Rapid Communication

First record of *Leucanthemum vulgare* (Lam. 1778) (Asterales: Asteraceae), ox-eye daisy in Limpopo province of South Africa

Moleseng C. Moshobane[1,2], Joshua O. Olowoyo[2], Sylvie Kremer-Köhne[3] and Lorraine Middleton[2]

[1]*South African National Biodiversity Institute, Pretoria National Botanical Garden, 2 Cussonia Avenue, Brummeria, Silverton, 0184, South Africa*
[2]*Department of Biology and Environmental Sciences, Sefako Makgatho Health Sciences University, Ga-Rankuwa, South Africa*
[3]*Friends of the Haenertsburg Grasslands, South Africa*
**Corresponding author*
E-mail: *moshobanemc@gmail.com*

Citation: Moshobane MC, Olowoyo JO, Kremer-Köhne S, Middleton L (2022) First record of *Leucanthemum vulgare* (Lam. 1778) (Asterales: Asteraceae), ox-eye daisy in Limpopo province of South Africa. *BioInvasions Records* 11(1): 40–48, https://doi.org/10.3391/bir.2022.11.1.04

Received: 15 April 2021
Accepted: 11 August 2021
Published: 22 December 2021

Handling editor: Quentin John Groom
Thematic editor: Giuseppe Brundu

Abstract

Leucanthemum vulgare, Lam. (Asteraceae) (ox-eye daisy) is a perennial herb and an aggressive invader native to Eurasia. Today, the species is found in all continents except for Antarctica, and is an invasive in many countries. In this study, we present records of invading populations of *Leucanthemum vulgare* in the Limpopo province, South Africa, covering over 21.717 m^2 of critically endangered grassland. Management guidelines for *Leucanthemum vulgare* are provided.

Key words: invasive plant species, *Leucanthemum ircutianum*, *L. vulgare* aggregate, Haenertsburg

Introduction

Invasive alien species represent one of the major factors of global loss of biodiversity and disruption of natural ecosystems (Sala et al. 2009). The ox-eye daisy, *Leucanthemum vulgare*, Lam. (Asteraceae) is considered one of the invasive plant species with the greatest negative impact on global biodiversity (Ahmad et al. 2019a). *Leucanthemum vulgare* stricto sensu diploid (2n = 18) is closely related to *Leucanthemum ircutianum* (Turcz.) DC tetraploid (2n = 36) (Stutz et al. 2018), both are part of the *L. vulgare* species complex (*L. vulgare* aggregate), *L. ircutianum* is part of *L. vulgare* sensu lato, hereafter *Leucanthemum vulgare* s.l. (Greiner et al. 2012; Oberprieler et al. 2018). *Leucanthemum vulgare* is a perennial herb native to Eurasia, and an incredibly robust and widespread invasive species (Stutz et al. 2018; Ahmad et al. 2019a). It was introduced and naturalized into many countries around the globe (Clements et al. 2004; Stutz et al. 2018; Ahmad et al. 2019a), primarily for ornamental reasons, as a seed contaminant (Clements et al. 2004; McDougall et al. 2018), and for phytoremediation (Noori et al. 2018). Post introduction, *L. vulgare* tends to escape cultivation into the wild, where it establishes viable populations (Khuroo et al. 2010). The species has naturalised in most countries (Khuroo et al. 2010; McDougall

et al. 2018; Stutz et al. 2018; Ahmad et al. 2019a). Even in its natural range such as in Russia and Finland, for *L. vulgare* is regarded as an environmental weed (Jantunen and Saarinen 2002).

Leucanthemum vulgare is able to establish in a wide range of habitats, such as high-altitudinal mountainous landscapes (McDougall et al. 2018; Ahmad et al. 2019a), valleys (Khuroo et al. 2010), and disturbed areas like grazing pasture, open meadows, roadsides, and forest openings (Cofer et al. 2008; Stutz et al. 2016, 2018; McDougall et al. 2018; Ahmad et al. 2019a, b, c). The distribution of *L. vulgare* globally attests to this ability to easily spread and occupy this wide range of habitats. *Leucanthemum vulgare* poses a major threat to natural landscapes because its invasion reduces plant species diversity (Clements et al. 2004). *Leucanthemum vulgare* can also form dense, extensive populations in pastures where it is generally avoided by grazing cattle, and its shallow roots often promote soil erosion in areas it has invaded (Clements et al. 2004). A recent Species Distribution Modelling (SDM) study by Ahmad et al. (2019a), reported *L. vulgare* to have suitable habitats in only in the winter rainfall parts of South Africa. The finding of a thriving population in the north most part of South Africa is intriguing. In this study, the records of wild populations of *L. vulgare* invading the Woodbush Granite Grassland (WGG) in the Limpopo province, South Africa, are presented, as well as recommendations on how to manage the invasion.

Materials and methods

Multiple field surveys were conducted in the Haenertburg and surrounding areas of the Greater Tzaneen district municipality, in the Limpopo province, South Africa, in 2018–2019 (Moshobane et al in press). The purpose of the field surveys was to find and document the presence of invasive alien species in South Africa, with a special focus on species whose populations are limited or emerging invaders, in order to detect them early before the populations expand. This work was done as a programme of the Biological Invasions Directorate (formerly known as Invasive Species Programme) of the South African National Biodiversity Institute (SANBI) (Wilson et al. 2013). The recent major population of *L. vulgare* was reported by the third author, as the custodian of the WGG. The species was identified based on morphological features and verified by a Dr. Marinda Koekmoer taxonomist based at Pretoria National herbarium of the South African National Biodiversity Institute. Herbarium specimens were deposited at the Larry Leach Herbarium of the University of Limpopo (KRA 0529539, 0529545, 0529546). The occurrence map of *L. vulgare* in South Africa was prepared using the Herbarium records (Figures 1, 2) and records from Southern African Plant Invaders Atlas (SAPIA) records (Henderson 1998). The occurrence records for *L. vulgare* linked to preserved specimens (n = 16067) were obtained from the Global Biodiversity Information Facility (GBIF 2021, https://www.gbif.org) and they were used to produce habitat suitability map

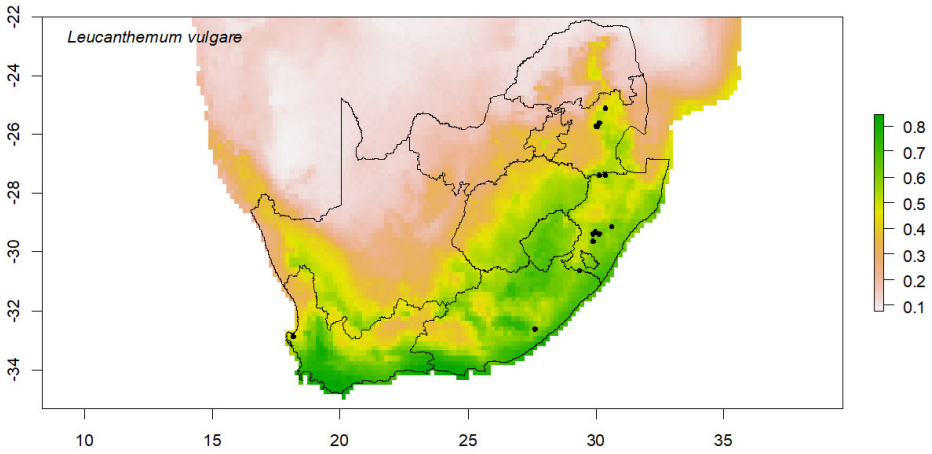

Figure 1. Habitat suitability map and distribution map for *L. vulgare* in South Africa (colour scale, 0.1 less suitable 0.8 more suitable). The black dots indicate the occurrence records of *L. vulgare* in South Africa.

Figure 2. Pretoria (PRE) herbarium specimen of *L. vulgare*, South Africa. Photograph by M. Mkhize.

for South Africa (Figure 1). The R-software version 3.6.4 (R Core Team 2020) R package sdm version 1.0–89 (Naimi and Araújo 2016), was used. We initially considered 19 bioclimatic variables that were downloaded from the WorldClim platform (www.worldclim.org) at approximately 1 km × 1 km spatial resolution (Fick and Hijmans 2017; Booth 2018). We validated the models by means of the Area Under the Curve (AUC) of a Receiver Operating Characteristic plot (ROC) (Fielding and Bell 1997), the True Skill Statistic (TSS) (Allouche et al. 2006) and the randomised correlation (COR) (Thuiller et al. 2009). Whereby, the AUC, An AUC value of 1 indicates perfect performance, whereas an AUC value of 0.5 indicates that the model performs no better than a random model. AUC > 0.7 generally indicates good model accuracy (Pearson et al. 2006), and A TSS value below 0 indicates a no better than random model performance, and a value of 1 indicates perfect performance (Allouche et al. 2006), and lastly COR values closer to 1 indicated which predictor variables contributed highly to the respective species suitability using the selected six methods (Thuiller et al. 2009). The present study considered three algorithms to test the performance of the model namely boosted regression tree (BRT: Friedman 2001), generalised linear model (GLM: McCullagh 1989), random forest (RF: Breiman 2001), and support vector machine (SVM: Vapnik 1995), maximum entropy (MaxEnt: Elith et al. 2006). In essence, the algorithms combines to the best fit the occurrence records and predictor variables to generate the model. The resultant map, is an indicator of habitat suitability (Phillips et al. 2006; Phillips and Dudík 2008).

Results and discussion

We found large populations of *L. vulgare* in two sites in Tzaneen district municipality, Limpopo province, South Africa. The first population was found in 2019 along the riverbed, on the R71 outside of Haenertsburg village. For the newly discovered populations of *L. vulgare*, which were found in October 2020 in the Haenertsburg graveyard, within the critically endangered Woodbush Granite Grassland (WGG), we estimated the occupied area to be 21.717 m^2, and the number of individuals to be 200 plants within the WGG. Despite the findings from Ahmad et al. (2019a), which indicated the suitable habitats to be only in the southern parts of South Africa, herbarium records indicate that the species occurs in six provinces (Supplementary material Appendix 1), the earliest record in South Africa was in 1884 in Kwa-Zulu Natal which is 950 km away from the reported point in Limpopo Province. The present study reports the most northern records of *L. vulgare*.

The discovery of *L. vulgare* in the WGG (Figure 3) is a great cause for concern because this species is a common grassland invader (Coulson et al. 2001). In particular, where *L. vulgare* invades, it spreads rapidly and significantly alters existing plant species' structure and composition, and

Figure 3. Invasion of *Leucanthemum vulgare* at Haenertburg graveyard and WGG: (A) Extent of invasion; (B) Spread from graveyard into WGG; and (C) Honeybee trapped by spider on *Leucanthemum vulgare* inflorescences. Photograph by M.C. Moshobane.

decreases species richness at all spatial scales (Ahmad et al. 2019b). Furthermore, Ahmad et al. (2019c) showed the significant impact of *L. vulgare* invasion on key soil properties such as soil organic carbon (OC) and total

Table 1. Results of evaluation of the performance of models. (AUC and TSS values closer to one indicate excellent model output) Methods performance run at 100 boostrap replication.

Models	AUC	COR	TSS	Deviance
BRT	0.92	0.72	0.75	0.53
GLM	0.86	0.61	0.64	0.52
SVM	0.95	0.86	0.85	0.27
RF	0.99	0.91	0.92	0.16
MaxEnt	0.95	0.82	0.80	0.88

nitrogen (N) between invaded and uninvaded areas. Upon inspection of inflorescences, beetles (coleoptera), butterflies (Lepidoptera), flies and mosquitoes (Diptera), ants (Hymenoptera), and bees (Hymenoptera) were found to visit the flowers of *L. vulgare*. Most notably were the spiders' traps, with a honeybee caught by a spider on one of the flowers found (Figure 3). These findings are consistent with other studies that have observed the same phenomenon (Suttle 2003).

The invasiveness of *L. vulgare* is widely reported in literature, and its invasive is noted in several countries around the world. The potential global invasiveness of this species is already established in a study by Ahmad et al. (2019a), as well as its impacts (Khuroo et al. 2010; Stutz et al. 2018; McDougall et al. 2018; Ahmad et al. 2019a, b, c). *Leucanthemum vulgare* is seen as one of the worst invasive alien species in protected areas across the globe (Foxcroft et al. 2017; McDougall et al. 2018; Ahmad et al. 2019a). For example, *L. vulgare* has invaded the Kosciuszko National Park in New South Wales (McDougall et al. 2018) and many other protected areas around the world (Foxcroft et al. 2017). The results obtained from different algorithms used for SDMs high excellent performance in projecting potential distribution of the target grass species (Table 1). The high values for AUC, TSS indicate the reliability of our models, and thus they were all incorporated into the ensemble models (Figure 1). The habitat suitability modelled in this study shows that the species has greater chances of expansion and it may colonise larger areas. The results show that *L. vulgare* has suitable areas in Limpopo province, this result is contrary to the findings reported by Ahmad et al. (2019a). This could be attributable to the algorithm used or the number of records included in the modelling.

Management

Initiating a rapid response and the development of an area based eradication and control strategy in order to curb the spread and associated impacts of this global invader (Clements et al. 2004; Ahmad et al. 2019b, c). Although mowing was shown to be ineffective in controlling *L. vulgare* as it is resistant to mowing (Wahlman and Milberg 2002), mowing may reduce seed production (Coulson et al. 2001). Root-feeding weevil *Cyphocleonus trisulcatus* Herbst is recommended as a biological control agent for *L. vulgare* (Stutz et al. 2020), and tribenuron is recommended as an effective herbicide (Olszyk et al. 2013). Therefore we recommend, both mowing and herbicide treatment.

In South Africa, invasive alien species are regulated under National Environmental Management: Biodiversity Act (NEMBA), which provides the list of invasive alien species (Moshobane et al. 2019). We recommend that this species should be listed in South Africa, possibly as category 1a, and that eradication plans be implemented.

The management implications of the present study are therefore especially relevant for:

(i) Preventing new introductions, through regulating the species in NEMBA regulations for invasive species.
(ii) Prioritizing controls on regulated species that could be placed on an eradication plan while the populations are still manageable at a low cost.
(iii) Educating the public about the regulations that manages invasive species.
(iv) Implementing an early detection and rapid response programme.
(v) Conduct a risk assessment.
(vi) Genetic analysis research should be conducted to ascertain the species identification.

Acknowledgements

The South African Department of Environment, Forestry, and Fisheries (DEFF) are thanked for funding, noting that this publication does not necessarily represent the views or opinions of DEFF or its employees. The study was financially supported by the Department of Botany at the Sefako Makgato Health Sciences University, the South African National Biodiversity Institute (SANBI), and Friends of Haenertsburg Grassland. Dr Marinda Koekemoer and Dr Bronwyn Egan are thanked for their support and identification of the species. Dr TC Shivambu is thanked for his assistance with aspects of this paper. The suggestions and comments of two anonymous reviewers and of the Handling Editor Quentin John Groom which greatly improved the manuscript.

Disclaimer

Any opinion, finding, and conclusion or recommendation expressed in this material is that of the author(s), and the funding agencies do not accept any liability in this regard.

References

Ahmad R, Khuroo AA, Charles B, Hamid M, Rashid I, Aravind NA (2019a) Global distribution modelling, invasion risk assessment and niche dynamics of *Leucanthemum vulgare* (Ox-eye Daisy) under climate change. *Scientific Reports* 9: 11395, https://doi.org/10.1038/s41598-019-47859-1

Ahmad R, Khuroo AA, Hamid M, Malik AH, Rashid I (2019b) Scale and season determine the magnitude of invasion impacts on plant communities. *Flora: Morphology, Distribution, Functional Ecology of Plants* 260: 151481, https://doi.org/10.1016/j.flora.2019.151481

Ahmad R, Khuroo AA, Hamid M, Rashid I (2019c) Plant invasion alters the physico-chemical dynamics of soil system: insights from invasive *Leucanthemum vulgare* in the Indian Himalaya. *Environmental Monitoring and Assessment* 191: 792, https://doi.org/10.1007/s10661-019-7683-x

Allouche O, Tsoar A, Kadmon R (2006) Assessing the accuracy of species distribution models: Prevalence, kappa and the true skill statistic (TSS). *Journal of Applied Ecology* 43: 1223–1232, https://doi.org/10.1111/j.1365-2664.2006.01214.x

Breiman L, Friedman J, Olshen RA, Stone CJ (1984) Classification and regression trees. Boca Raton London New York, Washington, D.C., 354 pp

Booth TH (2018) Why understanding the pioneering and continuing contributions of BIOCLIM to species distribution modelling is important. *Austral Ecology* 43: 852–860, https://doi.org/10.1111/aec.12628

Clements DR, Cole DE, Darbyshire S, King J, McClay A (2004) The biology of Canadian weeds. 128. *Leucanthemum vulgare* Lam. *Canadian Journal of Plant Science* 84: 343–363, https://doi.org/10.4141/P02-112

Cofer MS, Walck JL, Hidayati SN (2008) Species richness and exotic species invasion in middle Tennessee cedar glades in relation to abiotic and biotic factors. *Journal of the Torrey Botanical Society* 135: 540–553, https://doi.org/10.3159/08-RA-039.1

Coulson SJ, Bullock JM, Stevenson MJ, Pywell RF (2001) Colonization of grassland by sown species: Dispersal versus microsite limitation in responses to management. *Journal of Applied Ecology* 38: 204–216, https://doi.org/10.1046/j.1365-2664.2001.00585.x

Elith JH, Graham CP, Anderson R, Dudík M, Ferrier S, Guisan AJ, Hijmans R, Huettmann FR, Leathwick J, Lehmann A, Li JG, Lohmann LA, Loiselle B, Manion G, Moritz C, Nakamura M, Nakazawa Y, McC M, Overton J, Townsend Peterson AJ, Phillips S, Richardson K, Scachetti-Pereira RE, Schapire R, Soberón J, Williams SS, Wisz ME, Zimmermann N (2006) Novel methods improve prediction of species' distributions from occurrence data. *Ecography* 29: 129–151, https://doi.org/10.1111/j.2006.0906-7590.04596.x

Fick SE, Hijmans RJ, (2017) WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas. *International Journal of Climatology* 37: 4302–4315, https://doi.org/10.1002/joc.5086

Fielding AH, Bell JF (1997) A review of methods for the assessment of prediction errors in conservation presence/absence models. *Environmental Conservation* 24: 38–49, https://doi.org/10.1017/S0376892997000088

Foxcroft LC, Pyšek P, Richardson DM, Genovesi P, MacFadyen S (2017) Plant invasion science in protected areas: progress and priorities. *Biological Invasions* 19: 1353–1378, https://doi.org/10.1007/s10530-016-1367-z

Friedman JH (2001) Greedy function approximation: A gradient boosting machine. *Annals of Statistics* 29: 1189–1232, https://doi.org/10.1214/aos/1013203451

GBIF (2021) GBIF occurrence download, https://doi.org/10.15468/dl.eyqfxk (21 March 2021)

Greiner R, Vogt R, Oberprieler C (2012) Phylogenetic studies in the polyploid complex of the genus *Leucanthemum* Mill. (Compositae, Anthemideae) based on cpDNA sequence variation. *Plant Systematics and Evolution* 298: 1407–1414, https://doi.org/10.1007/s00606-012-0636-2

Henderson L (1998) Southern African Plant Invaders Atlas (SAPIA). *Applied Plant Science* 12: 31–32

Jantunen J, Saarinen K (2002) Vegetation of uncultivated arable land under different management in Finnish and Russian Karelia. *Agriculture, Ecosystems and Environment* 92: 225–233, https://doi.org/10.1016/S0167-8809(01)00289-4

Khuroo AA, Malik AH, ReshI ZA, Dar GH (2010) From ornamental to detrimental: Plant invasion of *Leucanthemum vulgare* Lam. (Ox-eye Daisy) in Kashmir valley, India. *Current Science* 98: 600–602

McCullagh P, Nelder JA (1989) Generalized linear models. 2nd edn. CRC, New York, 506 pp, https://doi.org/10.1007/978-1-4899-3242-6

McDougall K, Wright G, Peach E (2018) Coming to terms with Ox-eye Daisy (*Leucanthemum vulgare*) in Kosciuszko National Park, New South Wales. *Ecological Management and Restoration* 19: 4–13, https://doi.org/10.1111/emr.12296

Moshobane MC, Mukundamago M, Adu-Acheampong S, Shackleton R (2019) Development of alien and invasive taxa lists for regulation of biological invasions in South Africa. *Bothalia* 49: 1–12, https://doi.org/10.4102/abc.v49i1.2361

Moshobane MC, Olowoyo JO, and Lorraine Middleton L (2021) Alien plant species of Haenertsburg Village, Limpopo Province, South Africa. *BioInvasions Records* (*in press*)

Naimi B, Araújo MB (2016) sdm: A reproducible and extensible R platform for species distribution modelling. *Ecography* 39: 368–375, https://doi.org/10.1111/ecog.01881

Noori A, Zare Maivan H, Alaie E,Newman LA (2018) *Leucanthemum vulgare* Lam. crude oil phytoremediation. *International Journal of Phytoremediation* 20: 1292–1299, https://doi.org/10.1080/15226514.2015.1045122

Olszyk D, Blakeley-Smith M, Pfleeger T, Lee EH, Plocher M (2013) Effects of low levels of herbicides on prairie species of the Willamette Valley, Oregon. *Environmental Toxicology and Chemistry* 32: 2542–2551, https://doi.org/10.1002/etc.2331

Oberprieler C, Konowalik K, Fackelmann A, Vogt R (2018) Polyploid speciation across a suture zone: phylogeography and species delimitation in S French *Leucanthemum* Mill. representatives (Compositae-Anthemideae). *Plant Systematics and Evolution* 304: 1141–1155, https://doi.org/10.1007/s00606-018-1537-9

Pearson RG, Thuiller W, Araújo MB, Martinez-Meyer E, Brotons L, McClean C, Miles L, Segurado P, Dawson TP, Lees DC (2006) Model-based uncertainty in species range prediction. *Journal of Biogeography* 33: 1704–1711, https://doi.org/10.1111/j.1365-2699.2006.01460.x

Phillips SJ, Dudík M (2008) Modeling of species distribution with Maxent: new extensions and a comprehensive evalutation. *Ecography* 31: 161–175, https://doi.org/10.1111/j.0906-7590.2008.5203.x

Phillips SJ, Anderson RP, Schapire RE (2006) Maximum entropy modeling of species geographic distributions. *Ecological Modelling* 190: 231–259, https://doi.org/10.1016/j.ecolmodel.2005.03.026

R Core Team (2020) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. https://www.r-project.org/

Sala OE, Stuart Chapin F, III, Armesto JJ, Berlow E, Bloomfield J, Dirzo R, Huber-Sanwald E, Huenneke LF, Jackson RB, Kinzig A, Leemans R, Lodge DM, Mooney HA, Oesterheld M, Poff NL, Sykes MT, Walker BH, Walker M, Wall DH (2009) Global Biodiversity Scenarios for the Year 2100. *Science* 287: 1770–1774, https://doi.org/10.1126/science.287.5459.1770

Stutz S, Štajerová K, Hinz HL, Müller-Schärer H, Schaffner U (2016) Can enemy release explain the invasion success of the diploid *Leucanthemum vulgare* in North America? *Biological Invasions* 18: 2077–2091, https://doi.org/10.1007/s10530-016-1152-z

Stutz S, Mráz P, Hinz HL, Müller-Schärer H, Schaffner U (2018) Biological invasion of oxeye daisy (*Leucanthemum vulgare*) in North America: Preadaptation, post-introduction evolution, or both? *PLoS ONE* 13: 1–18, https://doi.org/10.1371/journal.pone.0190705

Stutz S, Hinz HL, Schaffner U (2020) Evaluation of *Cyphocleonus trisulcatus* (Coleoptera: Curculionidae) as a potential biological control agent for *Leucanthemum vulgare* in North America. *Journal of Applied Entomology* 144: 81–93, https://doi.org/10.1111/jen.12704

Suttle KB (2003) Pollinators as mediators of top-down effects on plants. *Ecology Letters* 6: 688–694, https://doi.org/10.1046/j.1461-0248.2003.00490.x

Thuiller W, Lafourcade B, Engler R, Araújo MB (2009) BIOMOD - A platform for ensemble forecasting of species distributions. *Ecography* 32: 369–373, https://doi.org/10.1111/j.1600-0587.2008.05742.x

Vapnik V (1995) The nature of statistical learning theory. 2nd edn. Springer, New York, 324 pp, https://doi.org/10.1007/978-1-4757-2440-0

Wahlman H, Milberg P (2002) Management of semi-natural grassland vegetation: Evaluation of a long-term experiment in southern Sweden. *Annales Botanici Fennici* 39: 159–166, https://www.jstor.org/stable/23726791

Wilson JRU, Nänni I, Wilson J (2013) A new national unit for invasive species detection, assessment and eradication planning. *South African Journal of Science* 109: 1–13, https://doi.org/10.1590/sajs.2013/20120111

Supplementary material

The following supplementary material is available for this article:

Table S1. Records of *L. vulgare* in South Africa..

This material is available as part of online article from:
http://www.reabic.net/journals/bir/2022/Supplements/BIR_2022_Moshobane_etal_1_SupplementaryMaterial.xlsx