The area of land cleared was calculated as: Total number of hours worked by the groups annually/ number of hours to clear 1 ha at an assumed 5% density as per WfW standards: 42 165/8 = 5 271 ha cleared by 26 groups annually, again this is probably closer to 10 000 ha.

2.3.3. Challenges mentioned by volunteer groups

The top ranked challenge for most groups was to attract new members (23%) (Figure 2.3). The challenge of extirpating the targeted IAPS (19%) was ranked highly by the groups. Some groups have volunteers that are old (60 or more years) (16%) who struggle with some aspects of controlling IAPS, which also links to difficult terrain (12%). To a lesser extent sustainability for long-term funding (6%) was also viewed as a challenge. Historically bad control of IAPS, lack of support from government entities and landowners and fluctuating volunteer support were equally ranked as an issue (4%) by only two groups. The “other” category (12%) included responses which relate to time constraints (volunteering time) as well as health and safety issues.

Most groups (72%) indicated that they need extra support from government entities with the removal of biomass, for manpower to remove big trees, training for new group members, as well as for extra funding, tools, labour and herbicide.

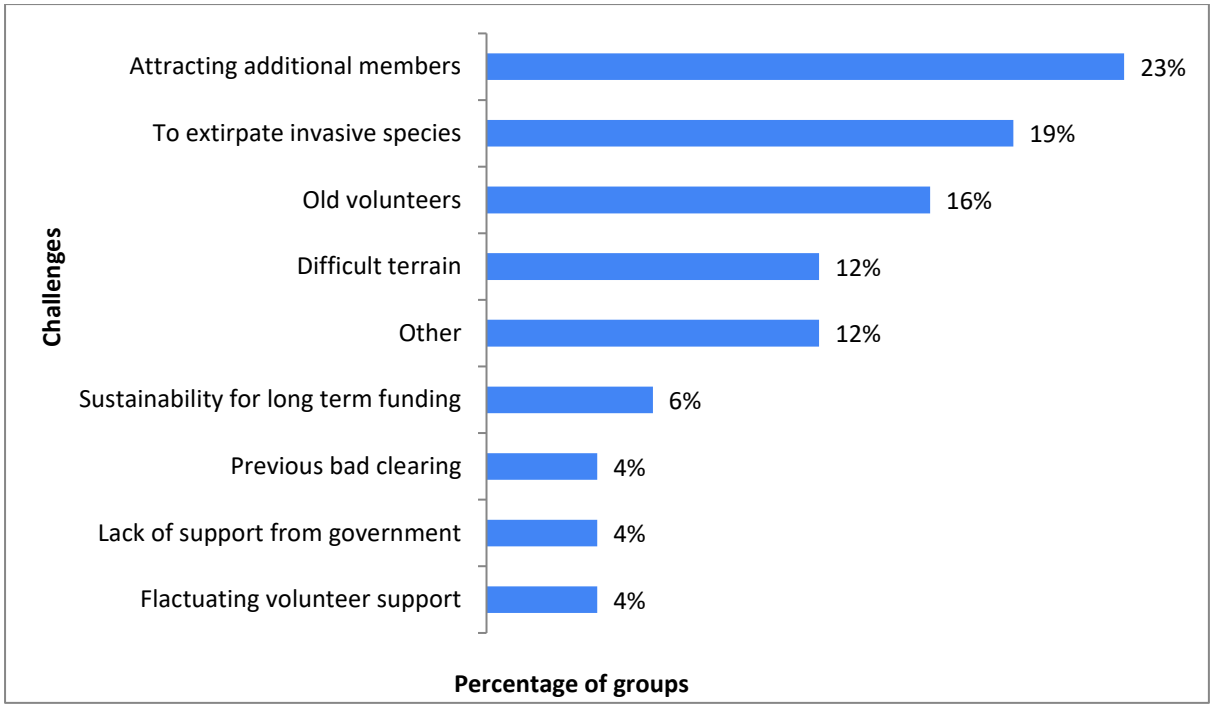

Figure 2.3. Challenges (n = 26) faced by volunteering by groups in the management of invasive alien plants in Western Cape, South Africa. This is a categorised representation of answers to open-ended questions.

2.3.4. Volunteer profiles

Respondents' ages ranged between 24 and 83, with a mean age of 56. Most respondents (32%) had been volunteering for five years or more, while (30%) had been volunteering for three to four years and 38% for one year and less. Most respondents were highly educated with the minimum education level being matric (completed high school) and some had a PhD. Eighty two percent of respondents had a degree (bachelors to PhD). Six percent of respondents were employed in the environmental sector.

Most volunteers (31%) initially got involved to stop the expansion of IAPS and to preserve nature (18%). The desire to protect nature (moral obligation, environmental values) played an important role for some volunteers to join the groups (25%). For example, one volunteer said, "*I wanted to contribute something to environmental protection*" whereas another said, "*I take much from nature and want to give back*". Enjoyment and socialising (8%) also triggered some volunteers to take part in IAPS management. Aesthetics (3%), preserving ecosystem services (8%), exercise (4%) and education awareness (2%) were ranked as the last four initial motivations to get

involved in IAPS management. The “other” category included one response associated with looking for something useful to do because they were retired.

The initial motivations for volunteers to get involved in IAPS management were often different to the current motivations (Figure 2.4). Forty six percent of the volunteers felt their motivations had changed over time, in particular, their motivations changed from social reasons to contributing towards protecting nature and sharing their knowledge.

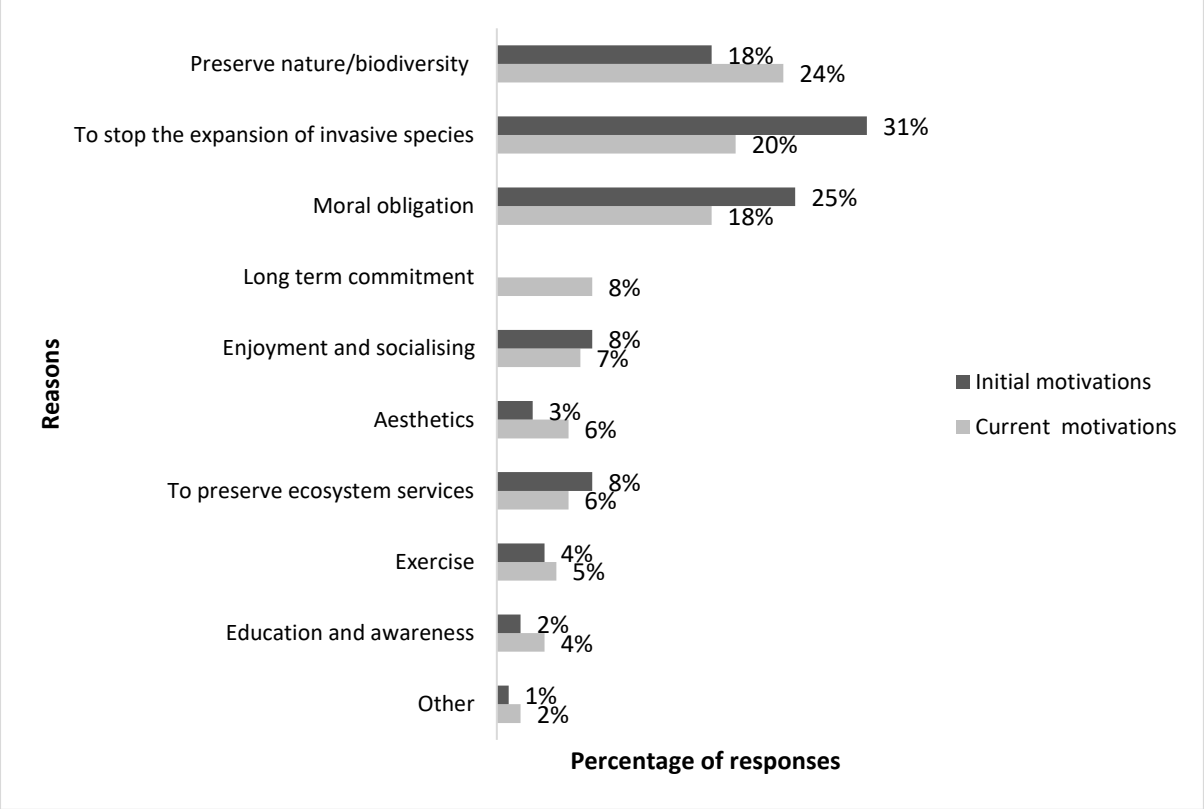

Figure 2.4. Reasons for initial engagement (n = 71) in volunteering and the current motivations (n = 86) for volunteers to be involved in the management of invasive alien plant species in Western Cape, South Africa.

In answer to the question on current motivations to remain involved in the management of IAPS, many respondents said they were volunteering to preserve nature and biodiversity (24%) and to stop the expansion of IAS (20%) (Figure 2.4). Some responses (18%) were linked to moral obligation. These include responses such as “*It would be a shame to lose our indigenous species*” and “*I care very much about nature*”. A few volunteers (8%), said they have been doing this for many years and it is very difficult to give up as they can see some progress (long term

commitment): "*Difficult to give it up after 16 years*". Some volunteers (7%) were more interested in socialising, while others (6%) were doing it for aesthetic reasons and to preserve ecosystem services. There were also reasons relating to exercise (5%) and education and awareness (4%) (teaching and learning from others about IAS). Two responses that were difficult to classify into any of the mentioned categories (included in the "other" category) were mostly related to poor implementation by state institutions, for example, "*the managing authority [name withheld] and other state environmental entities, including provincial and local structures, are not doing their job to conserve and protect the Lourens river riverine area"*.

Over a third of volunteers (38%) identified a great sense of achievement and progress (i.e. reduction in IAPS numbers and recovery of indigenous vegetation) as the primary positive experience they get from volunteering. The second most listed positive experience by volunteers was the sense of camaraderie and spending time with like-minded people (20%). For example, one volunteer said, *"We have a lovely friendly group of volunteers; we laugh as we work, it is healthy to be outdoors in the fresh air; we get exercise and all of this leaves us with a really good feeling".* Getting some exercise and being outdoors (27%) was also identified as an important primary benefit by volunteers. Other volunteers (15%) were happy with knowing that they are making a difference by contributing something back to nature, teaching others about IAS and at the same time learning from others. For example, one volunteer said "*The satisfaction of knowing I'm doing something to contribute to benefiting society, as well as nature. Not only for now, but for future generations*", while another said, "*I get a great sense of achievement, teaching the volunteers about invasive and indigenous species and also learning from others."*

On average, respondents volunteered once a week to clear IAPS, depending on their availability and most volunteers (54%) said they would do more if they had the time. Most respondents (54%) indicated that volunteering does not cost them anything financially while others (46%) said they spend money on transport (between their home and the site) and membership fees.

Most volunteers (82%) said that they do detect and report IAS. Most sightings were reported to group leaders (54%) and on iNaturalist (11%). For example, in 2019, the Friends of Tokai discovered *Callitris rhomboidea* (Oyster Bay pine) which is currently

not listed on NEM:BA and this represents the first record of this species in the region. Other volunteers (29%) reported their sightings to different relevant local environmental authorities.

2.3.5. Challenges faced by volunteers

Most respondents (39%) said that they do not face any challenges, while some (23%) mentioned challenges related to time constraints (they feel they do not volunteer enough due to other commitments) (Figure 2.5). Lack of coordination and support from government management institutions and landowners was another important barrier identified by volunteers (13%). For example, one volunteer said, "*Better co-operation between official bodies involved with alien vegetation management and volunteer groups is needed. Though we engage with SANParks and let them know what we are planning, we've had an instance where we spent a day clearing with volunteers, only to find that the site was already earmarked by SANParks and cleared by them the week after. We could have spent our time a lot better!"* Another volunteer said, "*There are just too many invasives and no help from government. From emails it is apparent to me that* [name withheld] *is battling to get CapeNature to send us a team of helpers"*. Physical strength (7%) was ranked as a challenge by a few volunteers. Some volunteers are old and unable to get to some areas, especially those with difficult terrain. Some "other" (5%) responses were also mentioned, for example '*I prefer to operate as an individual - more flexibility for targeted work"*. The challenge of extirpating or even containing the spread of IAPS was ranked the bottom three motivations by volunteers (5%). For example, one volunteer said, "*Sometimes it feels that our small group is never going to be able to succeed, there are just too many invasives and no help from government"*. Lack of funding and shortage or fluctuating support of volunteers was identified as the last two challenges identified by volunteers (4%).

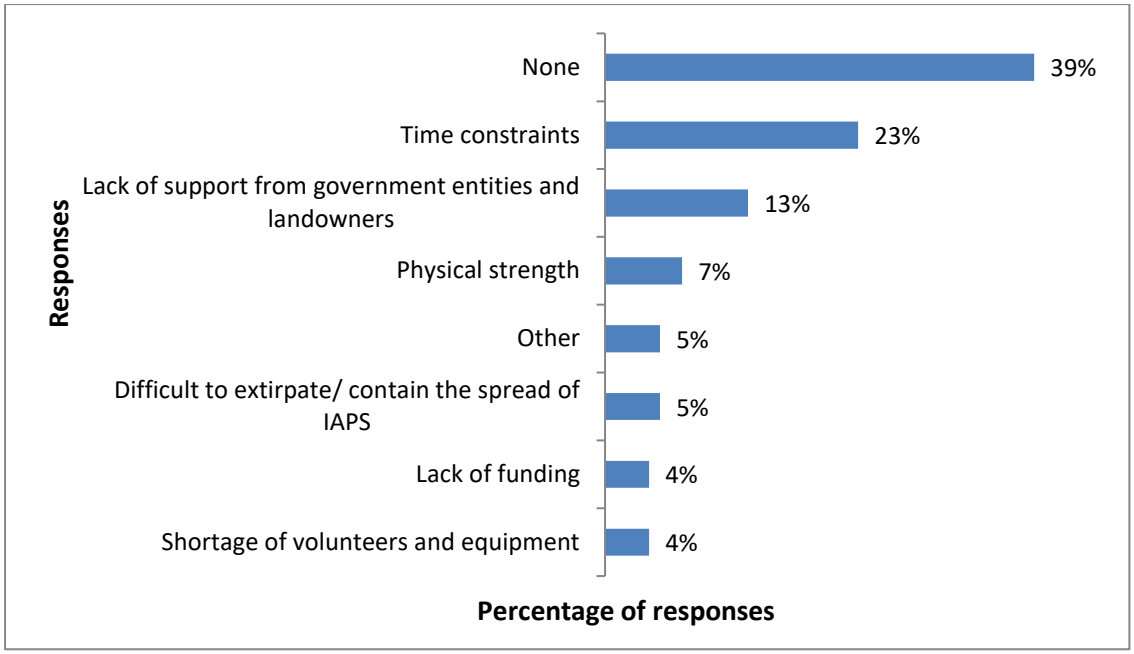

Figure 2.5: Challenges (n = 56) faced by individual volunteers in the management of invasive alien plant management in Western Cape, South Africa.

2.4. Discussion

2.4.1. Identifying and promoting volunteer groups

In this study, we established a list of 52 volunteer groups controlling IAPS in South Africa's Western Cape province (see Appendix 2.4). Half of these groups did not participate in the survey and it is therefore unknown if they currently exist or not, or if our survey simply did not reach these groups. The geographical spread of the groups has a full coverage of the Western Cape, with volunteering groups in fynbos biome being more represented than other biomes (Figure 2.1). Interestingly, this biome corresponds closely with invasion hotspots in South Africa, and is an area with a long history of research and management of biological invasions (Bennett & van Sittert 2019; van Wilgen et al. 2020). Interest in the management of biological invasions and preserving unique and famous indigenous fynbos species is also stronger in this region than elsewhere in the country (Bennett & van Sittert 2019). Volunteer groups also seems to be more closely associated with larger towns and cities in the region. Half of the groups that participate in the survey are estimated to clear approximately 5 300 ha of land annually although if all groups are considered this is more likely to be 10 00 ha. This shows a huge commitment from these volunteer groups in stopping the expansion of IAPS. However, to do this effectively, there needs to be better voluntary engagement between groups, conservation managers and other relevant actors (see Crall et al. 2010). Volunteer initiatives could be co-ordinated and focus on areas that are lightly invaded while the state-run management programmes could focus in highly invaded areas. Formal state-run management programs can also work on projects or species that require chemical control and extensive labour force to remove IAPS, removing this burden from volunteer groups. Assessing the distribution and contributions of volunteer groups and to IAPS management should also be conducted elsewhere in South Africa, and in other countries. Volunteer groups could also engage more with scientists to produce useful research moving forward.

2.4.2. The benefits of volunteer groups and volunteering

Volunteers contribute directly to the control of IAPS thus providing valuable services for the state, landowners and broader society (Pagès et al. 2019). This is evident from our results where we estimated the groups to clear approximately 5 300 ha of

land with estimated labour value of ZAR 5.1 million annually when aligned with formal WfW rates and control programs. Most volunteers were also engaged in detecting and reporting IAPS, which is another valuable contribution for management of biological invasions.

Over and above the actual detection and clearing of IAPS, volunteers can possibly play an important role in promoting awareness and social learning about IAPS among themselves and to the public (Shackleton et al. 2019). This could result in a change in the knowledge and perceptions of the public and volunteers themselves with respect to IAPS (Shackleton et al. 2019), which is important for future management.

At the same time volunteers themselves gain fulfilment and build their social capital by meeting new people and making friends, giving something back to nature by helping to stop the expansion of IAPS (Figure 2.4) (Measham & Barnett 2008; Geoghegan et al. 2016). Many aspects of volunteering, as indicated in this and other studies globally, can contribute to psychological and physical well-being as well (Koss & Kingsley 2010; Molsher & Townstead 2016).

2.4.3. Volunteers' motivations for controlling IAS

Volunteers have a variety of different motivations and it is important for managers implementing IAPS control initiatives to have a sound understanding of volunteers' knowledge, needs, and their motivations (Measham & Barnett 2008; Geoghegan et al. 2016; Ganzevoort et al. 2017). Knowing and addressing volunteers' needs can help with keeping volunteers motivated as well as aid with promoting initiatives and attracting new members. Most volunteers ranked environment-related motivations higher than social related motivations as both their initial and current motivations. This is in accordance with previous studies where the preservation of the natural environment is noted to be the central motivation for volunteers (e.g. Hobbs & White 2012; Ganzevoort et al. 2017; Pagès et al. 2019). It also shows the importance of volunteers and their connection with nature (Ganzevoort et al. 2017). With time, respondents' motivations changed from social reasons to making a contribution towards protecting the natural environment and learning and sharing their knowledge (Figure 2.4). This suggests that volunteering makes people more environmentally aware and proactive (Ganzevoort et al. 2017). Respondents were encouraged by

seeing reduction of IAPS and recovery of indigenous vegetation, as a result this was identified as a primary positive experience they get from volunteering. Our study therefore supports the notion that the recovery of indigenous vegetation is very encouraging, and a key reason for the long-term commitment of volunteers (Pagès et al. 2019), especially for those that have been involved in volunteering work for long periods.

2.4.4. Challenges to volunteering and the way forward

The biggest challenge faced by groups was attracting new volunteers to join the groups (Figure 2.3). This may be linked to the lack of advertising by groups as well as piscicultures making contact which was an issue was reinforced during data collection. Both active and passive recruitment can be used to attract more people to join the groups. The moderate number of responses received (26 out of 52 groups) in this study was because many groups were untraceable due to invalid contact details and/or non-existent group websites and pages on the internet or the fact that some of these groups might no longer exist. This could also mean that the number of extant volunteer groups is lower than 52. According to Ganzevoort et al. (2017), social media and websites of environmental groups are the best platforms for the promotion of nature-based citizen science projects. More volunteer groups should take advantage of the available online and social media platforms to publicise their groups and share the work that they are doing. Volunteers and groups can further use social media to attract more volunteers, aid with co-ordination and increase awareness about IAS (Blood 2018). However, this may potentially require on-going technical and administrative support (Pagès et al. 2019).

Another important challenge to volunteering identified by group leaders and individual volunteer respondents related broadly to co-ordination between and long-term support from government entities, NGO’s and landowners. It is recommended that there is improved communication and coordination between all stakeholders involved in IAPS management and volunteers to improve the work done by volunteer groups and support them (Ellwoodd et al. 2017). According to Dechoum et al. (2019), volunteers can be helpful across multiple scales, but their effort must be combined with other stakeholder’s efforts to ensure long-term success and improved outcomes which would also address another challenge of making little progress

(Figure 3 and 5). The groups indicated that they require support from government entities, landowners and Non-Government Organisations (NGO's) mainly for removal of biomass, manpower to remove bigger plants, tools, training for new members and herbicide. In order for this to happen, we recommend a better engagement between groups and other actors and relevant platforms for this need development.

The coordination of multiple volunteer groups using umbrella partnerships and other actors seems particularly successful, or by appointing a co-ordinator to support groups (Pagès et al. 2019). A co-ordinator should create a database of all groups across the country, respond to their needs and aid with promotion that helps with recruitment of volunteers. Linking volunteer groups and schools could lead to beneficial education and learning opportunities for children and potentially increase interest in volunteering in future generations. The co-ordinator could also assist with planning control activities and the prioritisation of species and areas. For example, the Custodians of Rare and Endangered Species (CREW), where citizens assist with the monitoring of threatened plant species (Araya et al. 2009; Young 2009), and SANParks honorary rangers are both useful models for developing co-ordinated volunteer networks in South Africa. Importantly, the co-ordinator has a role that reduces the bureaucracy while supporting groups, integrating volunteers' work to national and local programmes dealing with biological invasions. Their role could link the groups together and bridge the work done by volunteers with science, policy and the management (Novoa et al., 2018; Abrahams et al., 2019). It could also help to promote these groups and the work they do in the wider community, increasing awareness of IAS. This could also help to monitor and collect data to account for the valuable contributions of volunteers to controlling IAS at regional and national levels (Delaney et al. 2008; Dechoum et al. 2019). The process of coordinating the groups will come with other costs such as technical support and equipment and not just salary for the appointed co-ordinator.

Most volunteer groups work on containing established invasive Australian species (the most widespread invasive taxa in South Africa) with very few groups working on South Africa's emerging IAS or populations with low densities (for example, *Lythrum salicaria, Melaleuca* sp. and *Spartina alterniflora*). This work is invaluable, however, in the long term, early detection and extirpation of IAS is the most cost-effective management option (Rejmánek & Pitcairn 2002; Fitzpatrick et al. 2009). Volunteers

offer an avenue for detecting and containing the spread of IAPS while the populations are still small and localised (e.g. Delaney et al. 2008; Dechoum et al. 2019). It would be beneficial if volunteers can be trained on relevant species identification and effective ways of controlling IAPS to improve their early detection and extirpration efforts (Gallo & Waitt 2011). Volunteers should also be trained about the correct use of herbicides including health and safety measures to avoid possible health effects (Macfarlane et al. 2013). The use of mobile apps such as iNaturalist should also be utilised for species identification and to connect citizens and experts in the field (Silvertown et al. 2015).

2.5. Conclusion

In conclusion, it is evident that volunteers play an important role in IAPS management and are likely to do so into the future. Better co-ordination and engagement between volunteers and mandated authorities on science, policy and management is required to improve the groups and keep volunteers motivated about managing IAPS and could lead to improved.

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2.7. Competing interests

The authors declare that they have no financial or personal relationships which may have inappropriately influenced them in writing this article.

2.8. Authors' contributions

NJ, RTS and JM conceived the study. NJ collected and analysed the data and drafted the article. All authors gave final approval of the version published in Bothalia.

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Appendix 2.1: Questionnaire directed to volunteer group leaders/ co-ordinators. The final questionnaire was piloted prior to the actual survey. The questionnaires were circulated by intermittent posting from August 2019 to May 2020 via emails where users could access a link to the survey and complete it voluntarily

Questionnaire for volunteer group leaders/ co-ordinators to understand the group and what they do

1. In your volunteer group, do you control invasive alien species? [yes] [no]: if yes, give name of the group ……and continue, if no answer Q2 and skip the rest.

2. Does the group only control invasive species [Yes][No] or does it also contract other social or environmental activities. If it conducts other activities what are these?
   ……
   ……
   ……
   ……..
3. How much of your time (as a group) do you spend on invasive species control? [>25%] [25-50%] [50-75%] [75-100%] [100%]

4. When was the volunteer group formed?
   .....
   .....
   .....
5. What was the motivation behind forming the group?
   .....
   .....
   .....
6. Who/which organisations helped to form the group?
   ……
   ……
   ……
   …….
7. Which areas does the group work on and how do they prioritise these areas?
   .....
   .....
   .....

8. Which invasive species does the group target and how do they prioritise the species?
   ……
   ……
   ……
   ……..
9. Is there a particular growth form that you target?
   .....
   .....
   .....
10. How many people are in the group?
    .....
    .....
    .....
11. How often does the group go out to remove invasive species? [once a week][twice a week] [three times a week] [more than three times a week]
    .....
    .....
    .....
12. Which season does the group most go out to control invasive species? [summer][winter][spring][autumn]

13. For how long does the group go out?[<3 hours][five hours][more than five hours]
    .....
    .....
    .....

14. How does the group control (what methods) identified invasive species? [mechanical][chemical control]
    .....
    .....
    .....
15. Please rate the effectiveness of your control methods on a scale of 1 to 5 [1 not effective and 5 highly
    effective.....
    .....
16. How does the group measure success (do they collect data)?
    .....
    .....
    .....
17. Does the group have a budget? [yes] [no]: If yes, how much per year?
    .....
    .....
    .....

18. Who is funding the group?
    .....
    .....
19. What is the budget for?
    .....
    .....
20. Does the group own any assets i.e. chainsaw, GPS's etc.
    ……
    ……
    ……
    ……
21. What are the primary expenses for the group?[transport][tools][herbicides][protective clothing] Other, specify
    .....
    .....
    .....
22. Are these expenses covered by funding or do people cover their own expenses e.g. petrol?
    .....
    .....
23. Do you use herbicide in your group [yes] [no]: If yes, is there someone sponsoring the group with herbicides and how much? If no, how much do you spend on herbicides?
    .....
    .....
24. Is the group/at least one member of the group trained and have PCO licences for herbicide applications?[yes][no]
    ……
    ……
    ……
25. Does the group require support from other conservation sectors such as DEA, SANBI, SANParks and CoCT etc.? [yes] [no]: If so, what?
    ……
    ……
    ……
26. How does the group recruit and advertise for new participants? /what are the criteria for being a member of a hack group?
    .....
    .....
27. What are the group's main challenges?
    .....
    .....
28. Does the group detect and report new invasive species? [yes] [no]: If yes, where do they report these species?

……
……
……

29. Would the group be willing to monitor and collect data on emerging invasive species? [yes] [no]

30. Do you know of any other volunteer groups involved in invasive species management in Western Cape?[yes][no]:if yes, give the group name and contact details for the group
……
……
……

31. Would the group be willing to monitor their control efforts and provide me with data for six months to a year? [yes][no]

Appendix 2.2: Questionnaire directed at individual members of the groups. Questionnaire directed to volunteer group leaders/ co-ordinators. The final questionnaire was piloted prior to the actual survey. The questionnaires were circulated by intermittent posting from August 2019 to May 2020 via emails where users could access a link to the survey and complete it voluntarily

Questionnaire with volunteers "working" in each group controlling invasive species

1. Which Hack group are you involved in?
   .....
   .....
   .....
2. How did you hear about this hack group?[social media][by a friend or colleague][newspaper][a poster/flyer][from another volunteer group] If other, specify
   .....
   .....
   .....
3. How long have you been involved with this group? [< a year] [one year] [two years] [three years] [four years] [five years and more]
   ……
   ……
   ……
   ……
4. What were your reasons for initial engagement in volunteering?
   .....
   .....
   .....
5. What are the current motivations to volunteer and control invasive species?
   .....
   .....
   .....
6. What are the primary positive experiences or benefits you get from volunteering?
   ……
   ……
   ……
   …….
7. How often do you volunteer to control invasive species? [once a week][twice a week][>three times a week]
   ……
   ……
   ……
   ……..

8. Is this the maximum time you are willing to put in for volunteering or would you do more if there were more opportunities?
   .....
   .....
   .....
9. When do you find time to volunteer? [on weekends][mid-week][take annual leave for it][whenever you are available to do it]
   ……
   ……
   ……
   ……
10. Does volunteering cost you anything financially? e.g. membership fees, transport
    .....
    .....
    .....
11. Do you have to drive to sites personally? if yes, how far?
    .....
    .....
    .....
12. Do you detect and report invasive species?[yes][no]: If yes, where do you report these species?.....
    .....
    .....
13. What are your personal barriers to volunteering and negative experiences?
    .....
    .....
    .....
14. Suggestions of changes to improve the group or your personal experience
    ……
    ……
    ……
    ……
15. Do you know of any other volunteer groups involved in invasive species management in Western Cape?[yes][no]:if yes, give the group name and contact details for the group
    ……
    ……
    ……
    ……..

Demographic

1. Name: ……

2. Age …….
3. Location …….
4. Residency time in this location: [Born here] [> 20 yeas] [10-20 years] [5-10 years] [1-5 years] [<1 year]
5. Education level……
6. Current or previous field of work……
7. Contact details:
   ……

Appendix 2.3. Categories for motivations and challenges for groups and for individual members/volunteers of the groups.

Categorising motivations		**Categorising challenges faced**	
Motivation categories for groups	**Motivation categories for volunteers**	**Categories for challenges faced by the groups**	**Categories for challenges faced by volunteers**
To stop the expansion of invasive species	To stop the expansion of invasive species	Attracting additional members	None
Preserve nature/biodiversity	Preserve nature/biodiversity	To extirpate IAPS	Time constraints
To preserve ecosystem services	To preserve ecosystem services	Old volunteers	Lack of support from government entities and landowners
To protect cultural and biodiversity sites	Enjoyment and socialising	Difficult terrain	Difficult to extirpate/contain the spread of IAPS
Moral obligation	Exercise	Sustainability for long term funding	Lack of funding
Aesthetics	Aesthetics	Previous bad clearing	Shortage of volunteers and equipment
	Education and awareness	Lack of support from Government	Other
	Moral obligation	Fluctuating volunteer support	
	Other	Other	

Appendix 2.4: Identified volunteer groups in Western Cape. Groups were identified by doing an online search on Google using the following terms in English, Isixhosa and in Afrikaans (hack groups, volunteer groups, invasive alien species control, and friends' groups) in April 2019. Snowball sampling was also used in search of volunteer groups. Groups that participated in the survey are indicated by the date of their establishment, group size or both.

	Hack group name	**Location**	**Established**	**Group size (individual members per group)**
1.	Friends of Helderberg Nature Reserve	Somerset West	Before 2006	20
2.	Friends of Stellenbosch mountains	Stellenbosch		
3.	Friends of Blaauberg Conservation Area	Blaauberg	2014	5
4.	Friends of Rondebosch Common	Rondebosch		9
5.	Friends of Bot river estuary	Kleinmond		5
6.	Friends of Kenilworth Conservation Area	Kenilworth		
7.	Friends of the Liesbeek River	Mowbray	1994	8
8.	Friends of the Prince Alfred's Pass	De Vlugt	2014	4
9.	Fiends of Tokai Park (light hack group)	Tokai		5
10.	Friends of Tokai Park (Chainsaw gang)	Tokai		10
11.	Friends of Tokai Park (Arboretum clearing)	Tokai	2015	5
12.	Friends of Tygerberg	Tygerberg		
13.	Friends of Bracken Nature Reserve	Brackenfell		
14.	Friends of Pledge Nature Reserve in Knysna (Weeding Wednesday)	Knysna	2017	10
15	Friends of Lions Head & Signal Hill	Table Mountain National Park	23 years ago (1996)	5
16.	Friends of & Signal Hill (FLASH)	Table Mountain National Park	2019	5

17.	Friends of Zeekoevlei and Rondevlei	Grassy Park Retreat and Muizenbuerg		
18.	Mountain club of South Africa	Cape Peninsula		
19.	Scouts SA	Wellington		
20.	Greyton Conservation Society	Greyton	1980	8
21.	Nirvana fynbos reserve	West Coast		
22.	Pringle Bay Hack Group	Pringle Bay		
23.	Betty's Bay Hack Group	Betty’s Bay		
24.	Hermanus hack group	Hermanus	2008	20
25.	Friends of Silvermine	Silvermine Reserve		8
26.	Riverine Rovers	Fish Hoek		
27.	Noordhoek Wetlands	Noordhoek		
28.	Fish Hoek and Glencairn group alien invasive eradication group	Fish Hoek and Glencairn	1980	8
29.	Great Braak River Conservancy	Great Braak	1997	20
30.	Napier Hack Group (Klippedrift Alien Clearing	Napier	2018	9
31.	SANParks Honorary Rangers	Table Mountain Natioanl Park		5
32.	Vineyard Hotel group	Silvermine Reserve	2006	25
33	The Botanical society, Kirstenbosch Branch	Kirstenbosch		
34.	Southern Overberg Botsoc	Overberg Region		
35.	Zandvlei estuary nature reserve	Zandvlei		
36.	Cape West Coast Biosphere	West Coast		
37.	Wolfkloof Boerdery	Swellendam		
38.	Sonderend Alien Clearing	Garden route area		
39.	Precious tree project	Knysna/George area		

40.	Plet Botanical group	Plettenberg Bay		
41.	The Crags	Kurland		
42.	Bain's kloof and Hex River Mountains	Wellington		
43.	Green prop			
44.	Friends of Vlakenberg	Observatory		
45.	Kommetjie Residents' and Ratepayers' Association	Kommetjie	1990	50
46.	Lourens River Conservation Society	Somerset West		
47.	Montagu	Montagu		
48.	Elsies Peak	Elsies Peak Nature Reserve	Early 1980's	4
49.	Botfriends	Fisherhaven	About 12 years ago	6
50	Klippedrift Alien Clearing	Riebeek Wes	2018	9
51.	Knysna Alien Busters	Knysna	2018	10
52.	Ladismith Hackers	Ladismith	2018	3

Appendix 2.5: List of species that are being controlled by volunteer groups who participated in the survey in Western Cape, South Africa

No.	Species name	Common name	NEM:BA Category
1.	*Acacia cyclops*	Red eye/ Rooikrans	1b
2.	*Acacia longifolia*	Golden wattle	1b
3.	*Acacia mearnsii*	Black wattle	2 Exempted for an existing plantation.
4.	*Acacia melanoxylon*	Australian blackwood	2 Exempted for an existing plantation.
5.	*Acacia saligna*	Port Jackson	1b
6.	*Ageratina adenophora*	Crofton weed	1b
7.	*Anredera cordifolia*	Madeira vine	1b
8.	*Canna indica*	Indian shot	1b Sterile cultivars or hybrids are not listed.
9.	*Casuarina cunninghamiana*	Beefwood	2 1b within 100 metres of riparian areas or untransformed land
10.	*Casuarina equisetifolia*	Horsetail tree	2
11.	*Cortaderia selloana*	Pampas grass	1b Sterile cultivars or hybrids are not listed.
12.	*Echium plantagineum*	Patterson's curse	1b
13.	*Eucalyptus globulus*	Blue gum	Not listed on NEM:BA
14.	*Greviella striata*	Beef wood	3
15.	*Hakea gibbosa*	Rock hakea	1b
16.	*Hakea sericea*	Silky hakea	1b
17.	*Hedera helix*	English ivy	3

			Sterile cultivars or hybrids are not listed.
18.	*Hedychium coronarium*	White ginger lily	1b
19.	*Lantana camara*	Lantana	1b
20.	*Leptospermum laevigatum*	Australian myrtle	1b
21.	*Lythrum salicaria*	Purple loosestrife	1a
22.	*Melaleuca spp*	Bottlebrushes	Various
23.	*Myriophyllum aquaticum*	Parrot's feather	1b
24.	*Opuntia spp.*	Preaky pears	Various
25.	*Paraserianthes lophantha*	Stink bean	1b
26.	*Pennisetum clandestinum*	Kikuyu grass	1b in Protected Areas and wetlands in which it does not already occur. b. Not listed elsewhere
27.	*Phytolacca americana*	American pokeweed	1b
28.	*Phytolacca octandra*	Forest inkberry	1b
29.	*Pinus pinaster*	Cluster pine	1b
30.	*Pinus pinaster*	Cluster pine	2 for plantations and wind-rows. 1b elsewhere.
31.	*Pittosporum undulatum*	Australian cheesewood, Sweet pittosporum	1b
32.	*Robinia pseudoacacia*	Black locust	1b
33.	*Schinus terebinthifolius*	Brazilian pepper tree	1b in Eastern Cape, KwaZulu-Natal, Limpopo and Mpumalanga. 3 in Free State, Gauteng, North-West, Northern Cape and

			Western Cape.
34.	*Sesbania punicea*	Red sesbania	1b
35.	*Solanum pseudocapsicum*	Jerusalem cherrie	1b
36.	*Solanum mauritianum*	Bugweed	1b
37.	*Spartina alterniflora*	Smooth cordgrass	1a
38.	*Spartium junceum*	Spanish broom	1b in Eastern Cape and Western Cape. 3 in Free State, Gauteng, KwaZulu-Natal, Limpopo, Mpumalanga. North-West and Northern Cape.
39.	*Tradescantia fluminensis*	Wandering Jew	1b
40.	*Vichia benghalensis*	Purple vetch	Not listed on NEM:BA

Chapter 3: Public awareness and perceptions of invasive alien species in small towns of South Africa's Western Cape province

Declaration: This chapter is intended for submission to the journal Koedoe

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All authors **NJ, JM and RTS** were involved in the planning and design of the study. **NJ** led the development of the manuscript, conducted fieldwork, data capturing and analysis and drafting of the manuscript with input from all other authors **RTS** and **JM. RTS and JM**: Assisted with data analysis, commented on the manuscript and improved the writing.

Abstract

Invasive alien species (IAS) are a growing threat globally and cause a variety of ecological, economic and social impacts. People play a key role in introducing IAS and facilitating their spread but also for implementing and supporting management, therefore understanding local awareness and perceptions are crucial to guide management and policy. In this study, we administered questionnaires to members of the public in eight small towns along the Berg River Catchment in the Western Cape, South Africa, aiming to assess: 1) awareness of IAS by the general public, 2) local perceptions of the impacts associated with IAS, 3) if awareness of IAS is correlated with demographic covariates and IAS density and 4) people's willingness to detect, report and support IAS management. Overall, 262 respondents participated in the survey. Most respondents 65% (n = 171) explicitly did not know the meaning of IAS and 10% (n = 25) were unsure. Many respondents also perceived IAS as beneficial. Using a logistic regression, we found that the minority of respondents who were familiar with the concept of IAS were most often well-educated men living in areas where IAS density is higher. There was a small number 4% (n = 10) of respondents currently detecting and reporting IAS on citizen science platforms or as part of their job. Awareness of IAS was found to be a pre-requisite for citizens engaging in reporting and removing IAS. We conclude that the citizens remain largely unaware of IAS and their impacts, in the Western Cape. However, once informed, some respondents 53% (n = 139) showed interest and willingness to learn more about IAS and their impacts regardless of their current level of awareness. It is therefore crucial that more is done to raise awareness and build support and engagement in management in the region and the country as a whole.

Key words: Beliefs, Biological Invasions, Environmental Education, Perceptions, Management, Stakeholders

3.1. Introduction

Invasive alien species (IAS) are a major growing threat and cause different ecological, economic and social impacts around the world (Pimentel et al. 2001; Jeschke et al. 2014; Seebens et al. 2017). The increased movement of people and goods globally is accelerating the problem (Seebens et al. 2017). Due to the relationship between people and the their contribution in introducing and spreading IAS, there is a need to involve and engage the public in their management (Bremner & Park 2007; Verbrugge et al. 2013; Adriaens et al. 2015; Novoa et al. 2018; Shackleton et al. 2019). Many studies have assessed awareness, perceptions and support for IAS management focusing on stakeholders that are known to be already impacted by IAS (García-Llorente et al. 2008; Andreu et al. 2009; Shackleton et al. 2015; Shackleton et al. 2019; Vaz et al. 2020; Bravo-Vargas et al. 2020) with little attention given to the general public that is not yet impacted. As a result, a large group of the public is still unaware of IAS, their negative impacts and the role they can potentially play in preventing their spread or in efforts to control them (Byrne et al. 2020).

Several actions are considered in the prevention and management of biological invasions, most of which rely on public awareness (Marchante & Marchante 2016; Novoa et al. 2018). For example, people transport IAS to new areas and therefore serve as primary pathways , so educating citizens on the issue could help prevent IAS spread and promote control while at the same time changing their perceptions, behaviours and attitudes about IAS which may increase overall support for managing them (García-Llorente et al. 2008; Reis et al. 2012; Cole et al. 2016 and 2019; Shackleton et al. 2020). The UK example of awareness raising and behaviour change is the “check, clean dry” campaign for managing the spread of aquatic IAS (Shannon et al. 2018). The public can also play an important role in broad scale monitoring programmes which can aid management authorities (Fitzpatrick et al. 2009). If IAS are perceived as beneficial, the public can also obstruct their management interventions. Therefore, understanding people’s awareness and perceptions about IAS can be useful to guide future awareness activities, management and research around IAS. This can also help prevent potential disagreements on the control of conflicting IAS (Shackleton et al. 2018).

Despite the major impacts of biological invasions in South Africa (Le Maitre et al. 2020; Zengeya et al. 2020), high profile research and management in the country (van Wilgen et al. 2020), and numerous and diverse attempts at raising public awareness of IAS (Murray 2005; Byrne et al. 2020), it is suggested that citizens have low awareness of IAS especially in urban areas (Shackleton & Shackleton 2016; Novoa et al. 2017; Potgieter et al. 2019). This low awareness could be due to many reasons such as urban residence facing limited exposure to IAS and their impacts (Colton & Alpert 1998; Shackleton & Shackleton 2016; Sharp et al. 2017), or low literacy and education levels in the country (both in urban and rural areas) due to the legacy of Apartheid (Potgieter et al. 2019). This limited awareness may hinder IAS control resulting in their increased spread and associated negative impacts as well as potentially lead to greater conflicts over management (Kapler et al. 2012; Zengeya et al. 2017). According to Hosking et al. (2004), increased awareness raising, and detection efforts should initially target populated areas because most plants first naturalise in urban areas due to the high concentrations of gardens where ornamental alien species are introduced (McLean et al. 2018). As a result, gardens of small towns in South Africa are launching sites for many alien plants, many of which are already invasive or have a potential to become invasive (McLean et al. 2018). For example, McLean et al. 2018, recorded two hundred and ninety-eight alien plant species that were either naturalised or invasive in the Berg River catchment. In this study, we administered questionnaires to members of the public in eight small towns along the Berg River Catchment in the Western Cape, South Africa, aiming to assess: 1) awareness of IAS by the general public, 2) local perceptions of the impacts associated with IAS, 3) if awareness of invasive species is correlated with demographic covariates and species density, and, 4) people's willingness to detect, report and support IAS management. In this study we consider detection as part of IAS management.

3.2. Methods

3.2.1. Study site

We selected the Berg River Catchment in South Africa's Western Cape Province as a study site (Figure 3.1). The area supports mainly dryland agriculture (primarily wheat). Natural areas are dominated by fynbos shrublands with high species diversity. The Berg River Catchment has 28 towns that differ in sizes with alien plant occurrence data (McLean et al. 2017). There is substantial interest in environmental issues in the area, including the management of IAS (Ruwanza et al. 2013; Fill et al. 2017) as this is a key water catchment area for agriculture and the City of Cape Town. The Berg River Catchment includes towns from five different local municipalities namely, Drakenstain, Stellenbosch, Swartland, Berg River and Witzenberg. Urban areas range in population size from 330 to just over 100 000 with population densities ranging from 10 to 5 000 people/km^2. For this study we focused on eight of the small towns with differing population densities and IAS threat levels (Figure 3.1) (McLean et al. 2017).

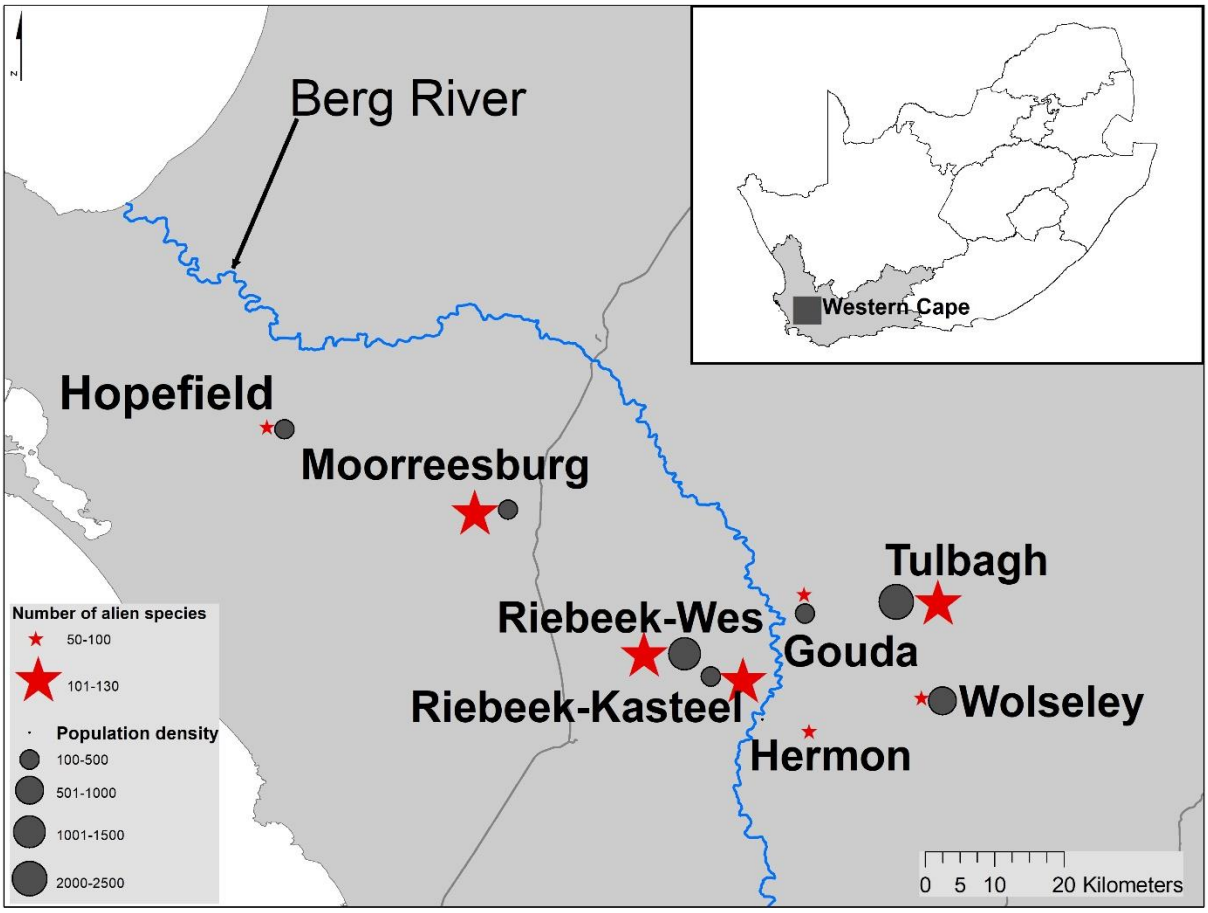

Figure 3.1. Location of the Berg River catchment in South Africa's Western Cape Province and eight small towns selected for this study with population densities and the number of alien species estimated to be in each town. Population density and number of alien species was taken from (McLean et al. 2017).

3.2.2. Questionnaires/ Face-to-face surveys

Questionnaires were conducted with 30-40 randomly/ haphazardly selected citizens (>18 years of age) willing to participate in each of the eight towns except for Hopefield where only 10 questionnaires were filled. Citizens were directly approached and asked if they were willing to participate in the survey. Questionnaires consisted of five sections relating to: (1) respondents general awareness about IAS, (2) their ability to identify species that were illustrated with pictures, (3) their perceptions on the benefits and negative impacts of these target species and IAS in general, (4) their attitudes towards the detection and management of IAS, and, (5) socio-demographic information which included information such as age, gender, level of education and length or residence time in the town (see Appendix 3.1).

The questionnaire contained both closed-ended and open-ended questions with an average completion time of 15 min. We conducted face-to face surveys between February 2018 and November 2019, in some cases with a translator. In each town, we balanced our sampling by visits to both administrative town centres and townships. In South Africa, a township is a residential area that was previously designated for only black residents during the Apartheid regime. Initial questionnaires were developed by the authors. A pilot version was tested but not included in the results or analysis.

3.2.3. Species selected

To better understand citizens' awareness on IAS, we selected three invasive plant species, two invasive animal species and one indigenous species as a control and asked citizens (>18 years of age) if they could identify each species from a series of photographs. Chosen species were noted as abundant within the studied area (McLean et al. 2017). Species selected represented different growth forms (e.g. tree, grass, herbaceous and animals). The pictures for each IAS were embedded in the questionnaire and another separate document with higher quality pictures were shown to participants. IAS selected included: *Metrocideros excelsa* (New Zealand Christmas tree), *Genista monspessulana* (French Broom), *Pennisetum setaceum* (Fountain Grass), *Harmonia axyridis* (Asian Ladybird) and *Sus scrofa* (Feral Pig). The species selected as indigenous to South Africa was *Aloe arborescens* (Krantz Aloe). A short description for the selected species is provided in Appendix 3. 2.

3.2.4. Analysis

Statistical analyses of the survey response data were made in statistical package for the social sciences (SPSS version 26). In addition to descriptive statistics, we used Pearson's Chi squared tests to analyse associations between categorical variables and respondents' answers (i.e. to test if factors like gender or education level were associated to awareness of IAS). In all cases, $p < 0.05$ was taken as a minimum value for statistical significance.

We also used R (v3.6.3) to run generalised linear models (logistic regression) to assess if awareness of IAS is correlated with invasion density (how much people know in relation to the number of IAS in their towns) and demographic variables.

Thus, the dependent variable (categorical) was the binary response from respondents stating whether or not they knew the meaning of IAS and the independent variables were gender (categorical), age (categorical), education level (categorical) and alien density (continuous). We categorised these responses as binary variables. For the analysis, respondents that were unsure if they knew what an IAS is or not were included in the “no response” category. If they were not sure but defined the term IAS correctly, they were removed from unsure/no to the yes response. Location was not used as alien density was coded through location information in each town (i.e. they co-vary) and collinearity of variables was tested.

Further, we assessed if recognition of the individual plants (*Metrocideros excelsa* and *Pennisetum setaceum*) is correlated with species density in different towns. In this regard, the recognition of the species (categorical) was used as dependent variable and species density as independent variable (continuous).

Species density data (coded as a continuous variable per town) were taken from McLean (2017). Species density data was not available for some of the alien plant species i.e. *Genista monspessuala*, invasive animals (*Harmonia axyridis* and *Sus scrofa)* or indigenous *Aloe arborescens*. Candidate linear models were built from each of the explanatory variables, which combined if they demonstrated significant interactions. An additional null model was included with candidates’ models for selection. To select the best model, we used Akaike’s information criterion (AIC) (Akaike 1973) to compare candidate models (see Appendix 3.3: Table 1 & 2). Models within 2 dAIC were considered equal.

3.2.5. Ethics

Ethical clearance to conduct the research was obtained from the REC: Humanities at Stellenbosch University - Project number: 9578. All ethical standards were adhered to. An informed consent was obtained from all participants and anonymity was assured.

3.3. Results

3.3.1. Demographic statistics

In total, 262 citizens from eight towns along the Berg River Catchment participated in the survey. Overall, there was a higher proportion of woman respondents (n = 153) than men (n = 109), but disproportionately allocated among towns (Appendix 3.4). Women predominated in five towns (Gouda, Hermon, Morreesburg, Riebeek Kasteel, Riebeek West and Hopefield) while men predominated in the other two towns (Tulbagh and Wolseley). Respondents were primarily middle-aged, with low formal education levels (i.e. never finished school), and long-time residents of the different towns. The majority of respondents (48%) were between the age of 18-29, followed by middle aged (30-49) respondents 32% and older respondents (20%) aged between 50-80.

3.3.2. Citizens' awareness and perception of the impacts of IAS

3.3.2.1 Awareness of the term invasive alien species

Firstly, we asked all respondents "*do you know what IAS is [yes] [no] [unsure]: if yes, describe what IAS is*". In response to this question, more than half of the respondents 65% (n = 171) said they did not know what an IAS is and 10% (n = 25) were unsure. We classified this group as those that are "unaware" of what an IAS is (unaware group). The other group of respondents 25% (n = 66) said they knew what an IAS is. We classified this "aware" group as people that professed familiarity with the term IAS. Out of the 25% (n = 66) of respondents who said they knew what IAS are, only (n = 47) were able to give correct definition. Those that were able to give correct definition were classified as "fully aware group". A notable number of respondents defined ''IAS'' along the lines of: plants that do not belong in our country which may cause harm to the environment and human life and use up a lot of water. This closely follows the narrative provided by the Working for Water program. The results from the logistic regression show that the meaning of IAS was better understood by men with higher education levels in towns where IAS density is higher (Table 3.1; Figure 3.2), a significant model explaining 33.12% of variance in the data ($P < 0.00001$). The correlation between knowledge of IAS and each demographic variable was significant except for age (Appendix 3.5).

We also asked all groups of respondents (aware, unaware and fully aware group) to answer the question: "*Do you know what is an indigenous species*?, similarly, most respondents 73% (n = 190) did not know the term, while others were unsure 6% (n =

17). Only 21% (n = 55) of respondents said they knew what an indigenous species is with 6% (n = 3) giving an incorrect definition. The majority of respondents (n = 38 out of 47) from the fully aware group said they knew what indigenous species are (with n = 32 of these respondents giving a correct definition). Only (n = 7) of respondents from this form the fully aware group did not know and (n = 2) respondents were unsure of the term indigenous species.

We further asked all groups of respondents to rate their own level of awareness of IAS "*How would you categorise your knowledge of invasive and indigenous flora? [very good] [good] [average] [very poor] [I don't know].* The fully aware group categorised their own level of awareness of IAS as very poor (n = 3), poor (n = 12), average (n = 23), good (n = 5) and very good (n = 2) and (n = 2) of the respondents did not know.

3.3.2.2. Awareness of invasive alien species in the region

All groups of respondents were asked if they could name any IAS "*Can you name any IAS occurring in your town or in South Africa"? [yes] [no] [unsure], if yes, list the ones they mention*. Those who could define IAS were more likely to correctly name one (Chi square = 199.562, df = 57, p = 0.001). Seventeen species were specifically mentioned by respondents as IAS occurring in their small towns and in South Africa of which one (*Aloe arborescens*) is indigenous to South Africa, The most mentioned IAS were *Acacia saligna* (Port Jackson) (n = 24), *Eucalyptus spp* (Blue Gum) (n = 14), *Acacia mearnsii* (Black Wattle) (n = 13), and to a lesser extent *Eucalyptus grandis* (n = 3) and *Acacia cyclops* (Rooikrans) (n = 3). The species that were mentioned by two respondents included *Lantana camara* (Lantana), *Melaleuca spp* (Bottle Brush), *Pinus* species and *Quercus robur* (Oak tree). Species only mentioned by one respondent were *Parthenium hysterophorus* (Parthenium/Famin Weed), *Acacia longifolia* (Long Leaf Wattle), *Nerium oleander* (Oleander), *Jacaranda mimosifolia* (Blue Jacaranda), *Greviella striata* (Beefwood), *Gilia tricolor* (Birds' eye) and *Schinus mole* (Pepper Tree).

Table 3.1. Candidate models explaining demographic covariates and species density. The models are ordered by their relative AIC and the best selected one is highlighted in bold.

Model Number	Model description	Log likelihoods	Number of parameters	Delta.AICs	Wi
1	**What_is_invasive ~ Gender + Education + alien_density**	**-82.4329**	**9**	**0**	**0.996473**
2	What_is_invasive ~ 1 (Null)	-123.262	1	65.65845	5.51E-15
3	What_is_invasive ~ Gender + Residency + Age + Education + alien_density	-80.1313	19	15.39675	0.000452

*Location was not used in combined models

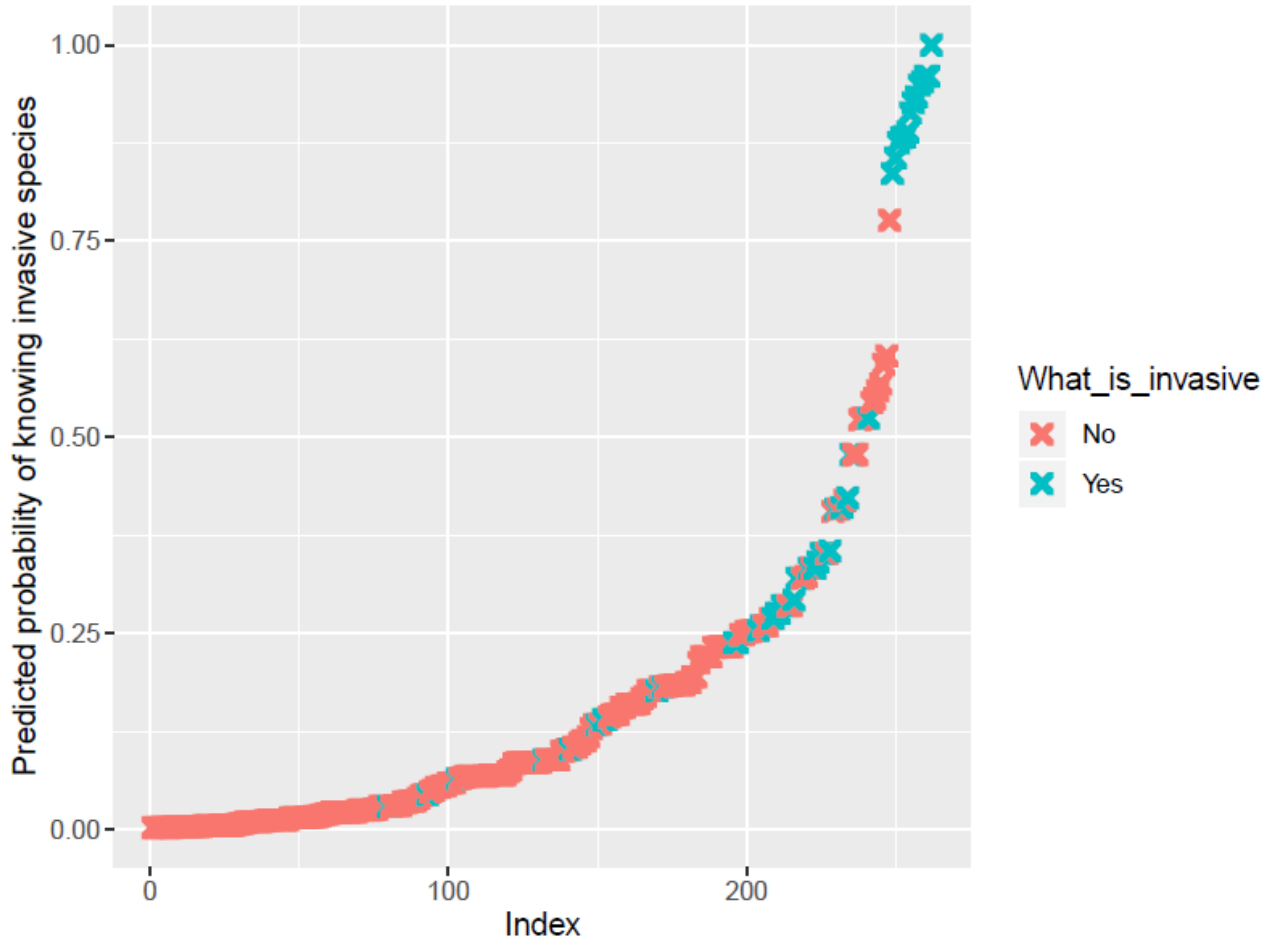

Figure 3.2. The relationship between awareness of IAS and invasive plant density. The graph shows that awareness on IAS is linked to invasive plant density. The best candidate model selected had explanatory variables of higher education, higher alien density and gender (men) to explain awareness of the term IAS by citizens.

3.3.2.3. Awareness and recognition of the target selected IAS and whether they are invasive/ indigenous

We asked all groups of respondents if they recognise the species in question (through photographs) and if they can identify them. The most correctly identified IAS were animals: *Harmonia axyridis* 47% (n = 124) and *Sus scrofa* 36% (n = 94) (Figure 3). This was followed by respondents (n = 16) who said they can identify *Genista monspessulana* 2% (n = 20) with only six positive identifications. *Pennisetum setaceum* was recognised by 17% (n = 45) and positively identified by two respondents. *Pennisetum setaceum* was misidentified for *Cortaderia selloana* (Pampas Grass) and *Alopecurus* species (Foxtail Grass) by some of the respondents. None of the respondents could positively identify *Metrocideros excelsa*

even though 15% (n = 38) respondents initially said they could recognise the species, which was mostly misidentified for a *Melaleuca* species (Bottlebrushes). The correct species identifications were irrespective of whether respondents knew if the plants or animals in question were indigenous or invasive. Knowledge of whether or not the species under question were invasive or indigenous varied between species (Figure 3.4). Interestingly, the most recognised and correctly identified IAS were the animals: *Harmonia axyridis* and *Sus scrofa*. However, most respondents categorised them as indigenous. Invasive plant species were not commonly recognised by respondents with *Genista monspessulana* being the most recognised, followed by *Pennisetum setaceum*, and *Metrocideros excelsa* being the least recognised species. Just more than half (n = 132) (Figure 3.4) of respondents did not know the status (whether they are invasive/indigenous) of the selected target species.

Most respondents from all groups were able to recognise and identify *Aloe arborescens* correctly 58% (n = 151) and some respondents (n = 89) knew that the species is indigenous. Only 19 respondents classified it as IAS, while other respondents (n = 43) said they did not know whether the species is invasive or indigenous even though they knew the plant.

The best linear model explaining recognition of two invasive plant species (*Metrocideros excela* and *Pennisetum setaceum*) included the relative higher density of these species in different towns in both cases. Specifically, the best model explaining identification of *Metrocideros excelsa* by citizens included higher density of *M. excelsa* and higher education level. This is equivalent to 10.46% of the variation in the data and it is significant (P = 0.0019). The best model explaining recognition of *Pennisetum setaceum*, included higher education level, *P. setaceum* higher density and younger respondents (age 20-29). This is equivalent to 16.49% of the variation in the data and is significant (P = 0.00016). See Appendix 3.3: Tables 1&2 for all candidate models.

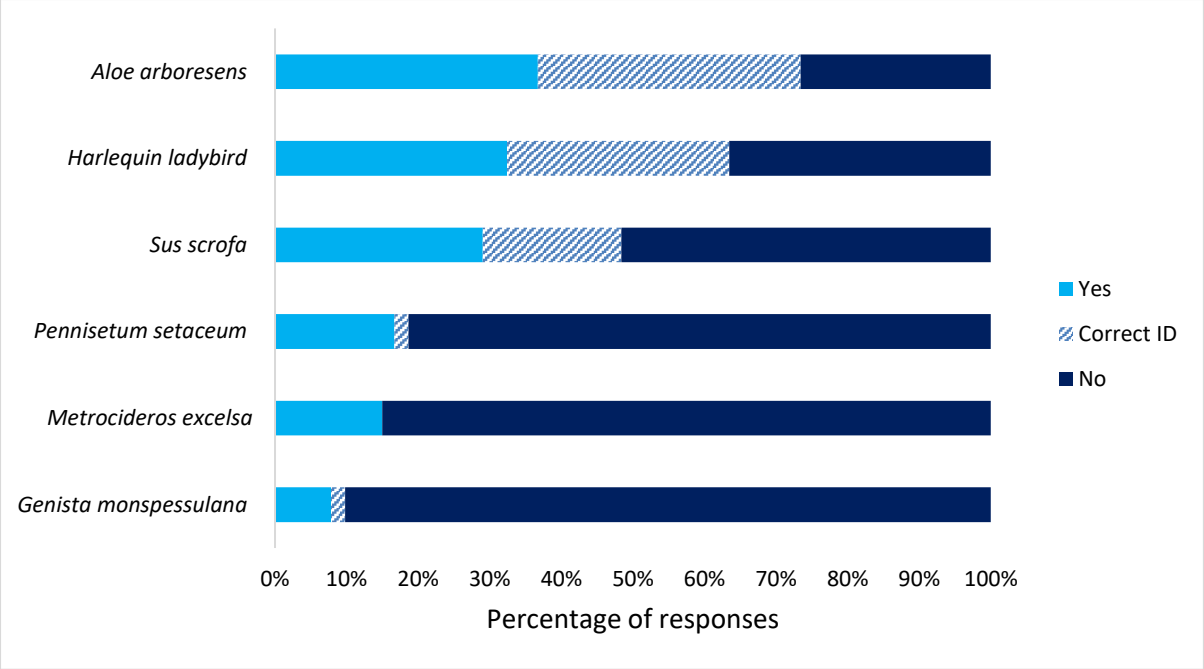

Figure 3.3. Figure 3.3. Percentage of questionnaire participants that could recognise the target species *(Aloe arborescens, Genista monspessulana, Harmonia axyridis, Metrocideros excelsa*, *Pennisetum setaceum* and *Sus crofa*). Categorised from very good to very bad recognition: ( ) respondents that could recognise the species but not name it, ( ) those that could recognised and correctly name/identified the species and ( ) those that did not recognise it. *Aloe arborescens* is indigenous to South Africa and the rest of the species are invasive.

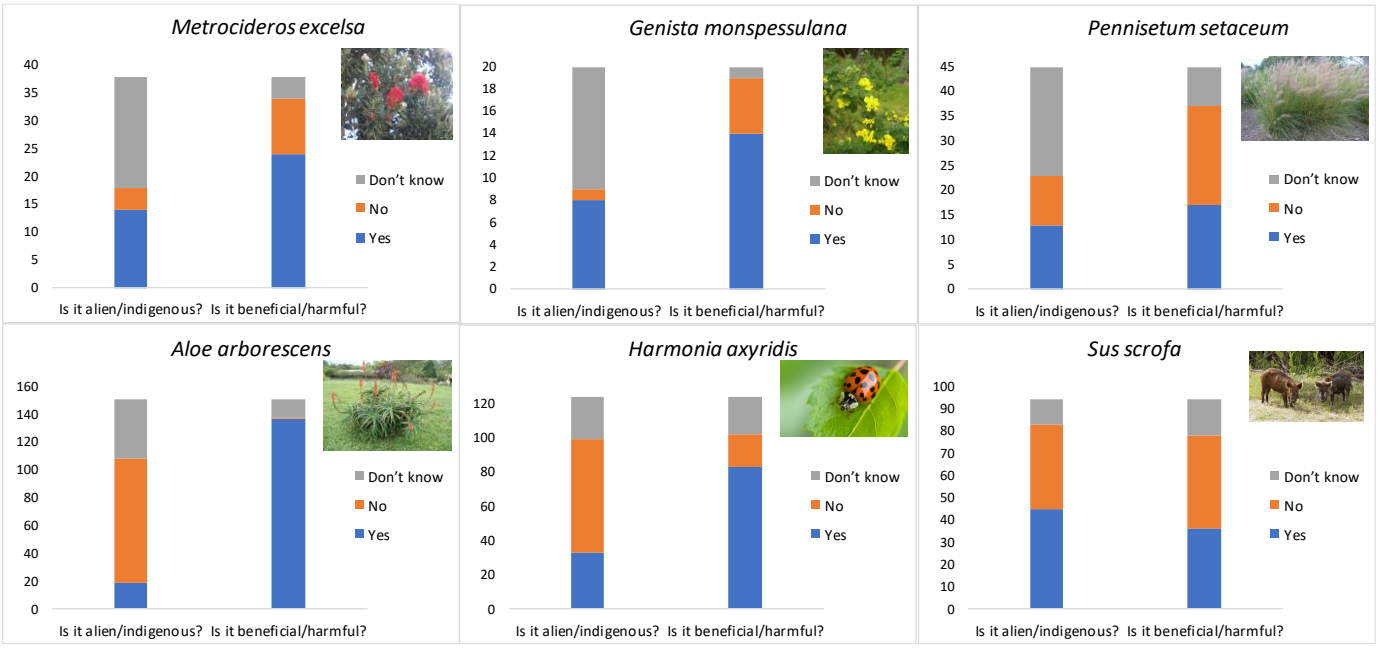

Figure 3.4. Number of respondents who knew the species in question were IAS or indigenous and the number who perceived each as beneficial or harmful. *Aloe arborescens* is indigenous to South Africa and the rest of the species are invasive species found in the study region

3.3.3. Citizens' willingness to detect, report and support IAS management

3.3.3.1. Willingness to detect and report IAS

Out of all three groups of respondents, there were a small number 4% (n = 10) of respondents currently detecting and reporting IAS around 1-5 times a year. These respondents reported their sightings mainly to project managers at CapeNature and Working for Water and seven (70%) of the ten respondents currently also worked for these organisations.

We asked all respondents if they would like to learn about detecting and reporting IAS, *"would you be interested in learning how to report the localities of IAS?"* Some respondents 56% (n = 148) did not show any interest in learning about detecting and reporting IAS, whereas 44% (n = 114) showed interest regardless of whether they aware or unaware what an IAS was before the survey. Generally, citizens showed interest to broaden their knowledge around the issue of IAS. For example, one respondent said, "*…maybe these species can be harmful, and I need to know where to report them and find help"* while another respondent said, *"I want to report all the Port Jackson on my neighbour's property".* Other reasons for wanting to learn were associated with negative impacts of IAS. For example, *"…it's good to know more about invasive species and identify them because they take up a lot of water".* The reasons for not wanting to learn more about detecting and reporting IAS varied amongst respondents. For example, one respondent said, "*Leave plants alone, they give us oxygen".* Other respondents said they do not have time or were too old to learn about them "*I am too old now to learn about these things".*

3.3.3.2. Willingness to support IAS management

We asked all respondents if they would be willing to support IAS management "*Would you like to see IAS removed and densities decreased in your area"? [yes] [no] [unsure] [I don't care].* In response to this question, 44% (n = 116) were unsure if management of IAS was necessary or not. Of the (n = 116) respondents that were

unsure if management of IAS was necessary or not, only eight were from the aware group and four were from the fully aware group. For example, one respondent said, "*If they are a danger to the environment and society they can be removed*". Other respondents from all three groups 21% (n = 56) were completely against the removal of IAS. Of the (n = 56) respondents, five were from the aware group and nine were from the fully aware group. Some respondents said "*Plants are good for the environment and they bring more oxygen*" and "…*they have to be replaced with other trees because they create oxygen*" while other reasons were associated with aesthetic reasons and benefits of IAS for example one respondents said "*Its nature, plants are beautiful, why remove them*?" Another respondent mentioned the benefit of *Acacia saligna* (Port Jackson) and said, "*Port Jackson stops hay fever*".

Conversely, 28% (n = 73) of respondents from all groups agreed that management of IAS is necessary due to negative impacts that these species cause such as increased water uptake. In this case, 40 of the 73 respondents that agreed that management of IAS is necessary were from the aware and fully aware group (32 respondents from the fully aware group and 8 respondents from the aware group). Some respondents did not care 7% (n = 17) and only two' of these respondents were from the aware group and two from the fully aware group, for example, one respondent said, "*It does not affect me, and I don't have knowledge of IAS causing trouble in our town at the moment*". Respondents who had prior experience and awareness of IAS supported their control more than those who did not have the prior awareness (Chi square = 78.873 df = 8, $P < 0.05$).

Participants from all groups were asked if they have ever volunteered to manage IAS and if they would like to join volunteer groups "*Have you ever volunteered to manage IAS? [yes] [no] and would you like to join groups that manage/control IAS in your area"? [yes] [no]*. Voluntary participation in IAS management was low among all groups of respondents. Most respondents 89% (n = 234) (n = 43 from the aware group and fully aware group) said they have never removed IAS while few respondents 11% (n = 28) have been involved in IAS management programmes before, whether they did it in their homes or at work.

Only 16 respondents (of which 3 were from the aware group and 8 from the fully aware group) have been associated with volunteer groups managing IAS before.

Only 26 respondents from all three groups said they would be happy to join local volunteer groups that manage IAS and five of these 26 respondents were from the aware group and 14 from the fully aware group.

3.3.3.3. Willingness to learn more about the general issue of IAS

To assess if respondents from all three groups were willing to learn more about IAS or not, we asked them: "*Would you like to learn more about Invasive species and their impacts"? [yes) [no] [unsure].* Just over half of respondents 53% (n = 139) (n = 87 from unaware group and n = 52 from aware and fully aware group) were interested and willing to learn more about IAS and their impacts, whereas 16% (n = 43) said they were unsure (n = 39 from unaware group and n = 4 from the aware and fully aware group). A quarter of respondents either said they were not interested 31% (n = 80) (n = 70 from unaware group and n = 10 from aware and fully aware group) in learning more. No reasons were given by respondents as to why they said that they did not want to learn more about IAS. We further asked the participants from all groups if they would like to receive information on IAS and most respondents said yes 55% (n = 145). Respondents who had previously heard of IAS and their impacts were more likely to want to learn more about IAS than those who had little or no knowledge of IAS (Chi square = 34.193 df = 6, $P < 0.005$).

We asked all groups of respondents if they have ever come across with information on IAS "*Have you ever read any articles with information about invasive alien species? [yes] [no], if yes, where?"* Most respondents 86% (n = 225) said they have never been exposed to information on IAS. Other respondents 3% (n = 9) mentioned they got information and learned about IAS though their jobs in conservation, forestry, education, local government institutions. Local newspapers 3% (n = 7) and magazines 3% (n = 7) were also mentioned as important medium of communication where a few respondents had learned about IAS. Other people said they learnt about this IAS at school 2% (n = 6) and 1% (n = 2) of respondents said they learned about IAS on TV. A few respondents mentioned that they learnt about IAS and their impacts through personal observations and experiences 2% (n = 6).

3.4. Discussion

Our results demonstrate that the meaning of IAS is understood by a minority of people (fully aware group) but more so by men with higher education levels, who live in areas with higher IAS density. This is similar to the findings of previous research where awareness and understanding of the concept of IAS is associated with people with higher education levels, especially in South Africa where education levels differ enormously due to the legacy of Apartheid (Colton & Alpert 1998; Shackleton et al. 2016; Potgieter et al. 2019). We did not come across any published information associating higher IAS awareness to gender, where in our case men had higher awareness levels. However, there is work linking IAS density, awareness and perceptions (e.g. Shackleton et al 2017) although this is not highly comprehensive. In our case the trend of IAS being better known by men than woman could possibly be driven by their occupation as it was noted in this study that it was mainly men were employed in education and conservation sectors where they learned about IAS. We also found that men were better educated than woman and this may be a reflection of the educational inequality reality. We speculate that educating woman could represent a structural underlying solution towards greater awareness and engagement on IAS issues.

The majority of the respondents from all three groups did not know whether the species presented in images (many of them common in the research area (McLean et al. 2017)) were indigenous or invasive and did not know their impacts. Many respondents perceived IAS as beneficial due to their lack of knowledge. Surprisingly, many respondents from all three groups did not know the term indigenous either. This shows that impacts of fundamental biological concepts are not being communicated to citizens. Despite Western Cape being the most invaded province in South Africa (van Wilgen et al. 2020), the public from the eight small towns along the Berg River Catchment of South Africa's Western Cape province remains largely unaware of IAS but also other biological terms.

The results of low levels of awareness of IAS by citizens in our study is in agreement with other studies. For example, Colton & Alpert (1998) concluded that the public in California, USA had poor understanding of IAPS. However, Californians were more familiar with the term "weed" which was understood to be a nuisance than an

environmental problem. Similarly, Lindemann-Matthies & Bose (2012) discovered that people in the Canton of Zurich Switzerland are still unfamiliar with the term biodiversity and associated concepts like IAS, similar to our findings. Steele et al. (2006) found that there were few landowners who knew about IAPS in West Virginia woodland. In South Africa, Shackleton & Shackleton (2016) found that awareness of IAPS among the public was poor, despite the long history of IAPS management by 'Working for Water' program. While another study by Potgieter et al. (2019), highlighted factors such as Apartheid legacy and education to contribute to different knowledge levels of IAS across different communities in Cape Town. Low levels of awareness of IAS and their status as listed invasive or indigenous and their impacts amongst citizens implies that the NEM:BA regulations are not widely known by citizens in these small towns in South Africa. Similarly, in Europe, Höbart et al. (2020) found that most respondents (>50%) were not aware of the role and existence of the European Union IAS regulation 1143/2014.

There are many reasons that may be associated with low levels of awareness about IAS amongst citizens. Firstly, it may be due to low levels of awareness raising and engagement activities conducted for the public which may be caused by the shortage of funding, or researchers/managers capacity and time (Novoa et al. 2018; Shackleton et al. 2020). Secondly, people have not been told about IAS and their impacts (Colton & Alpert 1998) and the topic was only introduced in 2007 in the school curriculum (Byrne et al. 2020). At the same time, people may be willing to learn (Sharp et al. 2017). For example, it is encouraging that more than half of the all respondents 53% (n = 139) in this study showed interest and willingness in learning more about IAS and their impacts regardless of their current level of knowledge. This suggests that awareness raising initiatives have the potential to support of IAS management efforts by the public. Another reason for low levels of knowledge is sometimes lack of interest or the resistance to information on biological invasions issues amongst the public (Lindemann-Matthies & Bose 2012; Sharp et al. 2017). For example, a quarter of respondents from all three groups 31% (n = 80) in this study were not interested in learning more about IAS and no reasons were given by respondents as to why they do not want to learn more about IAS. This is not surprising as other studies showed that the general public do not care about IAS unless they themselves are directly affected (Genovesi 2005; Silvertown et al. 2013; Sharp et al. 2017; Novoa et al. 2017).

Lastly, people may not think of the net ecological impacts of invasions as bad especially if they are not exposed to them and many may perceive them as good (Vaz et al. 2019; Sharp et al. 2017). For example when we asked respondents in this study if they would be willing to support management activities aimed at IAS, one respondent said "*plants are good for the environment and they bring more oxygen"*. This statement may be linked to the publicity around trees that have come from high profile global campaigns aimed at protecting tree species (e.g. Michaelson 1994).

Even though our linear model results show that IAS knowledge is correlated with IAS density, we found that the overall level of awareness of the target selected invasive plants and their impacts (*Pennisetum setaceum*, *Genista monspessulana* and *Metrocideros excelsa*) was low, with invasive animals *Harmonia axyridis* and *Sus scrofa* being better known. This is irrespective of species occurrence data that was available for the two species (*Metrocideros excelsa* and *Pennisetum setaceum*) for some towns (Hopefield, Moorreesburg, Riebeek- Wes, Tulbagh and Wolseley). This supports the notion that citizens do not have knowledge of IAS, even those in their own communities (Kapler et al. 2012; Shackleton & Shackleton 2016). Most respondents from all three groups categorised *Harmonia axyridis* and *Sus scrofa* as indigenous although they are in fact IAS, there are however, similar looking native species in the country. In addition, *H. axyridis* was correctly identified by most respondents 47% (n = 124) but perceived as beneficial, which suggest possible low support for the management action of these animals. Our results echo those of Novoa et al. 2017 that the species taxonomic position (i.e. animal or plant) may influence public knowledge and support for the management action (Novoa et al., 2017; Vaz et al. 2020).

3.4.1. Perceptions and support for management of IAS

Many respondents from all three groups perceived IAS as beneficial, especially for aesthetics, which shows that these IAS have important value to citizens regardless of them being invasive or not (Dickie et al. 2014; Zengeya et al. 2017). These respondents were not bothered about IAS but that they recognized the need for their management when they pose a threat to nature and human health (Sharp et al. 2017). This limited awareness may have implications to policy and management implementation (Warner & Kinslow 2011; Shackleton & Shackleton 2016; Höbart et al.

2020) as it might make the public less engaged in control and could therefore lead to the spread of IAS. Only a few respondents had the perception that IAS negatively impact biodiversity and most of these respondents belong to the fully aware group. Prior awareness of IAS was found to be an important factor in perceiving them as beneficial or harmful and for supporting control activities, which is similar to other studies (Verbrugge et al. 2013; Cordeiro et al. 2020; Vaz et al. 2020). Respondents who knew IAS were more likely to want to support control programmes for IAS and assist with detection efforts. This supports the view that the more the public is aware about IAS the more likely that they will support their management (Potgieter et al. 2019; Bravo-Vargas et al. 2020).

3.4.2. Education and awareness

Targeted and appropriate awareness techniques are the most important factor affecting people's involvement in environmental management. According to Silvertown et al. (2013), the most suitable recruitment and awareness technique depends on how many people need to be targeted, the geographical reach of the project and the skills required (if any) to participate in the project. This suggests that awareness raising should be tailor made for different groups of people. Emphasis should be on educating the public about the impacts of IAS on their lives. This may change opinions in favour of IAS control (Novoa et al. 2017). The public should also be informed about the control efforts of IAS that are done by government and funded by the Department of Environment, Forestry and Fisheries (DEFF), and coordinated by the National Resource Management Programme under WfW which is one of the government's largest public works programmes, to illustrate the huge effort the state is putting in to manage IAS issues.

Our results show that IAS awareness is correlated with education. We therefore support the notion that the school curriculum is an important opportunity to increase awareness about IAS amongst citizens (Byrne et al. 2020). Localised education efforts (communicating the issue through emphasis on species which are locally invasive) would also promote interest of students and the general public with the topic (Bryne et al. 2020).

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Appendix 3.1: Questionnaire directed to citizens before awareness raising treatments. Draft versions of the questionnaire were jointly developed by the authors and pilot tested. We conducted face-to face surveys between 2018 and 2019.

Questionnaire

1. Do you know what an invasive alien species is? [yes] [no] [unsure]: If yes, describe what is Invasive alien species
   ……
   ……
2. Can you name any invasive alien species? [yes] [no]: If yes, list the ones they mention
   ……
   ……
3. Do you know what an indigenous species is? [yes] [no] [unsure]: If yes, describe what is an indigenous species
   ……
   ……
4. Can you name any indigenous species? [yes] [no]: If yes list the first 5 they mention
   ……
   ……
5. Would you like to learn more about Invasive species and their impacts? [yes] [no] [unsure] [not interested]
6. How would you categorise your knowledge of invasive and indigenous flora? [very good] [good] [average] [poor] [very poor] [don't know]

6.1. Can you identify this plant? [yes] [no]: if yes, give name of the plant
…… and continue, if no skip rest

6.2. Is it invasive or indigenous?
……..

6.3. Have you personally seen this plant? [yes] [no] [not sure]

6.4. Is it [very common] [common] [moderate] [scarce] [very scarce] in your area?

6.5. Is it spreading and increasing in your area? [yes] [no] [same] [don't know]

6.6. Is this plant [beneficial] [harmful] [no impact] or [both harmful and beneficial]? Reason for answer

……

……

6.7. Where did you learn about these benefits or impacts? [personal observation] [verbal communication] [school/university] [the media] [the internet] [other – specify]

……

……

6.1. Can you identify this plant? [yes] [no]: if yes, give name of the plant
…… and continue, if no skip rest

6.2. Is it invasive or indigenous?
……..

6.3. Have you personally seen this plant? [yes] [no] [not sure]

6.4. Is it [very common] [common] [moderate] [scarce] [very scarce] in your area?

6.5. Is it spreading and increasing in your area? [yes] [no] [same] [don't know]

6.6. Is this plant [beneficial] [harmful] [no impact] or [both harmful and beneficial]? Reason for answer

……

……

6.7. Where did you learn about these benefits or impacts? [personal observation] [verbal communication] [school/university] [the media] [the internet] [other – specify]

……

……

6.1. Can you identify this plant? [yes] [no]: if yes, give name of the plant
…… and continue, if no skip rest

6.2. Is it invasive or indigenous? ……

6.3. Have you personally seen this plant? [yes] [no] [not sure]

6.4. Is it [very common] [common] [moderate] [scarce] [very scarce] in your area?

6.5. Is it spreading and increasing in your area? [yes] [no] [same] [don't know]

6.6. Is this plant [beneficial] [harmful] [no impact] or [both harmful and beneficial]? Reason for answer

……

……

6.7. Where did you learn about these benefits or impacts? [personal observation] [verbal communication] [school/university] [the media] [the internet] [other – specify]

……

……


6.1. Can you identify this animal? [yes] [no]: if yes, give name of this animal …… and continue, if no skip rest

6.2. Is it invasive or indigenous? ……

6.3. Have you personally seen this animal? [yes] [no] [not sure]

6.4. Is it [very common] [common] [moderate] [scarce] [very scarce] in your area?

6.5. Is it spreading and increasing in your area? [yes] [no] [same] [don't know]

6.6. Is this animal [beneficial] [harmful] [no impact] or [both harmful and beneficial]? Reason for answer

……..

……..

6.7. Where did you learn about these benefits or impacts? [personal observation] [verbal communication] [school/university] [the media] [the internet] [other – specify]

……..

……

6.1. Can you identify this animal? [yes] [no]: if yes, give name of this animal …… and continue, if no skip rest

6.2. Is it invasive or indigenous? ……..

6.3. Have you personally seen this animal? [yes] [no] [not sure]

6.4. Is it [very common] [common] [moderate] [scarce] [very scarce] in your area?

6.5. Is it spreading and increasing in your area? [yes] [no] [same] [don't know]

6.6. Is this animal [beneficial] [harmful] [no impact] or [both harmful and beneficial]? Reason for answer

……

……

6.7. Where did you learn about these benefits or impacts? [personal observation] [verbal communication] [school/university] [the media] [the internet] [other – specify]

……

……

6.1. Can you identify this plant? [yes] [no]: if yes, give name of the plant
…… and continue, if no skip rest

6.2. Is it invasive or indigenous? ……

6.3. Have you personally seen this plant? [yes] [no] [not sure]

6.4. Is it [very common] [common] [moderate] [scarce] [very scarce] in your area?

6.5. Is it spreading and increasing in your area? [yes] [no] [same] [don't know]

6.6. Is this plant [beneficial] [harmful] [no impact] or [both harmful and beneficial]? Reason for answer

……

……

6.7. Where did you learn about these benefits or impacts? [personal observation] [verbal communication] [school/university] [the media] [the internet] [other – specify]

……

……

6. Have you ever seen any articles with information about invasive alien species? [yes] [no], If yes, where? .....

7. Would you like to see invasive species removed and densities decreased in your area? [yes] [no] [unsure] [don't care] Reason:
   ……

8. Have you ever removed invasive species? [yes] [no] if yes, which ones and where?
   ……
   ……..

9. Do you know of any volunteer campaigns that manage/control IAS in your area? [yes] [no] if yes, which ones?
   ……
   ……..

10. Have you ever volunteered to manage IAS? [yes] [no], If no, would you like to join groups that manage/control IAS in your area? [yes] [no]

11. Have you heard of [iNaturalist/iSpot] [SAPIA] [City of Cape Town EDRR Face book page] [SANBI's Biological Invasion Directorate/Invasive species programme] [Working for Water] [Cape Nature] [SANParks]?

12. Have you ever reported the localities of invasive species? [yes] [no]: If yes in which platform do you report these localities to? [SAPIA] [iNaturalist] [City of Cape Town Face Book Page] [SANBI's Biological Invasion Directorate] [Working for Water] [SANParks] [Cape Nature] [report them to someone you know that works for these organisations] [you don't report them]. How many times in the past year you reported? [1-5][5-10][10-15][15-25][25-35][35-50] [more than 50 times] Name five species you reported
    ……
    ……
    If no, would you be interested in learning how to report the localities of Invasive alien species? [yes] [no]. Reason: ……..

13. Would you be happy to receive published information on Invasive alien species? [yes] [no] [only on certain species]. Reason ……

Demographic

8. Name: …….
9. Gender [M][F]
10. Age …….
11. Ethnic group ……..
12. Location …….
13. Residency time in this location: [Born here] [> 20 yeas] [10-20 years] [5-10 years] [1-5 years] [<1 year]
14. Education level……..
15. Current or previous field of work
16. Contact details: ……

Appendix 3.2: A short description of the selected IAS: *Metrociderous excelsa, Genista monspessulana, Pennisetum setaceum, Harmonia axyridis* and *Sus scrofa*. Indigenous species: *Aloe arborescens*

The text here on species description was mostly taken from (CABI 2021)

Metrosideros excelsa, native to New Zealand, is an evergreen multi-stemmed tree with a dome-like spreading form, branching close to the ground, usually grows 5 – 6m high (but up to 25 m) and stunted (1.0 – 1.5 m) where it grows in windy sites. Flowers are bright red and abundant in December. *Metrosideros excelsa* was introduced to South Africa for ornamental purposes and for hedge planting in coastal areas of the Western Cape. The plant is able to self-fertilise and produce thousands of very small seeds which germinate once they come into contact with moist soil. *Metrosideros excelsa* is a problematic invader, displacing fynbos vegetation. *Genista monspessulana* is a shrub native to Europe that can grow up to 3m high with one stem that is slender, erect, very leafy, with green branches and hairy (CABI 2021). Flowers are pea-like, yellow and up to 13mm long (CABI 2021). Flowering occurs from August-January. *Genista monspessulana* has been introduced to South Africa as an ornamental or hedge plant (Geerts et al. 2013). *Genista monspessulana* forms dense monospecific stands, increases the fuel load for fires and displaces native species (Geerts et al. 2013). *Pennisetum setaceum* is an a perennial grass native to the North African arid Mediterranean area of the Atlas Mountains and the Middle East (Rahlao et al. 2010). *Pennisetum setaceum* was introduced in South Africa around 1930s as an ornamental plant and for soil stabilisation (Rahlao et al. 2010). Where it invades, it outcompete native plants and increases fire frequency and spread by increasing fuel loads (CABI 2021). *Harmonia axyridis* is native to central and eastern Asia and has spread to Europe and North America through biological control and accidental introductions (Öztemiz & Keskin 2019). In South Africa, *H. axyridis* is found in nine provinces. *Harmonia axyridis* outcompete and displace native ladybird species and impact fruit production (Öztemiz & Keskin 2019). *Sus scrofa* native to Eurosia are pests that cause damage to the environment through wallowing, rooting for food and selective feeding (CABI 2021). They destroy crops and pasture, as well as habitat for indigenous plants and animals (CABI 2021). They spread environmental weeds and could spread exotic diseases.

Aloe arborescens native to Southern Africa is a shrub that can grow up to 5m tall (Smith et al. 2012). Leaves are green, curved with yellowish teeth (Smith et al. 2012). Flowers are usually red (but may be yellow or orange, depending on the locality) and appear from May to June (Smith et al. 2012).

Appendix 3.3. – Table 1: showing different linear models tried to assess if knowledge of *Metrocideros excelsa* is correlated with plant densities in different towns. The models are ordered by their relative AIC and the best selected one is highlighted in bold.

Model number	Model description	Log likelihoods	Number of parameters	delta.aics	Weight (wi)
1	**Metrocideros_ID ~ Residency + Education + Metrocideros_Density**	**-92.7919**	**12**	**0**	**0.323173**
2	Metrocideros_ID ~ Education + Metrocideros_Density	-97.1209	8	0.657984	0.232571
3	Metrocideros_ID ~ Education + Metrocideros_Density	-97.121	8	0.657984	0.232571
4	Metrocideros_ID ~ Education	-98.2583	7	0.932913	0.202701
5	Metrocideros_ID ~ 1	-108.469	1	9.3548	0.003007
6	Metrocideros_ID ~ Residency	-104.513	5	9.441782	0.002879
7	Metrocideros_ID ~ Gender	-107.96	2	10.33703	0.00184
8	Metrocideros_ID ~ Metrocideros_Density	-108.397	2	11.21047	0.001189
9	Metrocideros_ID ~ Age	-106.229	7	16.87379	7.00E-05

Table 2: showing different linear models tried to assess if knowledge of *Pennisetum setaceum* is correlated with plant densities in different towns. The models are ordered by their relative AIC and the best selected one is highlighted in bold.

Model number	Model description	Log likelihoods	Number of parameters	delta.aics	Weight (wi)
1	Pennisetum_ID ~ Education + Pennisetum_density + Age	-100.351	14	0	0.569819
2	**Pennisetum_ID ~ Residency + Education + Pennisetum_density**	**-96.8114**	**18**	**0.921027**	**0.359533**
3	Pennisetum_ID ~ Age	-110.189	7	5.676259	0.033354

4	Pennisetum_ID ~ Education + Pennisetum_density	-109.316	8	5.93041	0.029374
5	Pennisetum_ID ~ Education	-111.833	7	8.964689	0.006443
6	Pennisetum_ID ~ 1	-120.169	1	13.63557	0.000623
7	Pennisetum_ID ~ Gender	-119.754	2	14.80664	0.000347
8	Pennisetum_ID ~ Residency	-116.985	5	15.26824	0.000276
9	Pennisetum_ID ~ Pennisetum_density	-120.166	2	15.63004	0.00023

Appendix 3.4. Demographic details for the surveyed population from seven towns along the Berg River Catchment. Primary school = Grade 4-7, High school = Grade 8-12, Matric = completed Matric, N/A = respondents that did not disclose their education level.

Town	Total respondents (n)	Men/Woman (n)	Modal age	Modal residence time (years)	Modal education level
Gouda	39	19/20	20-29	10-20	Primary school
Hermon	40	11/29	30-39	10-20	Matric
Hopefield	10	2/8	40-49	Born here	Matric
Morreesburg	39	12/27	30-39	Born here	Matric
Riebeek Kasteel	41	17/24	30-39	10-20	N/A
Riebeek West	38	10/28	30-39	Born here	High school
Tulbagh	30	19/11	30-39	Born here	High school
Wolseley	25	19/6	30-39	5-10	High school

Appendix 3.5: Candidate models explaining correlation between knowledge of IAS and each demographic variable. The best selected models were based on the lowest AIC. Models within 2 dAIC were considered equal.

1	What_is_invasive ~ Gender + Education	-89.2397	8	11.61362	0.002996
2	What_is_invasive ~ Education	-94.2305	7	19.5952	5.54E-05
3	What_is_invasive ~ Location	-94.1041	8	21.34228	2.31E-05
4	What_is_invasive ~ alien_density	-112.339	2	45.81164	1.12E-10
5	What_is_invasive ~ Gender	-118.561	2	58.257	2.23E-13

6	What_is_invasive ~ Residency	-115.84	5	58.81469	1.69E-13
7	What_is_invasive ~ Age	-121.524	7	74.18283	7.76E-17

Chapter 4: Thesis Conclusion

Currently, there is no documented information on the status of volunteer groups and their contributions to IAS management in South Africa and limited information globally. This is despite the growing wealth of research engaging with the social dimensions of invasion science (Bravo-Vargas et al. 2019; Potgieter et al. 2019; Shackleton et al. 2019; Cordeiro et al. 2020; Höbart et al. 2020; Vaz et al. 2020). Furthermore, there are still gaps to be addressed with regards to assessing and understanding knowledge and perceptions of IAS by the general public and their potential to support IAS management in small towns and comparing invasion densities with peoples' knowledge and perceptions.

Findings presented in this thesis address some of these knowledge gaps and can assist invasion scientists, managers implementing IAS control and policy makers to have a better understanding of citizens' contributions to IAS management and to better engage with them moving forward.

Summary of research findings

In chapter 2 of this thesis, I assessed motivations and contributions of volunteer groups for the management of IAPS in South Africa's Western Cape province. Here, I identified 52 volunteer groups that are dedicated to stopping the expansion of IAPS. I found that the contribution of these volunteer groups to IAPS management is important, but that there is also the need for better co-ordination and engagement between volunteer groups and mandated authorities to improve long-term control. The results from this study can be used as a baseline to understand how volunteer groups operate, their motivations and their challenges in South Africa and in other countries. It is important for managers implementing IAPS control to have a sound understanding of volunteers' knowledge, their needs, and their motivations and ensure that volunteers are kept encouraged and motivated about IAPS control. The results will also help scientists, conservation managers in relevant government departments to become aware of the important work done by volunteers and incorporate volunteers' contributions into the national programmes aimed at controlling IAPS and decision-making processes to inform policy.

In chapter 3, I assessed public knowledge and awareness of IAS in small towns of South Africa's Western Cape province. In particular, a novel approach was used to assess if awareness of IAS is correlated with demographic covariates and IAS density using general linear models (logistic regression). In this study, I found that awareness of IAS amongst citizens in eight small towns along the Berg River Catchment is very low. The majority of respondents who understand the concept of IAS were men with higher education levels and lived in areas where IAS density was higher. I found awareness of IAS to be a pre-requisite for citizens engaging in reporting and removing IAS and for them to get involved in volunteer programmes aimed at controlling IAS. These results could help to inform outreach and educational programs to promote public awareness and engagement in IAS management.

Recommendations and the way forward

Given the fact that citizens play a major role in introducing IAS and facilitating their spread, they can also play a similar role in detection and reporting IAS and supporting management activities (Bremner & Park 2007; Verbrugge et al. 2013; Adriaens et al. 2015; Novoa et al. 2018; Shackleton et al. 2019). Educating citizens about IAS is important and could help prevent IAS spread and promote control. Volunteers could be used as a potential vehicle to promote awareness on IAS more generally. There is also a need for better education campaigns by the South African government to help to facilitate support for IAS management efforts by the public in the future. There are still gaps in our knowledge of citizens' involvement in the management of IAS in South Africa, and the research presented in this thesis should be expanded on to cover the whole of South Africa. Some future research needs in light of this study are the following:

- This work should be expanded to document volunteer groups across the whole country.
- A detailed study evaluating the clearing efforts and effectiveness of the volunteer groups should be conducted and could be part of a long-term monitoring study.
- Another study focusing on citizens involvement in invasive animals in South Africa is also recommended.

- Different awareness raising strategies should be conducted and assessed to determine the most effective and cost-efficient ways of raising awareness of IAS to the public.
- The results suggest a poor knowledge of basic biological terms and phenomenon and there is a need to better include and teach core concepts to young school children.

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