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RESEARCH ARTICLE

Community perceptions and management of the fleshy-fruited invasive alien plant *Pyracantha angustifolia*: Insights from South Africa's Montane grasslands

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Abstract

1. Invasive alien plants can provide economic or cultural benefits to local communities, influencing perceptions and potentially affecting management decisions. Understanding these perceptions is crucial to avoiding inefficiencies, misunderstandings and conflicts in the management of invasive alien species.
2. Our study explored community perceptions and interactions with the fleshy-fruited invasive shrub *Pyracantha angustifolia* (Franch.) C. K. Schneid in South Africa's montane grasslands, using mainly in-person questionnaires, as well as telephonic and online questionnaires, conducted between 2021 and 2022.
3. Results showed that while communities occasionally consumed the fruits, which were mostly eaten by children, acting both as seed predators and dispersers, the fruits were not used for subsistence purposes.
4. Residents generally did not perceive *P. angustifolia* as problematic, while farmers and conservation practitioners considered it detrimental because of its impact on grazing, recreation and vegetation structure.
5. Fire was considered the least effective control method over mechanical and chemical control, while government-supported initiatives, such as the Expanded Public Works Programme, were the most preferred form of assistance for management.
6. Understanding how communities interact with and perceive invasive alien plants is essential for aligning ecological goals with social realities and reducing potential conflicts.

KEYWORDS
conflict of interest, firethorn, interviews, introduced plant, invasion control, invasion science

1 | INTRODUCTION

One of the major drivers of environmental change is biological invasions (IPBES, 2023; Manzoor et al., 2021; Richardson et al., 2000). Introduced species have the potential to spread extensively in their new ranges and become invasive (Pyšek et al., 2020; Richardson et al., 2000). An introduced species becomes invasive when it progresses beyond naturalisation to achieve sustained reproduction and

dispersal, producing offspring at significant distances from parent populations (Richardson et al., 2000). These species often affect biodiversity, ecosystem processes and human well-being and often result in negative impacts (Jeschke et al., 2014; Pejchar & Mooney, 2009; Shackleton et al., 2018). However, these species may offer economic and intrinsic benefits, which lead to conflicts of interest in their management because some people may oppose specific control methods and want to continue deriving benefits (Crowley et al., 2017; Vaz et al., 2017; Villatoro et al., 2019; Zengeya et al., 2017). Conflicts of interest can arise when communities differ in their perceptions of invasive alien plants. For example, in the grasslands of Lesotho and South Africa, the fleshy-fruited invasive alien plant *Rosa rubiginosa* L. (Rosaceae) is one of the most widely distributed and abundant invasive alien shrubs (Martin et al., 2025; Rahlao et al., 2023), and therefore considered for management. However, the species provides economic benefits, as communities harvest the fruits and sell them to a factory that produces teas, oils and powders from them (Martin et al., 2025).

Consequently, it is important to include aspects of human perceptions in research to ensure the effective management of invasive alien plants (Shackleton et al., 2019). Many studies on human perceptions of invasive alien plants consider only one or two influencing factors, mostly impacts and benefits, lacking the development of a more comprehensive understanding (Kueffer et al., 2013; Shackleton et al., 2019). Other influencing factors include ecological, social and value and belief factors. In our study, we included five influencing factors because a comprehensive approach is beneficial for research, management, policy formulation and governance, as they include primary factors that shape perceptions (Kapitza et al., 2019; Shackleton et al., 2018).

Globally, research on human perceptions of invasive alien plants, especially through interdisciplinary studies, has gained momentum and increased rapidly over recent years (Kapitza et al., 2019). A review of geographical, methodological and taxonomic bias of research on social perceptions of invasive alien plants concluded that North America (32%) and Europe (28%) have dominated this research, followed by Africa (17%), Asia (8%), Oceania (9%) and South America (6%), showing a clear gap in the literature for the latter regions (Kapitza et al., 2019).

Pyracantha angustifolia (Franch.) C. K. Schneid (Rosaceae), also known as the yellow firethorn or narrowleaf firethorn, is native to southwest China and was introduced to South Africa as a hedging plant (Chari et al., 2020; Henderson, 2020). This plant has naturalised and has become invasive in many parts of the world, including Argentina (Vergara-Tabares et al., 2022), Australia (Swarbrick & Skarratt, 1992), Japan (Mito & Uesugi, 2004), the United States of America, some of the Hawaiian Islands (Nesom, 2010), Russia (Nobis et al., 2014) and South Africa (Henderson, 2020). The plant typically invades shrublands, forests and grasslands. In South Africa, invasion by *P. angustifolia* in the grassland biome was first reported in the early 1980s (Henderson & Musil, 1984). The species has since spread rapidly, forming dense stands in many high-altitude grasslands (Richardson et al., 2020). Although it has a wide distribution with occurrence records in all nine provinces, *P. angustifolia* is more abundant in the Gauteng, Free State and Eastern Cape provinces (see Adams et al. (2023) for *P. angustifolia* distribution). *Pyracantha* species are listed under category 1b in the South African legislature and must therefore be eradicated or controlled in accordance with the Alien and Invasive Species Regulations of the National Environmental Management: Biodiversity Act (NEM:BA) (South African Department of Environmental Affairs, 2014).

Fruits of *Pyracantha* species contain important nutrients such as amino acids, soluble sugars, fatty acids, mineral elements, proteins, starches, pectin and dietary fibre, vitamins and other nutrients (Doello et al., 2022; Yuan et al., 2010; Zhao et al., 2015). The fruits can be cooked to make jams, jellies, sauces and marmalade (Keser, 2014). *Pyracantha* roots, leaves and fruits have medicinal value, which can help improve immunity, antioxidant activity, digestion and spleen nourishment (Sharifi-Rad et al., 2020). Globally, *P. angustifolia* is valued in horticulture for its frost tolerance and colourful autumn berries (Bass, 1996). The shrub serves as a barrier plant, windbreak and security hedge because of its dense foliage and thorns (Csurhes et al., 2016; Henderson, 2020). It also has various local uses, including walking sticks in India, bonsai in Japan, roadside berry consumption in South Africa and wine production in North America (Alatorre, 1977; Chari et al., 2020).

Our study aimed to (1) assess the community interactions with *P. angustifolia*, (2) investigate the potential pathways of the plant spread and (3) evaluate management practices used by the community and gather community-driven recommendations for effective control of this invasive species.

2 | METHODS

2.1 | Study area

Our study was conducted in the Montane Grassland Biome of South Africa, which includes mainly the Drakensberg Escarpment and neighbouring foothills. The study was limited to this Biome as it is the most invaded by *P. angustifolia* (Chari et al., 2020). The study area receives an average rainfall of about 1800 to 2000 mm during the rainfall season from September to April and has cold winters with occasional snow. The dominant vegetation in the study area is the Eastern Free State Sandy Grassland (Gm 4), which is part of the Mesic Highveld (Mucina & Rutherford, 2011). Grasses from the Poaceae plant family dominate the area with at least 55 genera, followed by forbs from the Asteraceae family with more than 51 genera (Daemane et al., 2010).

The South African grasslands are threatened by invasive alien plants, particularly trees and shrubs, which alter vegetation structure and composition (Carbutt, 2012; Carbutt et al., 2011; Chari et al., 2020). Fleshy-fruited invasive alien shrubs, predominantly from the Rosaceae family, have been increasing in abundance for the past two decades, with *P. angustifolia* being the most notorious invader

spreading at rapid rates (Adams et al., 2023; Carbutt et al., 2011; Chari et al., 2020; Martin, 2021; Masole et al., 2022).

2.2 | Data collection

The study area description covers the areas where communities were surveyed in person in the Free State, KwaZulu-Natal and Eastern Cape provinces (Figure 1). In addition to in-person surveys, we distributed an online version of the questionnaire and telephonically interviewed participants, thereby also receiving responses from the Gauteng and Western Cape provinces (Figure 1).

Using a questionnaire, we conducted surveys to determine the use of *P. angustifolia* by rural and urban communities in invaded regions. Data on the participant's background information, species occurrences, attempted control methods, effectiveness of current control methods, suggestions for improvement and government involvement were collected (see the questionnaire template in Supplementary Information Survey 1). The electronic and in-person questionnaire was developed to capture demographic information, awareness, use and perceptions of management of *P. angustifolia* in South African grassland communities. Participants (≥18 years) provided background details (age, gender, occupation, education, residence), indicated whether they recognised the species, observed fruit consumption and seed dispersal, and described local population size and trends. Questions also addressed plant uses (e.g. food, wood, trade), perceived impacts, and control practices (mechanical, chemical, biological), including views on effectiveness, possible improvements and government involvement. Open-ended responses allowed for additional comments, and participants could volunteer contact details for follow-up engagement. To ensure that the data covered important areas of influence on the perception of invasive alien plants, data collected included ecological conditions (i.e. invasion status as the number of plants and the status of the population over time), social conditions (socio-demographics and interests), values and beliefs (uses and perceptions), impacts and benefits of the target species (Kapitza et al., 2019). The data were collected while the study species was fruiting to ensure respondents could correctly identify the species (December 2021–May 2022).

To ensure high ethical standards, the following steps were taken: (1) all participants were informed about the purpose of the study, and they had to give verbal consent for in-person questionnaires or online-click consent for online questionnaires. The respondents could stop the interview anytime they felt like doing so, and (2) data were collected in a way that promoted the anonymity of the participant and presented in a

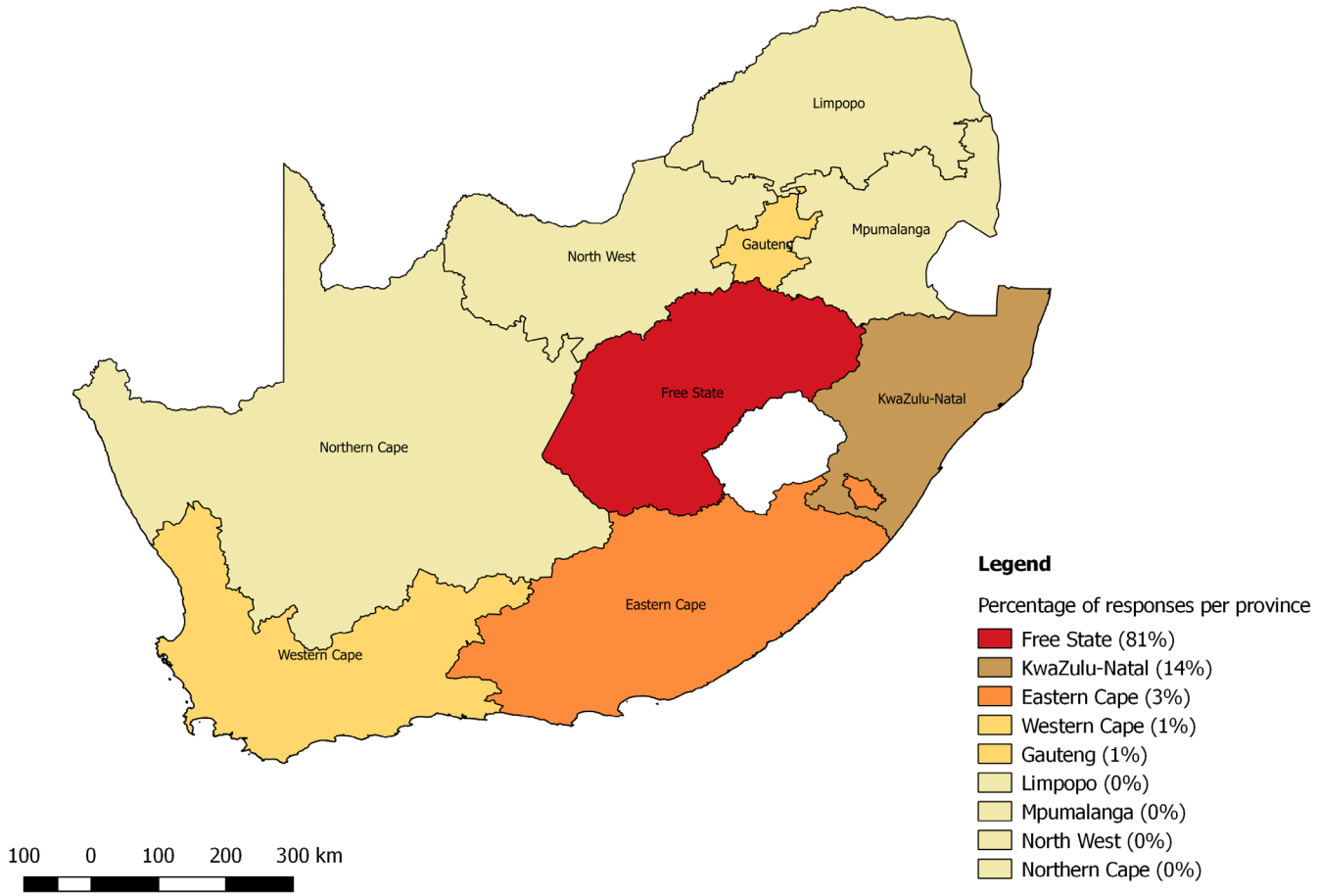

FIGURE 1 Map showing participants' percentage responses per province of South Africa. Responses were administered mainly in-person ($N = 202$) in the Free State, KwaZulu-Natal and Eastern Cape provinces, but there were some online ($N = 4$) and telephonic ($N = 2$) responses from other provinces. Most responses were from the Free State Province.

way that prevented individuals from being identified. Participants were not obliged to answer all questions and could skip questions at their convenience. The questionnaires were translated into isiZulu, Sesotho and IsiXhosa, as these were the dominant languages spoken in the study area. Humanities Ethical clearance (HSSREC/00003340/2021) was obtained from the University of KwaZulu-Natal, and all COVID-19 regulations were observed during data collection.

A total of 208 questionnaires (in-person [$n=202$]; telephonic [$n=2$] and online questionnaires [$n=4$]) were completed. For in-person interviews, we walked around towns during the day, between 9:00 AM and 3:00 PM, and asked prospective participants whether they would like to participate in the study. We read the aims of the study and obtained their consent before beginning the questionnaire interview. It took two people to conduct each in-person interview: an interviewer and a scribe. The interviewer asked the participant questions, and the scribe recorded the responses on a printed hard copy of the questionnaire. Online questionnaires were administered using Google Forms®. The Google Forms® link was circulated to different research units and associations. Telephonic interviews were conducted only when the interested prospective participant could not access the online questionnaires or could not be interviewed in person because of distance or differing availability.

Participants' demographic details, including age, location, gender, ethnicity, occupation and length of residency, were collected to contextualise perception modelling in Generalised Linear Models (GLMs). To assess species occurrences and population changes, participants were shown a sample of the study species and asked about their familiarity and sightings of the species. They estimated the number of individual plants at specific locations, categorising responses into ranges (1–5, 5–15, 15–30 or >30 plants). Participants also indicated whether they perceived population trends as increasing, stable or decreasing. Data on plant uses included inquiries about harvesting activities and purposes, while perceptions of problems resulting from the plants were assessed using responses categorised as yes, maybe or no, with opportunities for detailed impact elaboration. The assessment of control efforts involved querying participants about the methods used, their effectiveness and suggestions for improvement. Details on how the government's involvement in helping communities clear the invasive alien plant were gathered, including whether any assistance was received, the assistance the community would like to receive from the government and suggestions for the type of assistance the community would like to receive from the government. For consistency, the impacts were transcribed by the researcher using Socio-economic Impact Classification of Alien Taxa (SEICAT) and Environmental Impact Classification for Alien Taxa (EICAT) guidelines (Bacher et al., 2017; Kumschick et al., 2024).

2.3 | Data analyses

The multinomial regressions were used to investigate which variables affect community perceptions. Perceptions were recorded as responses to whether participants thought *P. angustifolia* was a problem in their area. We analysed the collected data using multinomial regression (Generalised Linear Models) in the Statistical Package for Social Sciences v. 20 (SPSS, IBM, USA). Responses included 'yes', 'maybe' and 'no'. Independent variables included the participant's age, gender, land type associated with the participant, occupation and period of stay in the interview area. The period of stay referred to the time the participant had lived in the area where the interview was conducted. We conducted a Chi-square test to assess the model's goodness-of-fit. We used descriptive statistics to create frequency tables of participants' responses.

3 | RESULTS

3.1 | Background information of participants

The study received a total of 208 responses. However, since not all questions were mandatory, the data were incomplete, meaning most responses do not reflect the full sample size of 208. For example, only 168 participants indicated the type of land they were associated with. The age categories of people interviewed were evenly distributed; ~20% of participants were within each of the four categories, with the fewest participants in the over 55 years old category (10%, $n=21$; see Table 1 for total sample sizes). More male participants were interviewed (66%, $n=135$) than female participants (34%, $n=71$). The study mostly consisted of people who identified as African (83%, $n=173$), and to a lesser extent as Caucasian (14%, $n=30$) and Coloured (2%, $n=5$). Most participants were employed (60%, $n=114$), but some were unemployed (14%, $n=26$), self-employed (11%, $n=22$), students (9%, $n=17$) or pensioners (6%, $n=12$).

The period of stay differed among participants ($n=208$) (Table 1). Most participants had stayed in their area of interview for more than 10 years (59%, $n=119$), and some were permanent residents who had stayed in the area for 5–10 years (22%, $n=45$) or stayed for less than 5 years (15%, $n=30$). A minority of the participants were 'visitors' to the study area a few times a week (1.5%, $n=3$), a few times a month (0.5%, $n=1$) or a few times a year (2%, $n=4$). Residential was the most common land type among participants (75%, $n=156$). However, some were also associated with conservation units (9%, $n=19$), public works (5%, $n=10$), animal and crop farms (3%, $n=6$), animal farms only (3%, $n=7$), business (2%, $n=4$), holiday farms (1%, $n=3$) or crop farms only (1%, $n=1$) (Table 1).

3.2 | Population status

When asked to estimate the number of individual plants in a given area, more than half of the respondents selected more than 30 individual *P. angustifolia* plants (Figure 2). The population estimates included the estimated number of plants on one's property, another person's property and any land in the town/rural area of the

TABLE 1 Composition and demographic information of the participants gathered from questionnaires on uses, population status and management of the invasive alien plant, *Pyracantha angustifolia*, in South Africa.

Category (*N* = 208)	Selections	No. of responses	Percentage of responses
Age	18–25 years	43	21
	26–35 years	55	26
	36–45 years	44	21
	46–55 years	45	22
	>55 years	21	10
	Total	208	100
Gender	Male	135	66
	Female	71	34
	Total	206	100
Race	African	173	83
	Coloured	5	2
	Caucasian	30	15
	Total	208	100
Occupation	Employed	114	60
	Pensioner	12	6
	Self-employed	22	11
	Student	17	9
	Unemployed	26	14
	Total	191	100
Period of stay	Permanent (>10 years)	119	59
	Permanent (5–10 years)	45	22
	Permanent (<5 years)	30	15
	Visitor (few times a month)	1	1
	Visitor (few times a week)	3	2
	Visitor (few times a year)	4	2
	Total	202	100
Land type	Animal and crop farm	6	3
	Animal farm	7	3
	Business	4	2
	Conservation unit	19	9
	Crop farm	1	1
	Holiday farm	3	1
	Public works	10	5
	Residential	156	75
	Other	2	1
	Total	208	100

Note: No specific personal data were obtained in compliance with the Protection of Personal Information Act [POPI Act].

interview. Some participants (at least 5%) commented that 100s of plants were in their areas. Overall, the participants indicated that the *P. angustifolia* population numbers were increasing (52%, $n = 97/135$) in their respective areas (Figure 2).

3.3 | Community perceptions and uses

The final multinomial regression model explained a substantial portion of the variance in plant problem perception, as indicated by Nagelkerke $R^2 = 0.500$, Cox and Snell $R^2 = 0.392$ and McFadden $R^2 = 0.324$. We found that all participants were confident that they could identify the plant species. Likelihood ratio tests showed that race (χ^2 ($n = 213$) = 15.83, df = 3, $p < 0.05$) and land type (χ^2 ($n = 213$) = 12.47, df = 3, $p < 0.05$) were significant predictors in the model for predicting local people's perceptions. Most participants (80% of 168 respondents) associated with the residential land type (73.2%, $n = 123/168$; note: 168 is the total number of responses on whether the plant is a problem or not) did not regard the plant as a problem in their area. In contrast, those associated with conservation units and/or farms considered the plant a problem (18.5%). A few (7.7%) participants were unsure if the plant was a problem, responding with 'maybe'.

Participants reported harvesting roots, leaves, whole plants and stems, but fruits were the most frequently harvested plant parts (Figure 3a). Most participants who reported consumption indicated they had seen children eating the fruits for fun or had eaten them themselves (Figure 3b). Fruits could also be boiled to make juice or cooked to make jam. Of interest, one participant commented that 'Norwood Coaker, a British pharmacist from England, made medicine out of its fruits in Ladybrand around 1908. The fruits are high in vitamin C. He made a lot of money selling juice made from the fruits. Most of the old stone buildings in the town of Ladybrand were built by him, including a factory where he produced medicines using fruits from this plant. This may be the plant's initial introduction to the region, as there are no records or data on the species prior to this date. The plant was also harvested as an enhancement to agricultural fodder, medicine for livestock and humans, selling (retail), propagation and wood.

3.4 | Potential seed or propagule dispersal

Most of the participants who mentioned consuming fruits ($n = 64$) indicated that they swallow the seeds (31%), while some crush them (30%) or throw them away (39%). Seeds thrown away were regarded as potential seed dispersal events (39%), and crushed and swallowed as potential seed predation (61%). Thus, humans act both as potential seed dispersal agents and predators. Participants also commented on possible agents of seed dispersal ($n = 40$) in the questionnaire's comment sections. Birds (including ostriches, *Struthio camelus*), goats (*Capra hircus*), chacma baboons (*Papio ursinus*), cattle (*Bos taurus*), sheep (*Ovis aries*), elephants (*Loxodonta*

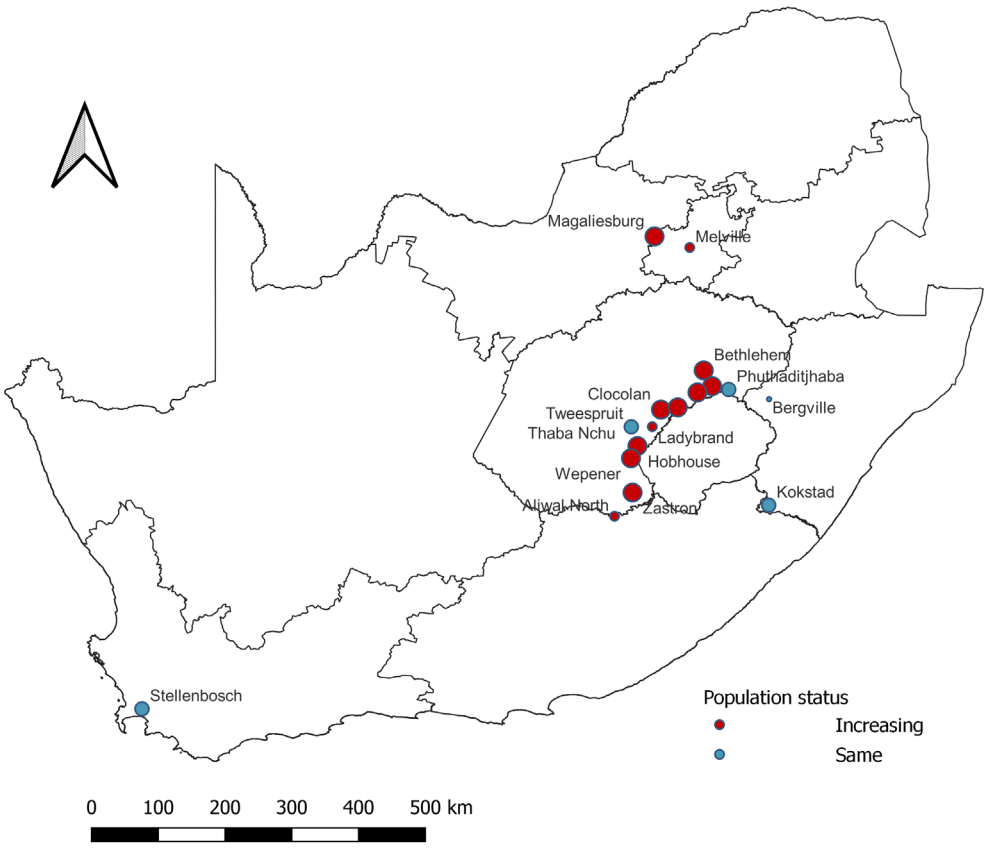

FIGURE 2 Map showing locations of respondents per town in South Africa and their responses for the *Pyracantha angustifolia* questionnaire. The population size of *Pyracantha angustifolia* estimated by the respondents is indicated by the size of the circle (the smallest size class was 1–5 plants, and the largest was more than 30 plants), and different colours indicate if respondents considered populations to be increasing (red) or staying the same (blue). None of the respondents indicated that the populations were decreasing. This map reflects the average responses from people in each sampled town.

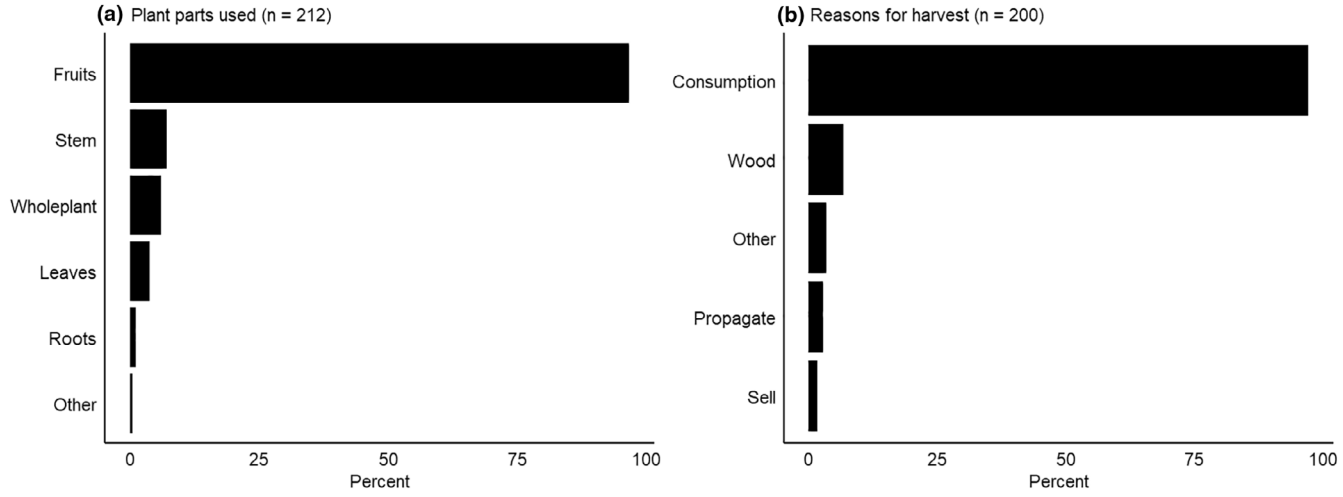

FIGURE 3 Frequency of responses on (a) plant parts harvested and (b) the reasons for harvesting *P. angustifolia* by communities within the grassland biome, South Africa.

africana) and mongooses (Herpestidae) were animals seen feeding on *P. angustifolia* fruits (Figure 4). Birds (30%), goats (28%) and baboons (20%) were the most frequent animals reported feeding on fruits.

3.5 | Socio-economic and environmental impacts

Respondents were only asked if the plant is a problem, and were asked to elaborate when they said yes. Only 31 respondents said

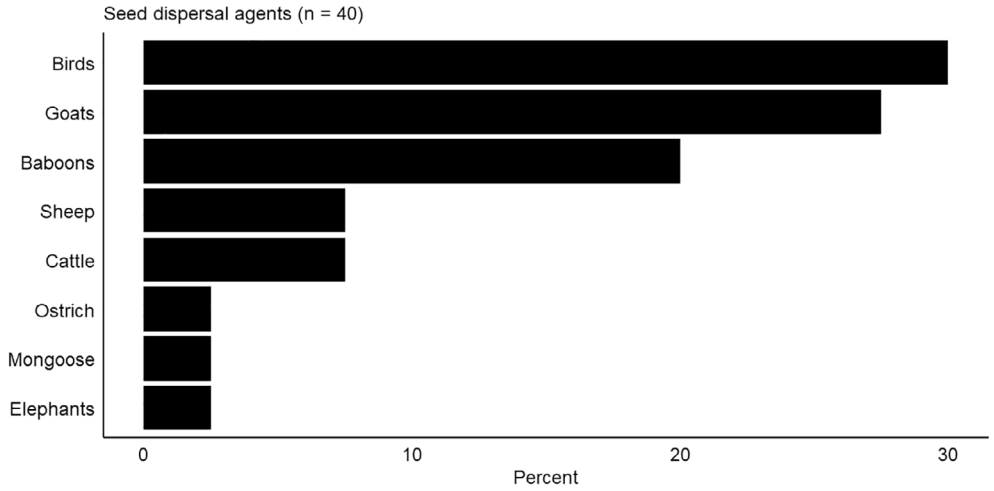

FIGURE 4 Frequency of potential seed dispersal agents of *Pyracantha angustifolia* as perceived by community participants in South Africa ($n = 40$). Seed dispersal agents are animals that feed on fruits observed by the community.

TABLE 2 Socio-economic and environmental impacts of *Pyracantha angustifolia* reported by the communities in South African grasslands through questionnaires.

Impacts reported	No. of responses	Percentage of responses
Environmental (n = 29)		
Threaten freshwater bodies	3	10
Take over the grasslands	18	62
Compete with native vegetation	8	28
Socio-economic (n = 21)		
Restrict access	7	33
Reduce grazing capacity	7	33
Damages property	2	10
Block roadside	2	10
Alter recreational use	3	14

yes. Environmental impacts reported by participants ($n = 29$) included threatening freshwater bodies, taking over grasslands and competing with native vegetation (Table 2). Restriction of access, reduction of grazing capacity, damage to property, blocking of road shoulders (obscuring views of oncoming traffic on road curves) and alteration of recreational use, such as the restriction or closure of hiking and mountain biking trails, were the main socio-economic impacts reported ($n = 21$).

3.6 | Attempted control methods and their effectiveness

In an attempt to control *P. angustifolia* invasion, communities have used biological control, fire, and mechanical and chemical control (Figure 5a), with mechanical (41%, $n = 31$) and chemical (47%, $n = 15$) control being the most frequent methods. Although some responded that fire was used, participants explained that it was used for rotational burning of the grasslands, which led to burning *P. angustifolia* plants; thus, the main intention was not *P. angustifolia* control.

Participants were uncertain about the effectiveness of biological control ($n = 22$), while fire was reported to be the least effective control measure (Figure 5b). Mechanical and chemical controls were believed to be more successful than fire and biological control. Most participants believed that control methods could be improved ($n = 32$) (Figure 5c). Herbicide use was the most frequent suggestion for improving control effectiveness, followed by the introduction of a clearing programme, more research, funding for clearing labour and other suggestions ($n = 19$) (Figure 5d). Most participants wanted government assistance. Some were sceptical and responded 'maybe', and others did not want any assistance. Suggested desired government assistance included funding, provision of labour, clearing programmes and supply of chemicals ($n = 23$) (Figure 5e). Several participants in the eastern Free State mentioned a previous Rand Water clearing programme that used herbicide spraying to control invasive alien plants. However, with the cessation of the latter, the impacts of the invasive alien plant have worsened over time.

4 | DISCUSSION

Our study shows that the spread and management of *P. angustifolia* in South Africa's montane grasslands are shaped by multiple, interacting ecological and social processes. Communities identified a broad suite of dispersal agents: humans, birds and several mammals, and reported behaviours (swallowing, discarding or crushing seeds) that together create both predation and dispersal pathways. In parallel, respondents commonly perceived local populations as large (often more than 30 plants, with some indicating this to be an underestimate) and increasing, and most residents did not view the shrub as problematic, in contrast to farmers and conservation practitioners.

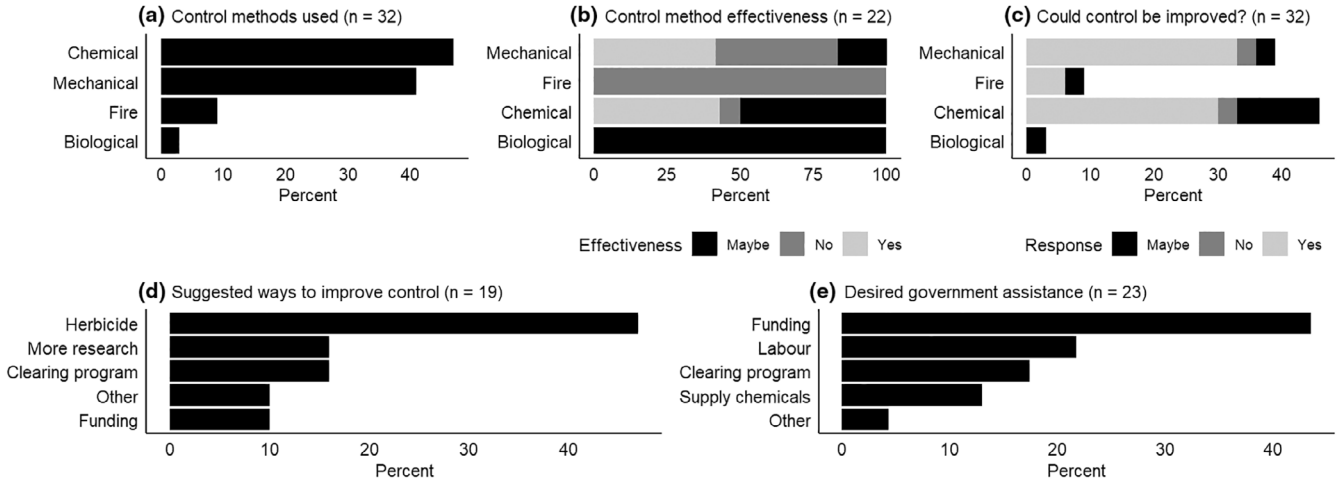

FIGURE 5 Frequency of community responses on perceived (a) control methods used against *P. angustifolia* in South Africa, (b) their effectiveness, (c) whether improvements were possible, (d) suggested improvements and (e) desired government assistance and its type.

These findings jointly explain why *P. angustifolia* is expanding in the region, and how management responses vary across land uses. They also clarify why communities favour government-supported assistance for control.

Reported fruit consumption by people and animals, combined with seed handling (swallowing or discarding), provides clear mechanisms for local establishment and potential longer distance spread. The same communities that listed diverse dispersal agents also reported increases in population size and frequency of larger stands, consistent with the expectation that multiple introduction pathways accelerate spread. These survey-based observations are consistent with evidence that vertebrates can pass viable seeds and that removing pulp can enhance germination, reinforcing the idea that ordinary human–wildlife interactions sustain invasion dynamics in these grasslands (Adams et al., 2022). Humans thus contribute to seed predation and fruit consumption, which may significantly impact the distribution and abundance of *P. angustifolia* (Chari et al., 2020).

Although fruits are occasionally eaten often by children for fun, communities did not report subsistence reliance on *P. angustifolia* products. Uses such as jam-making, ad hoc consumption, fodder enhancement or small-scale retail were mentioned but appeared incidental rather than livelihood-defining. The roots of *P. angustifolia* have been used to treat body pains in Limpopo Province, South Africa (Semenya et al., 2012). This matters for policy: where tangible benefits are limited, the opportunity costs of removal are smaller and arguments for proactive control are stronger, provided interventions are sensitive to local norms (e.g. children's foraging) and communicated clearly. Although selling and planting of the species have been prohibited according to the National Environmental Management: Biodiversity Act in the 2004 Alien and Invasive Species Regulations and Lists of 2014 (South African National Biodiversity Institute (SANBI), 2023), some community members still trade and plant the species; thus, further spread is likely to occur.

Respondents most often reported mechanical and chemical management methods; fire was seen as least effective, in part because burns were used for grassland management rather than targeted shrub control. Communities also expressed uncertainty about biological control and requested external assistance, particularly through funded labour, chemicals and organised clearing programmes (e.g. alignment with Expanded Public Works Programme models). Together, these findings point to a pragmatic pathway: integrate community-preferred methods (cut-stump/mechanical plus appropriate herbicide) with structured follow-up, and resource them through government-supported programmes that communities already recognise and trust. Prior on-the-ground experience (e.g. Rand Water clearing) further signals that resourcing, coordination and continuity, not just method choice, are pivotal to success.

Because perceptions vary predictably with land association, management should be co-designed at the scale of land-use mosaics. In residential areas, risk communication can focus on preventing the spread (e.g. discouraging planting, safe disposal of fruits/seed-bearing material). For farms and conservation units, where impacts are felt most, managers can prioritise integrated control, schedule follow-up and track progress with simple metrics acceptable to land users. The strong preference for government assistance suggests interventions should budget explicitly for labour, training and materials, coupled with compliance support under national regulations, to close the expectation–capacity gap highlighted by respondents.

The most widely used methods by communities to control *P. angustifolia* were chemical and mechanical control. This has also been observed in places such as Australia and Hawaii (Chari et al., 2020). Although the names of chemicals used by the communities were not collected in our study, glyphosate, hexazinone, imazapyr, picloram, tebuthiuron and triclopyr are several chemicals known to be used to control *Pyracantha* species in the USA (DiTomaso et al., 2013). Cut-stump treatments with glyphosate or

triclopyr oils are generally more effective than spraying stems or canopies (Chari et al., 2020; Motooka et al., 2003). Further investigation of the control methods for this species should examine the specific chemicals used by the communities and their compliance with national regulations, and should also provide thorough details on other attempted control methods. In Australia, moderate success has been achieved through prescribed burning, with bare ground replanted after the fire (Chari et al., 2020). Rather than a control method, seasonal burning of grasslands in South Africa acts as a driver of invasion by clearing the ground, enabling *P. angustifolia* to invade burned patches (Richardson et al., 2000). Although a few participants reported using biological control to manage *P. angustifolia*, no biocontrol has been released globally to control it. However, the species is a candidate for biological control in South Africa (Martin, 2021).

Our inferences reflect self-reported perceptions and behaviours; not all questionnaire items were mandatory, creating occasional gaps. We did not capture the specific herbicides or application protocols in use, limiting fine-grained evaluation of chemical efficacy. Future work should (i) document method-specific protocols and compliance, (ii) couple perception data with field monitoring of treatment outcomes and (iii) extend SEICAT/EICAT transcriptions with systematic impact scoring to quantify magnitude and pathways of socio-ecological change. Longitudinal designs would test whether shifting perceptions track visible changes in invasion status after interventions.

The most apparent environmental impact of *P. angustifolia* invasion reported by the participants was a change in vegetation structure, as most participants indicated that the plant became dominant in the landscape. In South Africa, the species reduces eco-tourism revenue because of biodiversity loss and the high visual impact in conservation and scenic areas (Henderson, 2020). This further threatens grasslands already affected by land use change and other factors. *Pyracantha angustifolia* exerts negative socio-economic impacts by negatively affecting activities, leading to a decline in participation. Livestock grazing, hiking and mountain biking were the main activities in which the species reduced activity size where it has invaded. A comprehensive SEICAT assessment is needed to determine the magnitude of the impact, as these impacts were collated only from the communities (Bacher et al., 2017). *Pyracantha angustifolia*, despite present control efforts by the communities, continues to spread and this spread is widely facilitated by mammals, birds and humans (Vergara-Tabares et al., 2016).

By linking dispersal behaviours, population status and stakeholder perceptions, our results explain both why *P. angustifolia* continues to expand and where management is most likely to be supported. Communities are not dependent on the species for subsistence, yet everyday actions still facilitate spread; managers in production and conservation landscapes perceive and experience the costs most acutely; and communities favour organised, government-backed programmes using mechanical/chemical control with proper follow-up. Embedding these insights into planning can increase acceptance, effectiveness and durability of interventions across South Africa's grasslands.

5 | CONCLUSIONS

We found that the communities were not dependent on *P. angustifolia* for subsistence roles, such as selling to make a living or as a source of food for survival. Respondents perceived that *P. angustifolia* has socio-economic and environmental impacts. Unaided introduction of *P. angustifolia* to new sites is highly expected, given the high diversity of seed dispersal agents found. Respondents perceived that mixed methods are more effective at controlling *P. angustifolia* invasions. These insights can inform planning to increase the acceptance, effectiveness and success of interventions to control *P. angustifolia* invasions across South Africa's grasslands. The community data are credible and can be used to improve the management of *P. angustifolia*.

AUTHOR CONTRIBUTIONS

All authors conceptualised the study. CTD and LDA sought funding. LDA collected and analysed data and drafted the manuscript. All authors reviewed and edited the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no competing interests.

DATA AVAILABILITY STATEMENT

The data used in this study belong to the University of KwaZulu-Natal and are available from the authors upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Data S1. Supplementary information Survey 1. A sample of the electronic questionnaire survey that was used online and in-person to collate data on community perceptions of the fleshy-fruited invasive alien plant *Pyracantha angustifolia* in South African grassland communities.

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SUPPLEMENTARY INFORMATION

Supplementary information Survey 1 A sample of the electronic questionnaire survey that was used online and in-person to collate data on community perceptions of the fleshy-fruited invasive alien plant *Pyracantha angustifolia* in South African grassland communities.

Fleshy-fruited invasive alien plants in grasslands

We are investigating the uses, public perceptions, and management of fleshy-fruited invasive alien plants in the grasslands. This questionnaire is for information purposes only, and we would highly appreciate it if you could contribute to our study based on your observations. This research forms part of a PhD study on fleshy-fruited invasive alien plants in the grasslands, which presently been undertaken in the School of Life Sciences, University of KwaZulu-Natal, Pietermaritzburg campus by Lehlohonolo Adams (PhD candidate) under the supervision of Prof CT Downs. If you have any queries about the questionnaire, please contact Lehlohonolo Adams at 0658019833 or email adams20165@gmail.com or Downs@ukzn.ac.za.

* Indicates required question

1. Are you 18 or above? *

Mark only one oval.

- ◯ Yes
- ◯ No

2. I understand the purpose and procedures of the study. I declare that my participation in this study is entirely voluntary and that I may withdraw at any time without affecting any of the benefits that I usually am entitled to. *

Mark only one oval.

- ◯ Yes
- ◯ No

Background information

3. Town

_____

4. Age

Mark only one oval.

- [ ] 18-25 years
- [ ] 26-35 years
- [ ] 36-45 years
- [ ] 46-55 years
- [ ] >55 years

5. Gender

Mark only one oval.

- [ ] Male
- [ ] Female

6. Race

Mark only one oval.

- [ ] African
- [ ] Caucacian
- [ ] Coloured
- [ ] Indian
- [ ] Other: _____

7. Current occupation?

Check all that apply.

- [ ] Student
- [ ] Employed
- [ ] Unemployed
- [ ] Pensioner
- [ ] Self employed
- [ ] Other: _____

8. Level of education? *Mark only one oval.*

- No education
- Primary
- Secondary
- Undergraduate
- Masters
- PhD
- Other:

9. Do you stay here permanently?

Mark only one oval.

- No
- Yes (Less than 5 years)
- Yes (5 - 10 years)
- Yes (more than 10
- years) Other:

10. If no, how often do you visit the place?

Mark only one oval.

- Ever years
- Few times a year
- Few times a month
- Few times a week
- Other:

Plant population growth

For plants that are not in anyone's garden or cultivation. Please choose one plant that you know. If you know both, please kindly submit two questionnaires at your convenience

11. Do you know this plant?

Mark only one oval.

- Yes
- No
- Maybe

12. Pyracantha. Have you ever eaten or saw someone feeding on this fruits?

Mark only one oval.

- Yes
- No
- Maybe

13. Pyracantha. If yes, did they swallow the seeds inside or throw them away?

Check all that apply.

- Swallow them
- Throw them away
- Crush them

14. Do you know of any populations nearby your town?

Mark only one oval.

- Yes
- No (Go to section 4)

15. If yes, how big is the population?

Mark only one oval.

- 1-5 plants
- 5-15 plants
- 15-30 plants
- >30
- plants

Other:

16. How has the number of plants been for the past years?

Mark only one oval.

- Increasing
- Same
- Decreasing
- Not
- sure

Other:

17. Comment

Plant uses

18. Have you or anyone that you know used/harvested this plants before

Mark only one oval.

- Yes
- No
- Maybe

19. If yes, which part(s) of the plant were used?

Check all that apply.

- [ ] Whole plant
- [ ] Roots
- [ ] Stem
- [ ] Leaves
- [ ] Fruits
- [ ] Other:

20. What were the collected part(s) used for?

Check all that apply.

- [ ] Wood
- [ ] To consume
- [ ] Sell
- [ ] Plant
- [ ] Other:

_____

21. Comment

_____

Management and impacts

For those who have these plants in the land they are associated with (e.g farm, conservation unit, estate....)

22. What type of land do you own or are you associated with?

Check all that apply.

- [ ] Animal
- [ ] farm Crop
- [ ] farm
- [ ] Conservation unit
- [ ] Holiday

Farm Other:

_____

23. If other, specify:

_____

24. Is this plant a problem in your area?

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Maybe

_____

25. If yes, explain impacts:

26. What methods do you use to control invasive alien plants

Check all that apply.

- [ ] Mechanical
- [ ] Chemical
- [ ] Biological
- [ ] Other:

27. If other, specify

28. How do you track control progress?

29. Is the control mechanism effective?

Mark only one oval.

- Yes
- No
- Maybe

30. Do you think the control mechanism can be improved?

Mark only one oval.

- Yes
- No
- Do not know

31. If yes, how?

32. Is the government assisting in any way in the control of the invasive plant species?

Mark only one oval.

- Yes
- No

33. If yes, how?

_____

34. If no, would you like any assistance from the government?

Mark only one oval.

- Yes
- No
- Maybe

35. If yes, what kind of assistance?

_____

36. Comment

_____

End of study

37. Would you like to contribute further to the study

Mark only one oval.

- Yes
- No
- Maybe

38. If yes, please write name and email address or phone number

_____

39. Thank you for your contribution! If you would like to contribute further to the study. Please include your email or contact numbers. Regards, Lehlohonolo Donald Adams,Ph.D. Candidate, South African National Biodiversity Institute& Centre for Functional Biodiversity, School of Life Sciences, University of KwaZulu-Natal, P/Bag X01, Scottsville, Pietermaritzburg, South Africa, 3209.