

# BOTHALIA – African Biodiversity & Conservation



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# **BOTHALIA –** African Biodiversity & Conservation

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# Table of Contents

Information for Authors and Readers . . . . .	v
Reviewer Acknowledgement . . . . .	vi
<b>Original Research, Reviews, Strategies, Case Studies</b>	
<i>Pseudoplectania africana</i> (Sarcosomataceae, Pezizales), a new species from South Africa . . . . .	1
Z. Sochorová, M. Carbone, M. Sedlářová, A. Polhorský, M. Sochor	
Bothalia – African Biodiversity & Conservation, Volume 52(1). 7 March 2022	
Precipitation mediates termite functional diversity and dominance in southern Africa . . . . .	17
B.M. Lind, V.M. Uys, P. Eggleton, N.P. Hanan	
Bothalia – African Biodiversity & Conservation, Volume 52(1). 16 March 2022	
To be or not to be a protected area: a perverse political threat. . . . .	31
A. Blackmore	
Bothalia – African Biodiversity & Conservation, Volume 52(1). 18 March 2022	
A taxonomic revision of the <i>Othonna auriculifolia</i> Less. group (Asteraceae: Senecioneae: Othonninae). . .	41
S.L. Magoswana, J.S. Boatwright, A.R. Magee, J.C. Manning	
Bothalia – African Biodiversity & Conservation, Volume 52(1). 18 March 2022	
Ecological factors determining the distribution patterns of <i>Cyrtanthus nutans</i> R.A.Dyer (Amaryllidaceae) in northwestern KwaZulu-Natal, South Africa . . . . .	51
L.M. Ruddle, E.A. van Zyl, J. Jordaan	
Bothalia – African Biodiversity & Conservation, Volume 52(1). 30 March 2022	
New identifications of Lamiaceae (Lamioideae and Scutellarioideae) from D.R. Congo, Rwanda and Burundi. . . . .	57
P.J. Meerts	
Bothalia – African Biodiversity & Conservation, Volume 52(1). 30 May 2022	
<i>Arctotis gazanioides</i> (Asteraceae: Arctotideae), a new species from the Bokkeveld Plateau, Northern Cape Province, South Africa . . . . .	65
R.J. McKenzie, N.A. Helme	
Bothalia – African Biodiversity & Conservation, Volume 52(1). 2 June 2022	
Trends in plant ecology research in Ethiopia (1969–2019): a systematic analysis. . . . .	73
K. Gebrehiwot, S. Demissew	
Bothalia – African Biodiversity & Conservation, Volume 52(1). 18 July 2022	
<b>Nomenclatural Notes</b>	
New combinations in <i>Drimia</i> Jacq. ex Wild. (Hyacinthaceae: Urgineoideae) and an updated key to the southern Africa species . . . . .	89
J.C. Manning	
Bothalia – African Biodiversity & Conservation, Volume 52(1). 7 March 2022	
A new name for the illegitimate later homonym <i>Leonotis capensis</i> (Benth.) J.C.Manning & Goldblatt (Lamiaceae: Lamioideae). . . . .	97
J.C. Manning	
Bothalia – African Biodiversity & Conservation, Volume 52(1). 19 May 2022	

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New combinations in <i>Crystallopollen</i> Steetz (Asteraceae: Vernonieae), the correct name for the illegitimate <i>Polydora</i> Fenzl ex H.Rob. ....	99
J.C. Manning, R. Govaerts	
Bothalia – African Biodiversity & Conservation, Volume 52(1). 27 May 2022	
New infrageneric taxa in <i>Leucospermum</i> (Proteaaceae) and <i>Tetragonia</i> L. (Aizoaceae) and a new name in <i>Aizoon</i> subgenus <i>Galenia</i> (Aizoaceae) in southern Africa .....	103
J.C. Manning, C. Klak	
Bothalia – African Biodiversity & Conservation, Volume 52(1). 18 July 2022	
Guidelines for authors .....	108

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## *Focus and scope*

The journal aims to disseminate, to a wide audience, knowledge, information and innovative approaches that promote and enhance the wise use and management of biodiversity in order to sustain the systems and species that support and benefit the people of Africa.

The journal publishes original research findings, as well as reviews, commentaries or perspectives, strategies and short communications. Special focus issues emanating from symposia or conferences that fall within the scope of the journal may also be published.

Authors should contextualise submissions within the framework of the value chain of biodiversity knowledge from its generation, to its application and use. We are especially interested in articles that are written using language and terminology that is accessible to a wide audience.

Specifically, the scope of the journal covers the following areas:

1. Generation of new knowledge that provides a foundation for assessment, planning or management of biodiversity, including new taxonomic discoveries within Africa, from across all Kingdoms of organisms, documenting the abundance, diversity and distribution of genes, species and ecosystems in Africa (including temporal changes in these), and understanding the interactions among components of biodiversity that contribute to the functioning of ecosystems.
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4. Cross-cutting fields specifically developments and innovation in human capital development in the biodiversity sector and innovation in biodiversity information management and dissemination systems and tools for use of biodiversity information.
5. Strategic frameworks that provide guidance and direction for biodiversity research, assessment and management at community, local, national, regional or continental levels, especially those that

integrate biodiversity management with local and regional socio-economic systems.

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
The editorial team of *Bothalia – African Biodiversity & Conservation* recognises the value and importance of the peer reviewer in the overall publication process – not only in shaping the individual manuscripts, but also in shaping the credibility and reputation of our journal. We are committed to the timely publication of all original, innovative contributions submitted for publication. As such, the identification and selection of reviewers who have expertise and interest in the topics appropriate to each manuscript are essential elements in ensuring a timely, productive peer review process. We would like to take this opportunity to thank all reviewers who participated in shaping this volume of *Bothalia – African Biodiversity & Conservation*. We appreciate the time taken to perform your review(s).

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# *Pseudoplectania africana* (Sarcosomataceae, Pezizales), a new species from South Africa

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**Background:** An undescribed species of *Pseudoplectania* was found during an excursion in Mpumalanga.

**Objectives:** To describe *Pseudoplectania africana* M.Carbone & Sochorová as a new species and to evaluate presence of crystals as a diagnostic character in *Pseudoplectania*.

**Methods:** The description was based on standard macro- and microscopical methods. Presence of crystals was tested for in UV light. Phylogeny was inferred using sequencing of the LSU and ITS loci.

**Results:** *Pseudoplectania africana* is characterised by shortly stipitate to sessile apothecia up to 18 mm broad, richly developed basal tomentum, ascospores with an eccentrically positioned, relatively small sheath, straight, sometimes bifurcate paraphyses, wavy to coiled external hairs and presence of large yellow crystals mainly in the hymenium and ectal excipulum. It was found on a decaying coniferous trunk. The species forms a distinct lineage in the clade with *P. tasmanica* and *P. ericae*. All of these three species exhibited presence of the large yellow crystals (sulphur yellow in UV light). No or only small hyaline crystals (whole mount blue in UV light) were found in *P. nigrella*, *P. lignicola*, *P. epispagnum* and *P. melaena*.

**Conclusion:** The new species represents the first report of *Pseudoplectania* in South Africa and probably also in the whole of continental Africa. Crystals in hymenium and excipulum appear to be an important trait in *Pseudoplectania* taxonomy.

**Keywords:** Ascomycota; crystals; fungal diversity; phylogeny; taxonomy.

## Introduction

*Pseudoplectania* Fuckel, typified by *Pseudoplectania nigrella* (Pers.) Fuckel, is a genus of ascomycetes belonging to the family Sarcosomataceae Kobayasi. It includes species with hemispherical, cupulate to plane apothecia, which are sessile or stipitate, coloured in shades of black or brown, having the outer surface covered by brown to black hairs and reaching a size between ca. 0.5 and 6.0 cm in diameter. Typical microscopical characters of the species of *Pseudoplectania* are globose, hyaline, usually smooth, thick-walled ascospores, operculate, inamyloid, octosporic asci arising from simple septa, presence of two types of paraphyses (common ones and so called hymenial hairs), medulla organised as a *textura intricata*, ectal excipulum with a *t. globulosa* or *t. angularis* and thick-walled, septate but unbranched hairs with blunt apex (Eckblad 1968; Donadini 1987). Fruit bodies of *Pseudoplectania* occur on dead wood, in litter, on soil or *Sphagnum*.

Nine species have been accepted by Carbone et al. (2014), namely *Pseudoplectania nigrella*, *P. episphagnum* (J.Favre) M.Carbone, Agnello & P.Alvarado, *P. melaena* (Fr.) Sacc., *P. ericae* Donadini, *P. affinis* M.Carbone, Agnello & P.Alvarado, *P. tasmanica* M.Carbone, Agnello & P.Alvarado, *P. stygia* (Berk. & M.A.Curtis) Sacc., *P. carranzae* (Calonge & M.Mata) M.Carbone, Agnello & P.Alvarado and *P. ryvardeenii* Iturr., M.Mardones & H.Urbina. In 2015, *P. lignicola* Glejdura, Kučera, Lizoň & Kunca was described (Glejduara et al. 2015), and in 2020 *P. sinica* Qiao Zhang & Jie Zhang (Zhang & Zhang 2020). The first six species and *P. sinica* have already been characterised by molecular methods (Carbone et al. 2014; Zhang & Zhang 2020) whilst the other four have been described only by their morphology and ecology (Calonge & Mata 2002; Iturriaga et al. 2012; Carbone 2013; Glejdura et al. 2015). One more species belonging to this genus, *Pseudoplectania kumaonensis* Sanwal is regarded to be doubtful (Sanwal 1953; Carbone et al. 2014).

Many reports of *Pseudoplectania* have been published from different regions of the northern hemisphere (e.g. Seaver 1913; Otani 1973; Breitenbach & Kränzlin 1981; Donadini 1987; Kristiansen 1990; Lincoff 1997; Calonge & Mata 2002; Medardi 2006; Barseghyan & Wasser 2008; Pant & Prasad 2008; Iturriaga et al. 2012; Van Vooren et al. 2013; Deckerová & Šuhaj 2014; Glejdura et al. 2015; Uzun & Kaya 2018), while data from the southern hemisphere are much rarer (Le Gal 1953; Sandoval 2012; Carbone et al. 2014; Gates & Ratkowsky 2016). No literature reports documenting *Pseudoplectania* spp. from continental Africa are known to us, with only a single report from the island of Madagascar (Le Gal 1953). In March 2018, a rich population of *Pseudoplectania* was discovered in Mpumalanga, South Africa, which did not match phenotypic descriptions of any of the currently known species. Especially striking were large yellow crystals found during microscopical examination in hymenium and ectal excipulum, which had been reported so far only in *P. tasmanica* (Carbone et al. 2014).

The aim of the present article is to introduce *Pseudoplectania africana* sp. nov., compare it with other species of the genus and evaluate presence of crystals in available *Pseudoplectania* spp. collections.

## Material and methods

### Sample collection and observation

Description of macroscopical characters is based on fresh apothecia. Microscopical characters were studied in living (\*) cells and tissues and rehydrated material (†) at magnifications up to 1000×, using light microscopes Olympus CX41 and CX21. The following media were

used: tap water (H<sub>2</sub>O), 3% potassium hydroxide (KOH), Lugol's solution (IKI), Brilliant Cresyl Blue (CRB) and Lactic Acid Cotton Blue (LACB). Nuclei were visualised in rehydrated apothecia upon staining with DAPI (4',6-diamidino-2-phenylindole; 10 µg/mL, 10 min, room temperature, dark) and fluorescence signal excited by a mercury lamp was combined with transmission light channel (50:50) (Olympus BX60 with attached DP73 camera). Measurements of microscopical characters were made in tap water (if not otherwise stated) directly with an ocular micrometre scale or in photographs with the PIXIMÈTRE 5.10 software (Henriot & Cheype 2020). Diameter of ascospores is given as minimal measured value – arithmetic mean – maximal measured value; Q = length/width ratio; n = sample size. Crystals were studied in exsiccates. Their solubility in *P. africana* was tested in Melzer's reagent (MLZ), 60% ethanol, 9% hydrochloric acid (HCl) and 40% KOH. Their autofluorescence was tested using excitation by Jaxman U1C UV flashlight (3W UV LED Nichia, 365 nm), which radiation was applied to mounts obliquely from above.

### DNA extraction, PCR amplification and sequencing

DNA was extracted from dried apothecia using the CTAB method (Doyle & Doyle 1987). Sequence data were generated for two loci – internal transcribed spacers (ITS) of ribosomal DNA (ITS1–5.8S rDNA–ITS2 region) using primers ITS1F (Gardes & Bruns 1993) and ITS4 (White et al. 1990), and the large subunit of ribosomal DNA (LSU) using primers LR0R and LR6 (Vilgalys & Hester 1990). PCR was performed with Kapa polymerase (Kapa Biosystems), following a standard protocol with 37 cycles and annealing temperature of 56°C. The PCR products were purified by precipitation with polyethylene glycol (10% PEG 6000 and 1.25M NaCl in the precipitation mixture) and sequenced in both directions using the Sanger method (Macrogen Europe, The Netherlands).

### Phylogenetic analysis

Sequences of *Pseudoplectania africana* and all other available *Pseudoplectania* species were included in molecular analysis (Table 1), *Urnula craterium* (Schwein.) Fr. served as an outgroup. Sequences were assembled, edited and aligned in GENEIOUS 8.1.9 (Biomatters, New Zealand) using the MAFFT plugin (ver. 1.3.3), manually checked and corrected. Bayesian phylogeny inference for concatenated data was computed in MRBAYES (ver. 3.2.4; Ronquist et al. 2012) with 5×10<sup>6</sup> generations, sampling every 1000th tree, in two independent runs, each with 4 chains, first 50% (2.5×10<sup>6</sup>) generations were excluded as burn-in. The most suitable substitution model for each locus was determined in PARTITION-FINDER 2.1.1 (Lanfear et al. 2017) using the corrected AIC (AICc) and a greedy search. SYM+I+G was selected for ITS and GTR+I+G for LSU. Single-locus phylogenies

**Table 1.** List of collections used in the phylogenetic study together with their GenBank accession numbers. Sequences newly generated for this study in bold font.

Species	Identification code in GenBank	Country, collection date	Herbarium code	GenBank accession numbers	
				ITS	LSU
<i>Pseudoplectania affinis</i>	PDD 81842 (holotype)	New Zealand, 24 Nov. 2004	PDD 81842	JX669826	JX669865
<i>Pseudoplectania africana</i>	ZE59/18 (holotype)	South Africa, 5 Mar. 2018	PRM 954013	<b>MT496892</b>	<b>MT496884</b>
<i>Pseudoplectania episphagnum</i>	ERD 6456	Spain, 30 May 2015	PRM 954123	<b>MT502112</b>	<b>MT500571</b>
<i>Pseudoplectania episphagnum</i>	TUR 064171	Finland, 30 May 1948	TUR 064171	KF305712	-----
<i>Pseudoplectania episphagnum</i>	TUR 064173	Finland, 26 Jun. 1943	TUR 064173	KF305711	KF305724
<i>Pseudoplectania episphagnum</i>	G00566257 (isolectotype)	Switzerland, 20 May 1945	G00566257	-----	<b>MT782281</b>
<i>Pseudoplectania ericae</i>	MCVE 27581	Italy, 23 Dec. 2012	MCVE 27581	KF305721	KF305731
<i>Pseudoplectania ericae</i>	TUR-A 195789	Spain, 16 Jan. 2007	TUR-A 195789	JX669822	JX669862
<i>Pseudoplectania ericae</i>	TUR-A 195790	Spain, 17 Feb. 2010	TUR-A 195790	JX669823	JX669863
<i>Pseudoplectania ericae</i>	ZE1228/18	France, 28 Dec. 2015	PRM 954131	<b>MT476910</b>	<b>MT476900</b>
<i>Pseudoplectania ericae</i>	CA1/18	Greece, 17 Mar. 2018	PRM 954125	<b>MT476909</b>	<b>MT496885</b>
<i>Pseudoplectania ericae</i>	MCVE 31255	France, 2 Dec. 2019	MCVE 31255	<b>MT498082</b>	<b>MT491442</b>
<i>Pseudoplectania ericae</i>	MCVE 30339	Italy, 2 Jan. 2020	MCVE 30339	MT226749	-----
<i>Pseudoplectania ericae</i>	Sousa	Portugal, 9 Feb. 2019	pers. herb. E. Sousa	<b>MT498083</b>	-----
<i>Pseudoplectania lignicola</i>	HR89756 (paratype)	Czech Republic, 1 Apr. 2011	HR 89756	<b>MT496886</b>	<b>MT496882</b>
<i>Pseudoplectania lignicola</i>	SAV 105/17	Slovakia, 21 Apr. 2010	SAV 105/17	<b>MT496881</b>	<b>MT496883</b>
<i>Pseudoplectania lignicola</i>	MCVE 27580	Canada, 17 Jul. 2011	MCVE 27580	KF305713	KF305726
<i>Pseudoplectania lignicola</i>	TUR 172564	Finland, 06 Nov. 2004	TUR 172564	-----	JX669860
<i>Pseudoplectania melaena</i>	MCVE 27579	France, 07 Apr. 2008	MCVE 27579	KF305717	KF305728
<i>Pseudoplectania melaena</i>	TUR-A 198588	USA, 21 Apr. 2006	TUR-A 198588	KF305719	KF305729
<i>Pseudoplectania melaena</i>	NY 54130	USA, 5 Apr. 2008	NY 54130	KF305718	KF305730
<i>Pseudoplectania melaena</i>	NY 96459	USA, 12 May 1947	NY 96459	KF305720	-----
<i>Pseudoplectania nigrella</i>	MCVE 27396	Italy, 1 May 2009	MCVE 27396	KF305715	KF305725
<i>Pseudoplectania nigrella</i>	MCVE 27397	Italy, 31 May 2009	MCVE 27397	-----	<b>MT491441</b>
<i>Pseudoplectania nigrella</i>	MCVE 27582	Italy, 13 Apr. 2013	MCVE 27582	KF305716	KF305727
<i>Pseudoplectania nigrella</i>	TUR-A 198587	USA, 30 Apr. 1999	TUR-A 198587	KF305714	-----
<i>Pseudoplectania nigrella</i>	Fan & Guo 1500201	China, 15 Aug. 2015		KX394804	-----
<i>Pseudoplectania sinica</i>	LYS02 (holotype)	China, 13 May 2017	CGMCC 3.19892	MN396767	MN396768
<i>Pseudoplectania tasmanica</i>	MCVE 27583 (holotype)	Australia, 22 Dec. 2012	MCVE 27583	KF305722	KF305732
<i>Pseudoplectania tasmanica</i>	MCVE 27584	Australia, 22 Dec. 2012	MCVE 27584	KF305723	KF305733
<i>Urnula craterium</i>	30.15.291.11	France, 13 Jan. 2011	pers. herb. R. Dougoud 30.15.291.11	KF311230	KF305734

were computed with similar settings, only the temp parameter was set to 0.01 for ITS to improve chain mixing.

## Phylogenetic results

*P. africana* forms a distinct lineage in the clade with *P. tasmanica* and *P. ericae* (Figure 1). Although it clearly appears to be the closest (known) relative of the former species according to the ITS locus (Bayesian posterior probability, PP=0.93; Sup. Figure 1), LSU provided an ambiguous signal due to a lack of shared apomorphic SNP's in the clade, which resulted in clustering of *P. africana* and *P. ericae* with very low support (PP=0.8; Sup. Figure 2). Subsequently, the concatenated dataset did not provide a well-supported phylogeny in this clade either (Figure 1). However, branch lengths indicate relatively large divergence between the three species (sequence divergence  $\pm$  20% and 1.8% at ITS and LSU, respectively, between *P. africana* and *P. ericae*, and 21% and 1.7% between *P. africana* and *P. tasmanica*).

## Taxonomy

***Pseudoplectania africana*** M.Carbone & Sochorová, sp. nov. (Figures 2, 3, 4 A, B).

Mycobank MB 838266.

TYPE: SOUTH AFRICA, Mpumalanga: Ehlanzeni district, 8.3 km SSW of the NG Kerk in Sabie, 25°10'7.6"S /

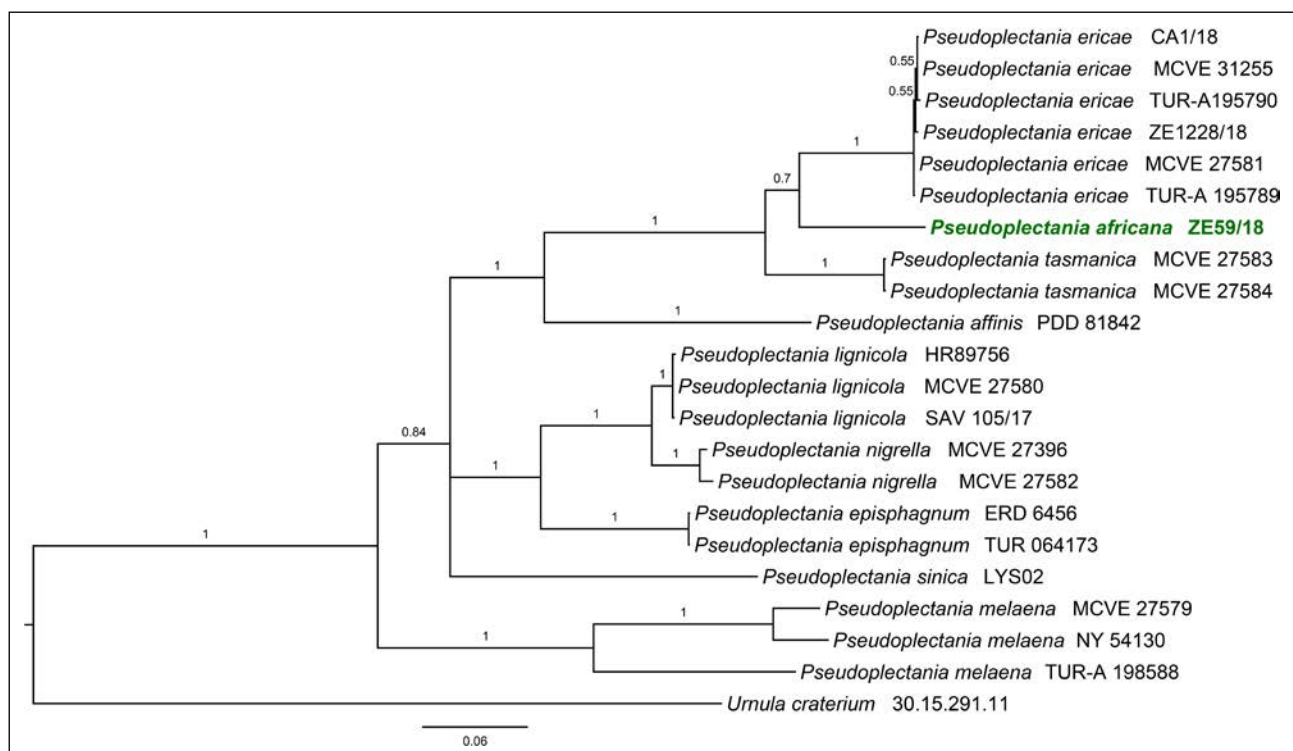
30°45'49.2"E, 1480 m asl, on a decaying trunk (probably *Pinus* sp.), 5 Mar. 2018, Z. Egertová (Sochorová) & M. Sochor (PRM 954013 – holotype, TUR-A 208915 – isotype, PREM - isotype).

**Diagnosis:** Differs from other *Pseudoplectania* species in a combination of the following characters: shortly stipitate or sessile, brown to black, sometimes olivaceous apothecia up to 18 mm in diameter, richly developed basal tomentum; smooth ascospores having an eccentrically positioned, relatively small sheath, straight, often bifurcate paraphyses, wavy to coiled external hairs and presence of large yellow crystals mainly in hymenium and ectal excipulum.

**Etymology:** From the Latin adjective '*Africanus-a-um*', referring to the African continent.

**Description:** Apothecia up to 18 mm in diameter, hemispherical or cup-shaped, becoming flattened, often irregularly deformed by a mutual pressure, shortly stipitate or sessile. Hymenium smooth, shiny, brown to brownish black, in some apothecia with an olivaceous tinge. External surface tomentose, brownish black, darker than the hymenium, base with a richly developed black tomentum. Stipe short or lacking, up to 3 mm long and 2 mm wide, black. Flesh pale greyish, rubbery. Occurring in groups or clusters.

Ascospores in H<sub>2</sub>O<sup>+</sup> globose, 10.5–11.4–13  $\mu$ m (n = 100); in H<sub>2</sub>O<sup>+</sup> globose or rarely subglobose, 9–10.7–13  $\mu$ m (n = 100), Q = 1.00–1.06; in heated LACB<sup>+</sup> globose



**Figure 1.** Bayesian phylogeny inference based on concatenated alignment of LSU and ITS sequences. Bayesian posterior probabilities are shown above branches; *Urnula craterium* serves as an outgroup.

or less often subglobose, 9–10.7–13  $\mu\text{m}$  ( $n = 100$ ),  $Q = 1.00\text{--}1.08$ ; hyaline, smooth, thick-walled, with vacuolar content, 1–4 nucleate, surrounded by an eccentrically arranged globose membranous sheath, which in its most convex part exceeds the spore wall for up to 2  $\mu\text{m}$ ; de Bary bubbles induced in heated LACB; ascospores germinating with one hypha. *Asci* narrowly cylindrical,  $^{\dagger}250\text{--}340 \times 11\text{--}14 \mu\text{m}$ , operculate, operculum  $^{\dagger}4.5\text{--}6 \mu\text{m}$  broad; inamyloid, 8-spored, *pars sporifera*  $^{\dagger}75\text{--}83 \mu\text{m}$  when all 8 ascospores are fully developed, base flexuous, tapered, arising from simple septa. *Paraphyses* of two types: 1) cylindrical, apical cell  $^{\dagger}12\text{--}29 \times 2\text{--}3.5 \mu\text{m}$ , lower cells  $^{\dagger}1\text{--}2.5 \mu\text{m}$  in diam., septate, branched, sometimes anastomosing with paraphyses of the same type or with the hymenial hairs, light brownish in the upper half; apex slightly enlarged, simple, bifurcate or less often diverticulate to lobed; some paraphyses showing short diverticula growing from the lower elements; 2) so called hymenial hairs cylindrical, measuring  $^{\dagger}2\text{--}3 \mu\text{m}$  in diam., very light brownish, with a single septum at the base; apex straight, hooked or bent in right or obtuse angle,  $^{\dagger}2\text{--}3 \mu\text{m}$  broad; cytoplasm in both types cyanophilic, walls cyanophobic. *Crystals* in hymenium very abundant, yellow, angular, cracked, sometimes very long (to over the whole thickness of hymenium), up to 60  $\mu\text{m}$  wide, oriented with their long axis like the hymenium, not dissolving in KOH (40%), HCl (9%), ethanol (60%) and MLZ. *Subhymenium*  $^{\dagger}25\text{--}55 \mu\text{m}$  thick, structured as a dense *textura intricata* with cylindrical septate hyphae. *Medullary excipulum*  $^{\dagger}200\text{--}380 \mu\text{m}$  thick at flanks, formed by a slightly gelified *textura intricata*, hyphae cylindrical, septate, subhyaline,  $^{\dagger}2\text{--}12 \mu\text{m}$  wide,  $^{\dagger}1.5\text{--}6.5 \mu\text{m}$  wide, walls up to 0.8  $\mu\text{m}$  thick; cytoplasm cyanophilic, walls cyanophobic. *Ectal excipulum*  $^{\dagger}40\text{--}120 \mu\text{m}$  thick, composed of a *textura globulosa-angularis*, cells thick-walled, in the inner layer subhyaline,  $^{\dagger}(7)12\text{--}24 \times (5)12\text{--}21 \mu\text{m}$ , in the 2–4 most external rows with blackish-brown walls,  $^{\dagger}5\text{--}15 \times 4\text{--}12 \mu\text{m}$ , walls cyanophobic; containing crystals of the same character like in hymenium, but smaller. *External hairs* emerging from the external layer of the ectal excipulum, cylindrical,  $^{\dagger}$ ca. 500–3000  $\mu\text{m}$  long, 5–8(–10)  $\mu\text{m}$  diam., with walls up to 1.5  $\mu\text{m}$  thick, septate, wavy or coiled; brown, unbranched, with blunt apex. Many very small hairs, up to  $^{\dagger}30 \mu\text{m}$  long, are present among the longer ones. *Basal tomentum* composed of very long cylindrical hairs looking similar to the external hairs,  $^{\dagger}5\text{--}7 \mu\text{m}$  diam., walls up to 1.1  $\mu\text{m}$  thick. Section in UV light – most of structures blue (subhymenium paler than hymenium, medulla and ectal excipulum), outline of ascospores whitish, external hairs and basal tomentum black, crystals sulphur yellow.

**Habitat and distribution:** The apothecia grew in a forest patch surrounded by logged pine plantations, on a decaying mossy trunk. Microscopical examination of the substrate showed a typical structure of a conifer wood. Resin canals further indicated the substrate was

most likely *Pinus* sp. (alien in South Africa; Van Wyk & Van Wyk 2013).

The species is so far known and confirmed only from the type locality. Although no *Pseudoplectania* species have been reported in the checklist of macrofungi of South Africa (Kinge et al. 2020), we are aware of the existence of four collections identified as *Pseudoplectania nigrella* housed in the PREM fungarium (R. Venter-Jacobs pers. comm.). Unfortunately, our attempts to loan these specimens for verification of their identification have not been successful.

## Evaluation of presence of the crystals and appearance in UV light

Beside *P. africana* (Figures 3A–C, Figures 4A, B), large yellow crystals have been confirmed in *P. tasmanica* (Figures 4D, F, G) and newly found in *P. ericae* (Figures 4C, E, H), i.e. the three closely related species. The crystals are located mostly in the hymenium and ectal excipulum, less so in the medullary excipulum or subhymenium, and appear sulphur yellow in UV light. Hymenium, subhymenium, medullary and ectal excipulum are in shades of blue, outline of ascospores whitish and hairs and basal tomentum black. All other species available for our study (*P. episphagnum*, *P. lignicola*, *P. melaena* and *P. nigrella*) lack these crystals; they contain only small hyaline crystals, which are most abundant in the medulla, but occur also in the hymenium, subhymenium and ectal excipulum. Therefore, the whole slide has shades of blue in UV light, only the outline of the ascospores is whitish with hairs and tomentum black (Figure 5). The quantity of crystals varies strongly between collections. In some of them, including the neotype of *P. nigrella* (KL BK-4914), aggregates of the crystals can be found, which look pale blue in UV light. As already mentioned in the material and methods chapter, studies on crystals have been performed on dry material. Whether the crystals are also present in vital collections is yet to be verified. Collections of *P. affinis*, *P. carranzae*, *P. rywardenii*, *P. sinica* and *P. stygia* were not available.

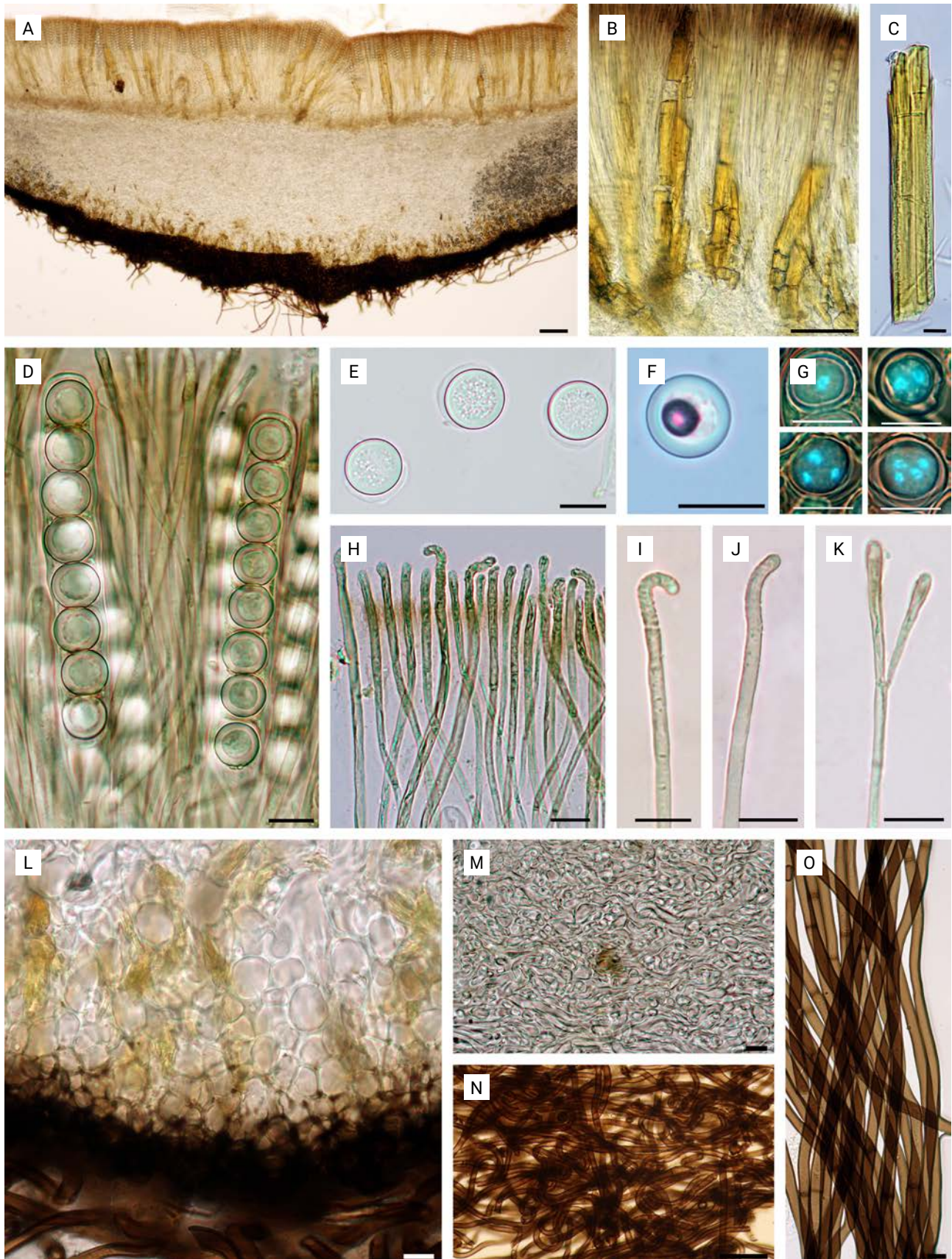
## Additional collections examined (collections studied for presence of crystals marked ☀):

### *Pseudoplectania episphagnum*

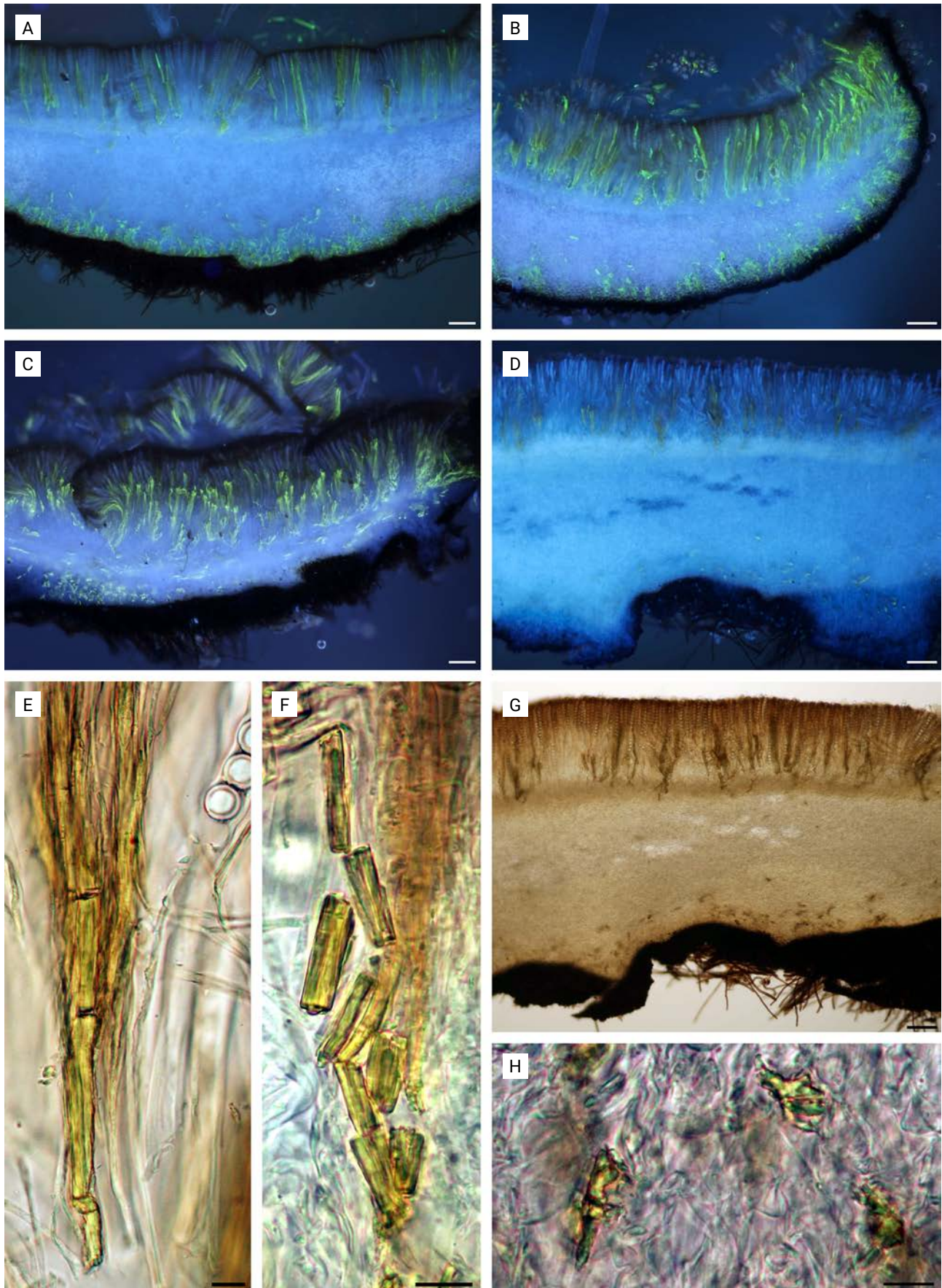
FINLAND, Lapland: Ranua, 6 km N of the church, on *Sphagnum fuscum* in a bog, 26 Jun. 1943, leg. A.V.



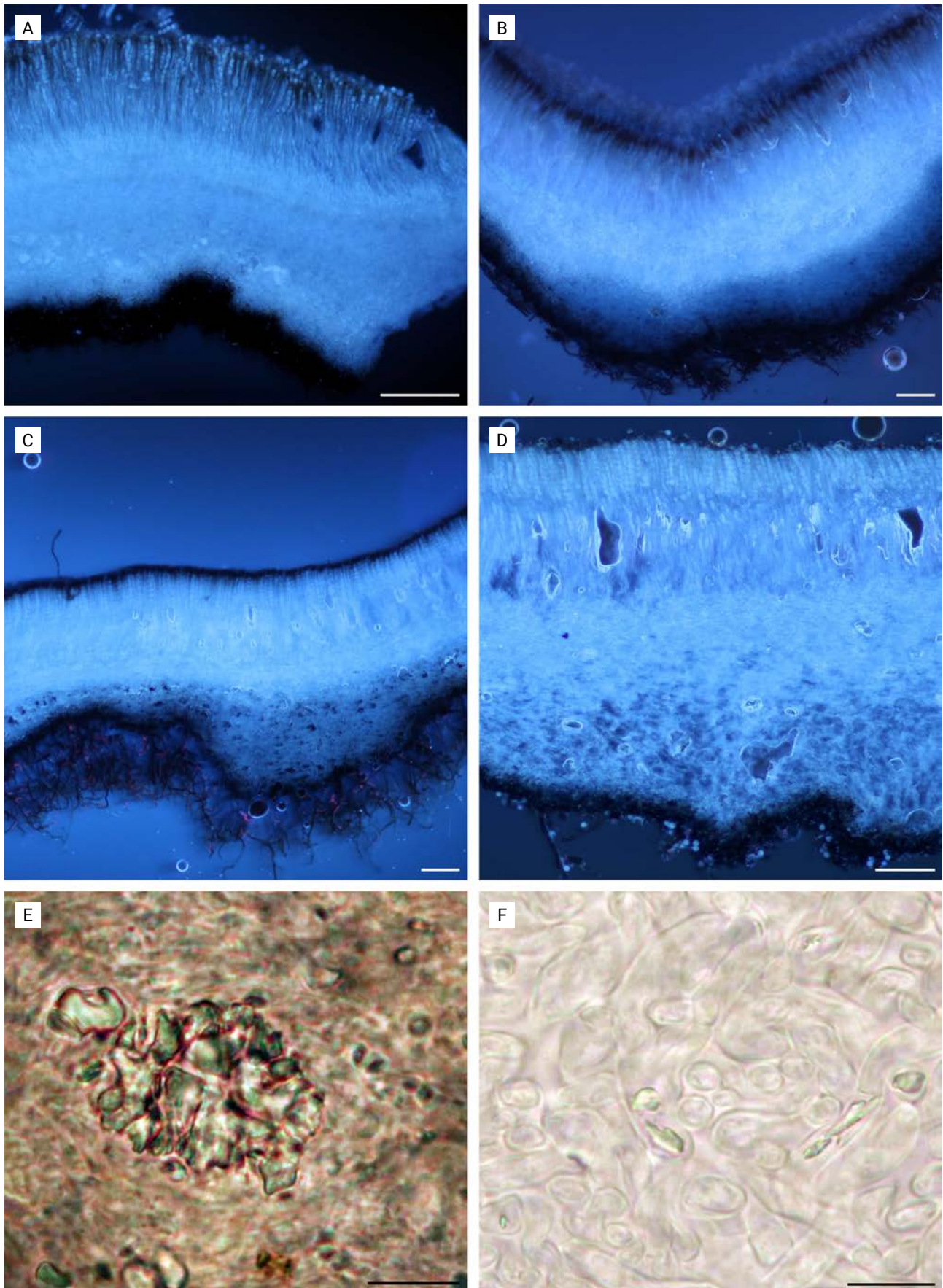
**Figure 2.** *Pseudoplectania africana* – apothecia *in situ* (PRM 954013). Photos: Z. Sochorová.



**Figure 3.** *Pseudoplectania africana* – microscopical characters (PRM 954013); A, section of an apothecium († in tap water); B, crystals in hymenium (in tap water); C, crystal freely floating in the mount (in tap water); D, asci with ascospores and paraphyses († in tap water); E, free ascospores († in tap water); F, ascospore with de Bary bubble († stained with LACB); G, nuclei in ascospores († stained with DAPI); H, two types of paraphyses († in tap water); I, J, hymental hairs († in tap water); K, bifurcate paraphyse († in tap water); L, ectal excipulum († in tap water); M, medullary excipulum († in tap water); N, external hairs († in tap water); O, basal tomentum († in tap water). Scale bars: A = 100  $\mu\text{m}$ ; B, N = 50  $\mu\text{m}$ , C–M, O = 10  $\mu\text{m}$ . Photos: A–F, H–O, Z. Sochorová; G, M. Sedlářová.



**Figure 4.** *Pseudoplectania* spp. – crystals and appearance in UV light; A,B, *P. africana* (PRM 954013) – sections in UV light; C,E,H, *P. ericae* – C, section in UV light (PRM 954125); E, crystals in hymenium (PRM 954124, in tap water); H, crystals in ectal excipulum (PRM 954124, in tap water); D, F, G, *P. tasmanica* (MCVE 27583); D, section in UV light; F, crystals in hymenium (in tap water); G, section of the apothecium (in tap water). Scale bars: A–D, G = 100  $\mu\text{m}$ ; E, F, H = 10  $\mu\text{m}$



**Figure 5.** *Pseudoplectania* spp. – crystals and appearance in UV light; A,E,F, *P. nigrella*; A, section in UV light (KL BK-4914); E, aggregate of crystals in excipulum (KL BK-4914, in tap water); F, crystals in excipulum (BRNM 728214, in tap water); B, *P. lignicola* (PRM 954130) – section in UV light; C, *P. episphagnum* (PRM 954123) – section in UV light; D, *P. melaena* (BRNM 705053) – section in UV light. Scale bars: A = 200  $\mu\text{m}$ ; B–D = 100  $\mu\text{m}$ , E, F = 10  $\mu\text{m}$

Auer, det. T. Ulvinen (TUR 064173 – as *Pseudoplectania sphagnophila*, PRM 954134);

SPAIN, Asturias: Santa María del Puerto, Vega Cimera, on *Sphagnum* sp., 30 May 2015, leg. P. Zapico, det. E. Rubio (PRM 954123 ☼).

SWITZERLAND, Vaud: Le Chenit, Le Sentier, vallée de Joux, among *Sphagnum* sp., 20 May 1945, leg. et det. J. Favre (G00566257 – isoelectotype ☼).

### *Pseudoplectania ericae*

FRANCE, Var: Hyères, Porquerolles island, under *Erica arborea* and *Cistus* sp., 28 Dec. 2015, leg. J.-M. Moinjeon, det. G. Moyne (PRM 954131 ☼); Pyrénées-Orientales: Argelès-sur-Mer, close to Château de Valmy, under *Erica arborea*, 2 Dec. 2019, leg. et det. M. Gomez (MCVE 31255);

GREECE, Chalkidiki: Ierissos, Gavriadia, under *Erica* cf. *manipuliflora*, 17 Mar. 2018, leg. et det. C. Agnello (PRM 954125 ☼).

ITALY, Liguria: Genova, Sestri Levante, Punta Baffe, in the ground on roots and buried sticks of *Erica arborea*, 23 Dec. 2012, leg. et det. M. Carbone & F. Boccardo (MCVE 27581, PRM 954132 ☼).

PORTUGAL, Norte Region: Oleiros, Vila Verde, under *Erica* sp., 9 Feb. 2019, E. Sousa (pers. herb.).

SPAIN, Cáceres: Talayuela, 8 Feb. 2013, on sandy soil, leg. et det. E. Rubio (PRM 954124 ☼)

### *Pseudoplectania lignicola*

CANADA, British Columbia: Fernie, Island Lake, on rotting and mossy wood of conifers, 17 Jul. 2011, leg. J. Harnisch, det. M. Carbone & C. Agnello (MCVE 27580 as *P. nigrella*).

CZECH REPUBLIC, Hradec Králové Region: Nový Hradec Králové, 50°10'45"N / 15°54'15"E, 260 m asl, among *Leucobryum glaucum* in a mixed forest of *Picea abies* and *Pinus sylvestris*, 1 Apr. 2011, leg. Z. Egertová & M. Sochor, det. S. Glejdura (HR 89756 - paratype ☼); Karlovy Vary Region: Vysoká u Staré Vody, 49°59'10"N / 12°31'51"E, 680 m asl, on an old twig and on needles among twigs, in a *Picea* monoculture, 6 May 2017, leg. M. Tauš, det. L. Zíbarová (HR B000901 ☼); ibid., 29 Mar. 2018, leg. M. Tauš, det. V. Halasů (PRM 954130 ☼); Liberec Region: Hamr na Jezeře, 50°40'58.5"N / 14°51'35.9"E, 360 m asl, in a relict *Pinus* forest, 20 Mar. 2020, leg. J. Štátný, det. V. Halasů (PRM 954129 ☼).

FINLAND, Varsinais-Suomi: Perniö, Mutainen, on a mossy stump of *Picea abies*, 6 Nov. 2004, leg. S. Tuominen, det. S. Huhtinen (TUR 172564, as *P. nigrella*).

SLOVAKIA, Banská Bystrica Region: Nízke Tatry Mts., ca 3 km N of Hiadel' village, 48°50'7.38"N / 19°18'39.84"E, 700 m asl, in a mixed forest (*Picea abies*, *Abies alba*, *Larix decidua*), on wood of *Abies alba*, 21 Apr. 2010, leg. et det. V. Kučera (SAV 105/17); Žilina Region: Zuberec – 1.9 km E of the St. Vendelín church, on the ground, in moss, on strongly rotten *Picea abies* trunk and immersed branches in moss, 49°15'34.4"N / 19°38'20.7"E, 825 m asl, 1 Apr. 2017, leg. M. Krivuš, det. A. Polhorský (pers. herb. A. Polhorský, AP17109 ☼).

### *Pseudoplectania melaena*

CZECH REPUBLIC, Moravian-Silesian Region: Bílá, Salajka, 850 m asl, on a dead *Abies* trunk covered with mosses, 30 Jun. 1971, leg. et det. J. Kuthan (BRA CR33022 ☼); South Bohemian Region: Pivonice u Pohorské Vsi, Žofínský prales NNR, on a decaying stem of *Abies alba*, in a mixed forest with *Picea abies*, *Abies alba* and *Fagus sylvatica*, 9 Apr. 2008, leg. J. Hlásek, det. P. Špinar (CB 17686 ☼, BRNM 739398 ☼); South Moravian Region: Adamov, Křtinský potok valley, on a decaying trunk of *Abies alba*, 15 Apr. 1951, leg. F. Valkoun, det. F. Šmarda, rev. J. Moravec (BRNM 705053 ☼).

ITALY, Veneto: Belluno, Bosco del Cansiglio, on mossy dead wood of *Abies alba*, 25 Mar. 2012, leg. et det. E. Campo & M. Carbone (MCVE 27433, PRM 954133).

### *Pseudoplectania nigrella*

AUSTRIA, Carinthia: Bodental, in *Picea abies* forest, 1050 m asl, 18 May 1976, leg. et det. H. Engel (KL BK-4914 – neotype ☼, PRM 954135 ☼).

CZECH REPUBLIC, Central Bohemian Region: Borovsko, 49°41'8.3"N / 15°6'42.9"E, 410 m asl, on the ground among moss, 28 Mar. 2016, leg. P. Včelička, det. V. Halasů (PRM 954128 ☼); Nová Ves pod Pleší, 750 m NNE of the Dolní Jezberná hill, 49°48'55.4"N / 14°14'27.2"E, 360 m asl, in a coniferous forest with *Picea*, *Pinus* and *Abies*, 2 Apr. 2018, leg. P. Včelička, det. V. Halasů (PRM 954126 ☼); Region of Vysočina: Jívoví, Šebeň, 49°24'32"N / 16°03'47"E, 560–626 m asl, under *Picea* and *Corylus*, 25 Mar. 2015, leg. V. Antonín et al., det. H. Ševčíková (BRNM 766905 ☼); South Bohemian Region: Třitím, Hněvkovický les, 49°10'49"N / 14°28'23"E, 445 m asl, on *Picea* needles among moss, 21 Mar. 2018, leg. M. Kofroňová, det. V. Halasů (PRM 954127 ☼); South Moravian Region: Borotín u Boskovic, Borotínské čihadlo, NW of the village, 400–480 m asl, in moss and needles on the ground, 18 May 1996, leg. et det. J. Vágner (BRNM 603997 ☼); Brumov u Lomnice, 600 m asl, in moss under *Alnus* sp. and *Picea abies*, 15 Apr. 2000, leg. et det. Z. Bieberová (BRNM 728142 ☼); Rudice, Seč quarry, 49°20'22"N / 16°43'33"E, on the ground under *Picea abies* and *Pinus sylvatica*, 4 Apr. 2019, leg. et det. V. Antonín & H. Ševčíková (BRNM 815866 ☼); Žďárec, 2000 m SE of the church, 460 m

asl, in moss under *Picea*, 17 Apr. 2005, leg. et det. Z. Bieberová (BRNM 728214 ☼).

ITALY, Valle d'Aosta: Morgex (AO), Arpy, on rotten mossy wood of *Picea abies*, 31 May 2009, M. Carbone (MCVE 27397).

SLOVAKIA, Trnava Region: Lakšárska Nová Ves - Bežniško military area, 200 m asl, in mosses on sandy soil, 25 Apr. 2008, leg. et det. V. Kučera (BRA CR14162 ☼); Žilina Region: Oravská Polhora – Slaná Voda, in a swampy *Picea* forest with *Sphagnum*, 200 m asl, 26 Apr. 2011, leg. I. Kautmanová, det. S. Glejdura (BRA CR17264 ☼); Pribylina, Podbanské, Hrdovo, behind the Kokavský bridge, in moss in a *Picea* forest, 27 Apr. 2011, leg. et det. I. Kautmanová (BRA CR17270 ☼).

### *Pseudoplectania tasmanica*

AUSTRALIA, Tasmania: Duckhole Lake, on mossy wood, 22 Dec. 2012, leg. G. Gates (MCVE 27583 – holotype ☼).

## Discussion

Apart from molecular analyses, delimitation of species within the genus *Pseudoplectania* is possible only through a combination of their ecology and morphological characters. The most recent key (Carbone et al. 2014) places emphasis mainly on the substrate, geography, size of apothecia, presence/absence of stipe and eventually its length, shape and furcation of paraphyses and the character of external hairs. Ascospores seem to be of a low importance being globose, hyaline, smooth (with an exception of *P. rywardenii*) and in the same size range (9.0–13.5  $\mu\text{m}$ ) in all known species. Glejdura et al. (2015) introduced the position of the membranous sheath surrounding the ascospores as a new diagnostic character. It seems that not only the position, but also the size of the sheath has a taxonomic value, although information on this character is lacking in some species. *Pseudoplectania africana* and the two phylogenetically closest species *P. tasmanica* and *P. ericae* share an eccentrically positioned sheath, which is distinctly smaller than in *P. nigrella*, *P. lignicola* and *P. melaena* [compare illustrations in Glejdura et al. (2015), Carbone et al. (2014), Rubio et al. (2013) and this paper]. Another important character shared by *P. africana*, *P. tasmanica* and *P. ericae* is the large yellow crystals located mainly in hymenium and ectal excipulum, appearing sulphur yellow in UV light.

*Pseudoplectania africana*, beside its genetic profile, can be characterised by the following main features: shortly stipitate or sessile apothecia, ascospores surrounded by a relatively small, eccentrically arranged membranous sheath and presence of large yellow crystals especially in the hymenium and ectal excipulum. So far, it is probably the only species of *Pseudoplectania* reported

from continental Africa. In the following, comparison of *P. africana* with other species of the genus is provided.

*Pseudoplectania ericae* differs in smaller apothecia, which do not exceed 1 cm in diameter, bi- to often trifurcate tips of paraphyses and wavy to straight external hairs (e.g. Donadini 1987; Pérez-De-Gregorio et al. 2009; Domergue 2012; Boccardo et al. 2014; Carbone et al. 2014; Uzun & Kaya 2018; Basso et al. 2019). It is a Mediterranean species typically growing on (or close to) roots of *Erica arborea*. It has been reported from France (Domergue 2012), Italy (Donadini 1987; Boccardo et al. 2014; Basso et al. 2019) including Sicily (Saitta 2020), Spain (Pérez-De-Gregorio et al. 2009; Rubio et al. 2013) including the Canary Islands (Ribes et al. 2015), and Turkey (Uzun & Kaya 2018), and molecular data have been available only for the Spanish and Italian collections. In the present study we have added French, Greek and Portuguese collections as well as a topotype collection from Porquerolles Island (France).

*Pseudoplectania tasmanica*, described from Tasmania (Australia), shares most of the microscopical features with *P. ericae*, but has apothecia up to 3 cm in diameter. Beside larger and darker apothecia it differs from *P. africana* in straight external hairs and sometimes trifurcate paraphyses (Carbone et al. 2014).

*Pseudoplectania affinis*, described from New Zealand, can be distinguished mainly due to the straight external hairs in combination with a very diverticulated apex of the paraphyses and lack of large yellow crystals (Carbone et al. 2014).

*Pseudoplectania melaena* (in its wide sense including the American *Peziza spongiosa* Peck) can be easily distinguished due to much larger apothecia (up to 6 cm in diameter), usually longer stipe, larger ascospore sheath (judging freshly ejected ascospores), often hooked paraphyses, straight external hairs, absence of large yellow crystals and growth on mossy decayed *Abies* trunks (Van Vooren et al. 2013, Carbone et al. 2014).

*Pseudoplectania nigrella* differs in somewhat darker apothecia, larger ascospore sheath and absence of large yellow crystals. It is a common vernal species in the northern hemisphere inhabiting mossy soil and trunks of conifers, mainly *Picea abies* (Carbone & Agnello 2012). As stressed by Carbone et al. (2014), *P. nigrella* most likely constitutes a complex of species, which are difficult to circumscribe at the current state of knowledge. At present we continue to follow Carbone et al. (2014) because a more detailed phylogenetic analysis conducted on this clade (data not shown here) seems to confirm the difficulty in separating the numerous lineages at species level.

*Pseudoplectania lignicola* differs from *P. africana* especially in its ascospores having a distinctly larger, centrally positioned sheath and by the absence of large

yellow crystals. The species was reported from Slovakia and Czechia and distinguished from *P. nigrella* based on morphology and ecology. Our phylogenetic analysis included a collection of *P. lignicola* from the type locality in Slovakia and the paratype collection from Czechia, and confirmed the species belongs to the intricate *nigrella*-clade. Two collections (TUR 172564 from Finland and MCV 27580 from Canada) previously sequenced and determined as *P. nigrella* (Carbone et al. 2014), fall into the *lignicola*-lineage as well. Re-examination of MCV 27580 has shown that a few ascospores (the most immature) were surrounded by a centrally arranged globose membranous sheath, which is a characteristic feature of *P. lignicola*.

*Pseudoplectania stygia*, reviewed by Carbone (2013), clearly belongs to the *P. nigrella* clade, but recent material collected from the type locality is needed to clarify its concept also from a phylogenetic point of view.

*Pseudoplectania episphagnum* is a sister species of *P. nigrella*, with which it shares many microscopical features (e.g. the coiled external hairs). It can be distinguished from *P. africana* by its ecology (growth in bogs on *Sphagnum* spp.), size of apothecia usually smaller than 1 cm, mostly bent paraphyses tips (Favre 1948; Kreisel 1962; Dennis 1969; Ulvinen 1976; Breitenbach & Kränzlin 1981; Kristiansen 1990; Bauer 1999; Dissing & Eckblad 2000; Spooner 2002; Carbone et al. 2014) and absence of large yellow crystals. In the tested specimens no or only very few hyaline crystals were found. In our study, LSU sequence of the isolectotype collection housed in the Conservatoire et Jardin botaniques de la Ville de Genève (G00566257; see Carbone & Agnello 2015) was obtained, and an additional specimen from Spain was analysed. The isolectotype collection is identical in LSU with the collections from Spain and Finland.

*Pseudoplectania sinica* has recently been described from China (Zhang & Zhang 2020) based on its asexual morph. Morphological comparison with *P. africana* is not possible, as the teleomorph of *P. sinica* is still unknown. Nevertheless, the genetic differences are distinct enough to be sure the species is not identical with *P. africana*.

*Pseudoplectania carranzae* is a species described from Costa Rica (Calonge & Mata 2002), as *Plectania carranzae*. Beside the geographical disjunction it differs from *P. africana* in shorter asci (170–200 × 10–14 μm), ectal excipulum formed by a *textura globulosa* and curved paraphyses. Unfortunately, the loan of the holotype collection, housed in CR, for morphological and sequencing studies was not possible due to Costa Rican restrictions. Presence of crystals is not mentioned by the authors.

*Pseudoplectania ryvardeenii* is so far known only from Venezuela, and it is distinguished from other *Pseudoplectania* species, including *P. africana*, mainly by its ornamented ascospores and the absence of the so-called hymenial hairs (Iturriaga et al. 2012). Unfortunately,

due to Venezuelan restrictions, it has not been possible to obtain the holotype on loan for morphological and genetic studies (Neida Avendaño, curator of VEN, pers. comm.). The absence of hymenial hairs appears almost impossible to us, being a characteristic present in all the species of *Pseudoplectania* and *Sarcosomataceae* [apparently except *Galiella amurensis* (Lj.N.Vassiljeva) Raitv. (Popov & Carbone 2021)]. Either way, the species as described in Iturriaga et al. (2012) seems to be distinct enough from our new species and therefore of low importance in this study.

## Conclusion

*Pseudoplectania africana* is a new species described from South Africa, where it was collected on a decaying coniferous trunk. Among species of *Pseudoplectania* with available molecular data, *P. ericae* known from Europe and *P. tasmanica* from Tasmania are phylogenetically the closest. In contrast to other known *Pseudoplectania* species, these three species are characterised by presence of large yellow crystals in the tissues. *Pseudoplectania africana* represents the first published record of the genus from South Africa and probably also from the whole of African continent.

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## Competing interests

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

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## Authors' contributions

ZS performed the fieldwork, studied microscopical characters in the new species and crystals in most

collections, wrote the article and took all of the photographs except those of nuclei, MC studied microscopical characters of the new species and wrote the first draft of manuscript, MSo performed phylogenetic analyses, MSe studied and documented nuclei in ascospores and AP studied crystals in five collections. All authors read and approved the final manuscript.

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# Precipitation mediates termite functional diversity and dominance in southern Africa

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**Background:** Termites are important ecosystem engineers in the tropics and sub-tropics, so understanding their diversity, particularly their functional diversity, across biogeographical scales is important for understanding where they alter the environment and deliver ecological services. Feeding groups combine phylogenetic and dietary information about termites into ecologically significant functional categories.

**Objectives:** To characterise termite feeding group prevalence, distribution and diversity in southern Africa and assess the effect of precipitation on termite diversity and assemblage composition.

**Method:** Termite genus and species-level occurrence data were acquired from the South African Termite Database and classified into one of five feeding groups. We evaluated the prevalence of each feeding group and assessed species and feeding group richness and dominance. Linear regressions were performed to determine the relationship between 1) species richness and precipitation; and 2) feeding group richness and precipitation.

**Results:** We find that southern Africa 1) is dominated by FG-IIw (feeding group – II, wood feeding) termites; 2) is occupied by multiple feeding groups across the entirety of the rainfall gradient; and that precipitation 3) influences feeding group species diversity variably; and 4) causes notable shifts in termite community structure.

**Conclusion:** Our results indicate that termites likely make substantial contributions to plant material decomposition across southern Africa and that while shifts in feeding group dominance are associated with rainfall gradients, the services unique to individual feeding groups are not isolated to certain regions, but rather are widespread regardless of the amount of precipitation received.

## Introduction

Termites are important ecosystem engineers (Lee & Wood 1971; Jones et al. 1994; Sileshi et al. 2010; Jouquet et al. 2011; Ashton et al. 2019), so understanding the species and functional diversity across biogeographic scales is important for understanding how and where they alter the environment and deliver services. Although all termites alter soil properties and facilitate nutrient cycling, their specific impacts vary with species composition and the functional traits (or feeding groups (Donovan et al. 2001; Jouquet et al. 2011)) that are most prevalent at a location.

Globally, termites have previously been organised into functional or feeding groups (FG-I, FG-II, FG-III, FG-IV) based on phylogenetic information and diet (Donovan et al. 2001). Divergence in food preference across feeding groups provides insight into services rendered. For example, FG-I mostly consumes wood and FG-II has broad diet preferences (including wood, leaves and grass),

suggesting that in areas where these feeding groups are present, decomposition of larger plant material will be enhanced. In contrast, FG-III termites consume partially decayed organic matter and FG-IV termites consume compounds stabilised in soils (Jouquet et al. 2011), indicating that in areas where these feeding groups are found, soil organic matter dynamics will be influenced. Scaling up these insights helps to clarify the presence or absence of broad scale processes across large geographical areas.

Several studies have explored how termite diversity shifts along climate and productivity gradients. Davies et al. (2003) showed that termites are most functionally diverse in lowland closed canopy tropical forests. Local (Buxton 1981; Davies et al. 2012) and inter-biome comparison studies (Eggleton 1994; Bignell & Eggleton 2000; Davies et al. 2003; Jones & Eggleton 2011; Dahlsjö et al. 2014) have documented an increased number of feeding groups, and a general shift from FG-I and FG-II termites to FG-III and FG-IV termites with increasing mean annual rainfall. Similarly, in Namibia, Vohland and Deckert (2005) found that termite species richness increased with increased rainfall. To our knowledge, no studies have assessed how feeding group diversity and assemblage composition shifts across a continuous and geographically extensive (multi-country) rainfall gradient.

Here we capitalise on a relatively comprehensive termite occurrence dataset in southern Africa to advance our understanding of termite biogeography and to assess the effect of precipitation on termite functional diversity and assemblage composition. Southern Africa contains roughly 54 genera and 165 species of termites,

which represents nearly 20% of 280 termite genera known globally (Uys 2002). In this study, we aim to 1) characterise termite functional prevalence, distribution and diversity across the bioclimatic and elevation gradients of southern Africa; and 2) assess the effect of precipitation on termite functional diversity and assemblage composition.

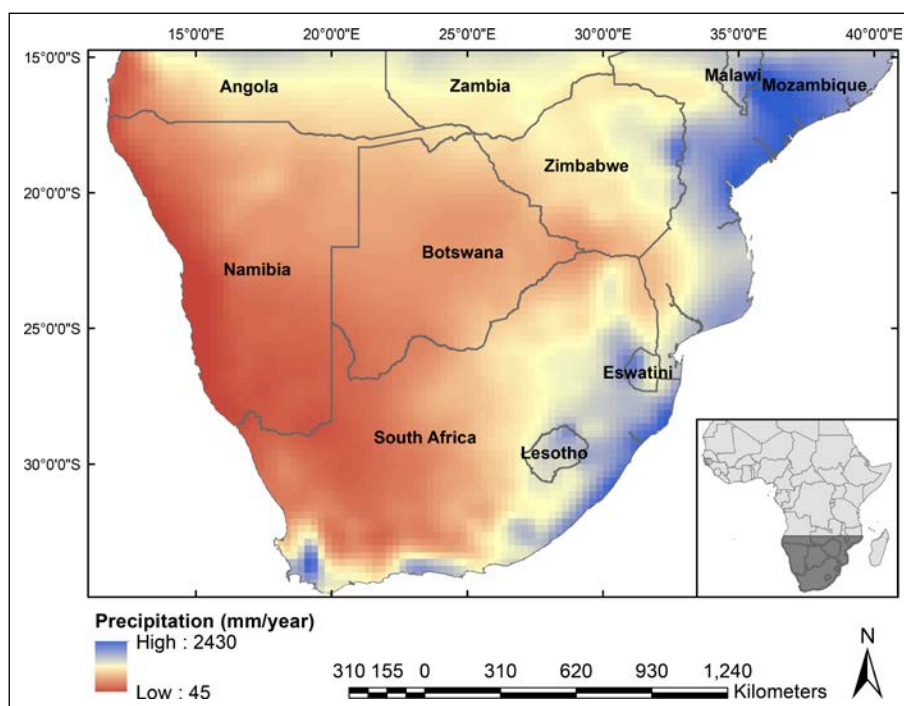
## Methods

### Data description

#### *Termite species data and study area*

Termite presence–absence data were acquired from the South African Termite Database (SATD) maintained by the Biosystematics Division of the Plant Protection Research Institute at the Agricultural Research Council in Pretoria, South Africa. The SATD contains >35 000 occurrence records, mostly a product of the South African National Survey of Isoptera (NSI) led by Dr W.H.G. Coaton and co-workers (Coaton & Sheasby 1972); some records were also gleaned from Mitchell (1980). The original survey was initially intended to include every quarter degree square ( $0.25^\circ \times 0.25^\circ$ , or  $50 \times 50$  km) of South Africa, but was later expanded to include surveys from Namibia, Zimbabwe and Eswatini. Unfortunately, no termite survey data is available from Botswana or Lesotho (Uys 2002; Figure 1).

The National Survey of Isoptera was conducted over two decades (~1960–1980). Termites were sampled mostly during the wet season (when they are most active),



**Figure 1.** Regional 100-year average cumulative annual precipitation (mm/year; Harris & Jones 2015) in southern Africa. Inset: Continental Africa, showing extent of the study region in dark grey and the rest of the continent in light grey.

through active searching by trained termitologists at one or more locations within each sample area (Coaton & Sheasby 1972; Uys 2002). Multiple sample locations falling within the same quarter degree square were aggregated to reduce bias and location error and maintain consistent resolution. All termite specimens were identified by an expert taxonomist (Coaton and colleagues engaged by the NSI) to genus level and, time permitting, to species level. As many database entries were recorded only to genus, overall species-richness estimates likely underestimate true diversity (Meredith et al. 2019). We re-examined the SATD to correct minor spelling mistakes and antiquated species names. Ambiguous georeferences (e.g., points where latitude–longitude did not correspond with additional locality information on nearby towns or country name) were corrected where possible or removed. In so doing, the database was ultimately reduced to 26 968 reliable presence records that cover 1 952 grid cells) and includes 52 genera and 121 species (Supplementary Table S1).

### *Feeding group classification*

Termites were classified into five feeding groups (FGs) based on their phylogeny and the level of decomposition of feeding substrate in their gut (Donovan et al. 2001). FG-I species are primitive termites belonging to families Kalotermitidae, Termopsidae, Hodotermitidae, Rhinotermitidae) and feed on non- or lightly decayed material including dead wood and grass, whereas FG-II through FG-IV species belong to the family Termitidae and feed on more decayed materials (Donovan et al. 2001). FG-II termites include species of the conspicuous mound-building genera (*Macrotermes*, *Odontotermes*), which have broad diet preferences including dead wood, grass, leaf litter and micro-epiphytes, and can be separated into fungus-feeders (FG-II<sub>f</sub>) and wood-feeders (FG-II<sub>w</sub>) (Jones & Eggleton 2011). FG-III termites feed on visible organic material in the soil, while FG-IV termites are known as ‘true soil feeders’ and feed on clay-bound proteins and peptides (Donovan et al. 2001; Ji & Brune 2005).

### *Precipitation Data*

Annual cumulative precipitation data at a 0.5° × 0.5° resolution were acquired from the Climate Research Unit at the University of East Anglia, UK (Harris & Jones 2015), averaged for 1901–2014 into 0.5° × 0.5° and disaggregated to a 0.25° × 0.25° grid using bilinear resampling in ArcGIS 10.7.1. to match the resolution of the South African Termite Database (Figure 1, ESRI, 2020). Mean annual precipitation in the study region ranges from 50 to 2 100 mm/year, encompassing a wide range of biomes including deserts and semi-deserts, fynbos, temperate Afromontane forests, grasslands, savannas, and moist broad leaf forests (Olson et al. 2001).

## Mapping and analysis

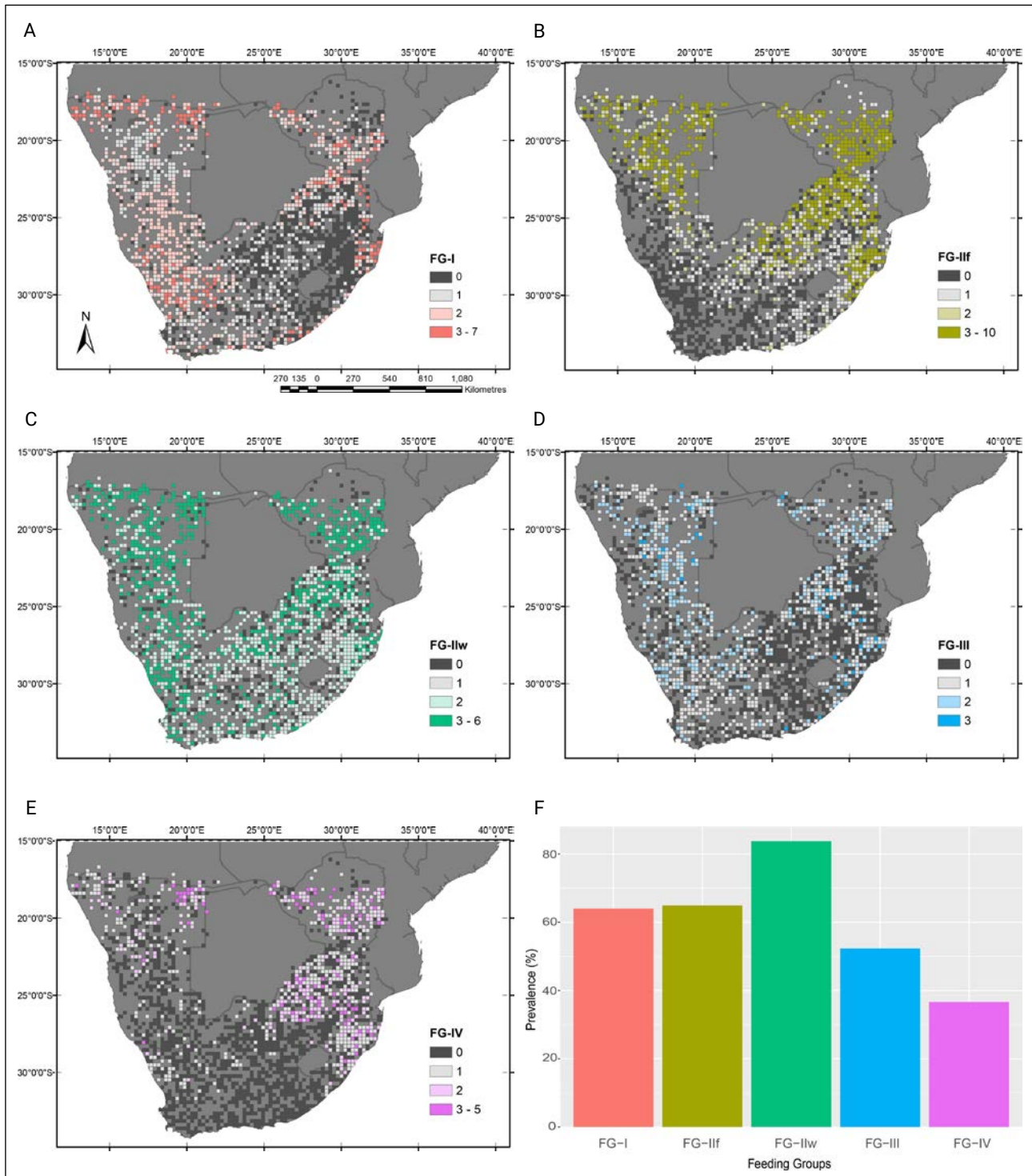
Termite feeding group distribution maps were generated in ArcGIS 10.7.1 (ESRI 2020). The maps depict the geographical extent of feeding groups in the nearly two thousand (n=1 952) 50 × 50 km areas sampled as part of the SATD. Darker shades indicate higher numbers of species present in a sampled area (Figure 2, Figure 3). We calculated the prevalence of each feeding group as the percentage of sampled locations that had a positive occurrence record, where prevalence = (no. positive samples / 1952) × 100. We also assessed species richness, or the number of species present in a single 50 × 50 km sampled location, and feeding group richness, or the number of feeding groups present in a sampled location. While the SATD is composed of acquisitions identified to both the genus and species levels, we combined all acquisitions to a ‘species richness’ value by conservatively assuming that species richness equals one when only genus-level acquisition is present and otherwise using the number of species-level acquisitions.

Simple linear regressions were performed to assess the relationship between 1) species richness and precipitation; and 2) feeding group richness and precipitation. We define feeding group richness as the number of species present at a sample location belonging to the same feeding group. To interrogate the relationship between feeding groups and precipitation further, we first organised the data into eight precipitation bins, each representing roughly 200 sampling locations and a 150–250 mm increase in precipitation between bin categories, and then calculated feeding group dominance by summing occurrence records for each individual feeding group and then dividing by the total number of occurrences in that bin. This provided the relative percentage that each feeding group contributed to the entire assemblage across the precipitation gradient. Statistical analyses were performed in base R version 4.0.3. (R Core Team 2020).

## Results

### Feeding group distribution and prevalence

Termite feeding groups are not distributed evenly in space or species number across southern Africa. While most feeding groups occur in more than half of sampled locations, FG-II<sub>w</sub> are by far the most widely distributed, occurring in over 80% of sampled locations. FG-IV termites are the least prevalent and occur in less than 40% of sampled locations, and mostly in the wetter northeast (Figure 2). Individual maps reveal trends in diversity and geographic preferences. Fungus-growing FG-II termites (FG-II<sub>f</sub>) have the highest maximum diversity, often with

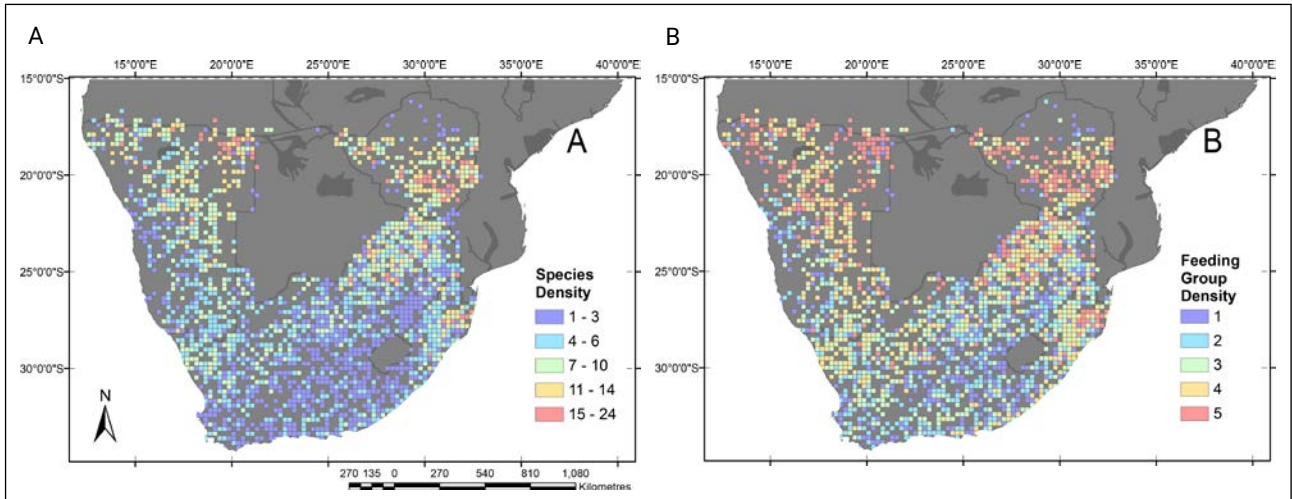


**Figure 2.** A–F, termite feeding group distribution maps for termites in quarter degree sample cells (n=1952) across southern Africa, showing species richness (number of species present in a pixel) for each feeding group. Colour schemes in A–E correspond to the feeding group prevalence diagram (F).

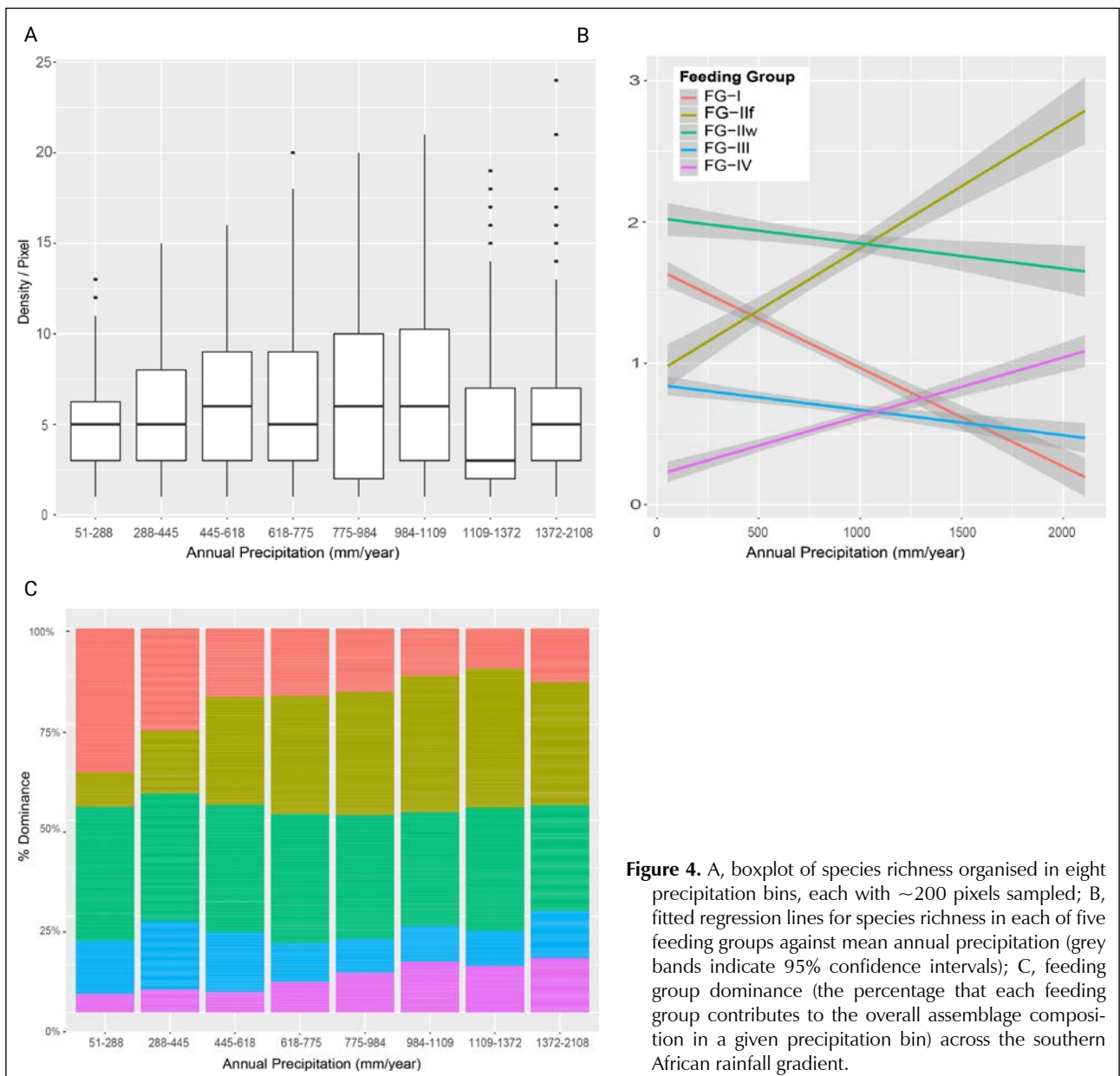
eight to ten different species in the same location. In contrast, FG-III termites exhibit the lowest diversity; a maximum of three different species rarely occurring in the same location. FG-I exhibits high diversity in western Namibia, whereas FG-II-f are rare in western Namibia and the western Cape, but widely distributed elsewhere. Feeding groups I, III and IV have low diversity and prevalence to the north, south and east of Lesotho (Figure 2).

### Taxonomic and feeding group species richness

Species richness ranged from 1 to 25 and at least one termite was found at all sampled locations. Areas of highest overall species richness generally occurred to the north of the study area in regions with higher rainfall (Figure 3A and 4A). Feeding group richness ranged from 1 to 5 and



**Figure 3.** A, species richness for termites in quarter degree sample cells (1952 locations) across southern Africa; B, feeding group richness. One feeding group is present in 353 cells, two are present in 356 cells, three are present in 454 cells, four are present in 485 cells, and five are present in 304 cells.



**Figure 4.** A, boxplot of species richness organised in eight precipitation bins, each with ~200 pixels sampled; B, fitted regression lines for species richness in each of five feeding groups against mean annual precipitation (grey bands indicate 95% confidence intervals); C, feeding group dominance (the percentage that each feeding group contributes to the overall assemblage composition in a given precipitation bin) across the southern African rainfall gradient.

while the majority of sampled locations (64%) contain at least three or more feeding groups, the regions to the north of the study area are generally more functionally rich (i.e., more FGs are present) than in the south.

## Relationship to precipitation

Although the relationship between overall species richness and rainfall is not significant (Figure 4A, Table 1), we find distinct, significant and contrasting relationships between precipitation and species richness within each of the five feeding groups (Figure 4B and Table 1). More specifically, the diversity of FG-II<sub>f</sub> and FG-IV is positively related with rainfall, while the remaining feeding groups (FG-I, FG-II<sub>w</sub> and FG-III) show a negative relationship in this regard (Figure 4B, Table 1).

Feeding group dominance also varies with precipitation. Whereas FG-I is the most dominant in arid landscapes (50–200 mm rainfall bin), its dominance decreases as precipitation increases. This decrease in FG-I dominance is mirrored by a nearly four times increase in FG-II<sub>f</sub>. FG-II<sub>w</sub> maintains a near constant ~25% of assemblage composition across the entire precipitation gradient, but in the wettest landscapes (> 950 mm precipitation), FG-II<sub>f</sub> and FG-II<sub>w</sub> combined constitute nearly 65% of the termite assemblage (Figure 4C).

## Discussion

The Southern African Termite Database provides an unprecedented opportunity to examine termite feeding group distributions at broad spatial scales across southern Africa. The major findings of this study are that southern Africa: 1) is dominated by FG-II<sub>w</sub> termites; and 2) is occupied by multiple FGs across the entire rainfall gradient; and that 3) precipitation influences feeding group richness variably, with some FGs increasing with rainfall, while others decrease in prevalence; and 4) patterns in FG variability with rainfall cause notable shifts in assemblage with possible implications for the role of termites in carbon and nutrient cycles.

We find that FG-II<sub>w</sub> termites have a nearly ubiquitous presence across southern Africa, covering over 80% of sampled locations. The broad diet of FG-II<sub>w</sub> termites allows them to thrive in climatically diverse environments ranging from semi-deserts to tropical rainforests (Jones & Eggleton 2011). This indicates that wood and litter decomposition is a geographically consistent ecosystem service provided by FG-II<sub>w</sub> termites in southern Africa.

Our research further suggests that despite southern Africa's aridity, multiple feeding groups occupy the region across the entire rainfall gradient. While previous studies have suggested that the number of FGs, and therefore the range of termite mediated services, are often greater in wetter environments (Bignell & Eggleton 2000; Davies et al. 2012), we find that most sampled locations, regardless of precipitation, contain between three and the maximum of five termite feeding groups. Similarly, even in areas of low species diversity, feeding group diversity (i.e., functional diversity) remains relatively high (>=3), broadly suggesting that despite low overall species richness, there is still the opportunity for termites to process organic material across a nearly complete humification gradient.

Linear regressions suggest that there is no significant relationship between overall species diversity and precipitation, but that significant relationships for individual feeding groups exist. In general, species diversity within FG-II<sub>f</sub> and FG-IV increases with increasing precipitation and tends to decrease in the remaining feeding groups, either strongly (FG-I) or slightly (FG-II<sub>w</sub>, FG-III), with increasing precipitation. Feeding group dominance varies similarly with precipitation. Whereas FG-I, which feed on lightly decayed materials, are the most dominant feeding group in arid landscapes (50–200 mm precipitation bin), as precipitation increases the fungus cultivating termites (FG-II<sub>f</sub>) become most dominant. There is a particularly strong positive trend with rainfall for FG-II<sub>f</sub> termites, which, given the water-limited nature of southern Africa, may suggest a preference for resource-rich environments where there is more readily available plant biomass for consumption. Because FG-II<sub>f</sub> termites are thought to have evolved in African

**Table 1.** Regression statistics of annual precipitation on termite diversity

Feeding group	F-Value	Slope	P-Value	Significance
I	(1, 1950) = 182.9	-6.97E-02	2.20E-16	***
II <sub>w</sub>	(1, 1950) = 7.129	-1.79E-04	0.007649	**
II <sub>f</sub>	(1, 1950) = 98.35	8.78E-04	2.20E-16	***
III	(1, 1950) = 21.06	-1.79E-04	0.00000474	***
IV	(1, 1950) = 97.22	4.16E-04	2.20E-16	***
All FGs Combined	(1, 1950) = 1.359	2.29E-04	0.244	not significant

rainforests (Aanen & Eggleton 2005; Bourguignon et al. 2014), they may have a natural preference for wetter environments that facilitate maintenance of optimal mound humidity and temperature conditions for fungus cultivation. This may be related to the high energy costs of growing and consuming fungus and associated with the indirect benefits of the greater availability of trees (providing shade) and rainfall (maintaining humidity) to facilitate maintenance of the physiological conditions required for fungus garden maintenance within mounds (Korb 2003; Turner et al. 2006).

Regardless of this shift, we find that plant material consumers (FG-I, FG-IIw, FG-IIf) dominate the assemblage composition across the entire precipitation gradient, consistently representing roughly 75% of termites sampled. As seen in the linear regressions, we find an increase in FG-IV diversity with precipitation, from barely 5% of the assemblage in the driest regions, to 12.5% in the wettest areas. While this represents over a doubling in assemblage representation, the relatively low overall contribution is lower than expected, based on previously documented shifts from litter feeders to soil feeders with increasing precipitation (Buxton 1981; Eggleton 1994; Bignell & Eggleton 2000; Davies et al. 2003; Jones & Eggleton 2010; Davies et al. 2012; Dahlsjö et al. 2014). This lack of representation of soil feeders in wetter regions is intensified by the consistently minor presence of FG-III termites. However, in the case of FG-III, the taxonomic difficulty in identification of soldierless Apicotermitinae may be a cause of under-sampling in the SATD. The lack of an anticipated transition point, where soil feeders comprise the majority of the assemblage over litter feeders, may be related to the character of the precipitation gradient. To allow species richness comparison across the full precipitation gradient, we chose to maintain a relatively equal number of samples per precipitation interval (i.e., bin, 200 grid cells per rainfall interval), and therefore sacrificed the consistency of our rainfall interval sizes. While all the rainfall intervals are between 150 and 250 mm along the rainfall gradient from 50 to 1 400 mm/year, the final precipitation interval covers nearly 700 mm (roughly 1 400–2 100 mm/year). This suggests that the range where we have the most reliable and comparable sampling power is closer to 50 to 1 400 mm/year, which may be too arid to observe large increases in soil feeding termites.

## Conclusion

Interpreting termite distribution data through a Feeding Group lens provides a spatially explicit framework for interpreting how individual FGs partition and contribute to the processing and recycling of primary production in the tropics at large biogeographical scales. While the SATD represents one of the most geographically

extensive and continuous survey efforts of termites globally, our analysis is restricted in the sense that it excludes a notable portion of southern Africa (Botswana and Mozambique) and the areas of highest precipitation in southern Africa (Mozambique). Thus, we are capturing a large, but abbreviated portion of the documented precipitation gradient, where termite feeding group diversity has been reported to increase into the moist tropical forests (Bignell & Eggleton 2000). In our analysis of arid and semi-arid systems across southern Africa, we find that multiple termite FGs occupy the majority of the landscape, suggesting that ecosystem services related to individual FGs are likely widely distributed regardless of the amount of precipitation received. We also find that plant material feeders (FG-I, FG-IIw, FG-IIf) dominate in distribution, diversity and assemblage composition across the entire precipitation gradient. The dominance of litter feeders suggests that termites make substantial contributions to plant material decomposition across southern Africa. Quantifying these contributions more systematically is an important next step in understanding how termite feeding groups contribute to ecosystem function in arid, semi-arid and moist environments. Specifically, contextualising the role of termites as consumers in relation to other well-known consumers like fire and mammalian herbivory (Archibald & Hempson 2016) is of high priority.

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## Competing interests

The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.

## Authors' contributions

B.M.L. (New Mexico State University) and N.P.H. (New Mexico State University) designed the study, V.M.U. (Agricultural Research Council, Pretoria) provided the data, B.M.L. analysed the data, and B.M.L., N.P.H., V.M.U., and P.E. (The Natural History Museum, London) wrote the manuscript.

## Ethical considerations

This article followed all ethical standards for research without direct contact with human or animal subjects.

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## Data availability statement

Upon acceptance of this manuscript, species density, feeding group density and precipitation data used to conduct the study will be made publicly available on [www.datadryad.com](http://www.datadryad.com).

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## Supplementary Material

Supplementary Table 1: List of termite species included in study

Family	Subfamily	Feeding Group	Genus	Species	
Kalotermitidae		I	<i>Bifiditermes</i> (Krishna, 1961)	<i>durbanensis</i> (Haviland, 1898) <i>sibayiensis</i> (Coaton, 1949)	
		I	<i>Cryptotermes</i> (Banks, 1906)	<i>brevis</i> (Walker, 1853) <i>havilandi</i> (Sjöstedt, 1900) <i>merwei</i> (Fuller, 1921) <i>naudei</i> (Coaton, 1950)	
		I	<i>Epicalotermes</i> (Silvestri, 1918)	spp. <i>mkuzii</i> (Coaton, 1949) <i>munroi</i> (Coaton, 1949)	
		I	<i>Kalotermes</i> (Hagen, 1858)	spp. <i>umtatae</i> (Coaton, 1949)	
		I	<i>Neotermes</i> (Holmgren, 1911)	spp. <i>zuluensis</i> (Coaton, 1949)	
		I	<i>Postelectrotermes</i> (1961)	spp.	
	Stolotermitidae	Porotermitinae	I	<i>Porotermes</i> (Hagen, 1858)	<i>planiceps</i> (Sjöstedt, 1904)
		Stolotermitinae	I	<i>Stolotermes</i> (Hagen, 1858)	<i>africanus</i> (Emerson, 1942)
	Hodotermitidae		I	<i>Hodotermes</i> (Hagen, 1858)	spp. <i>mossambicus</i> (Hagen, 1853)
			I	<i>Microhodotermes</i> (Sjöstedt, 1926)	<i>viator</i> (Latreille, 1804)
	Rhinotermitidae	Coptotermitinae	I	<i>Coptotermes</i> (Wasmann, 1896)	spp. <i>amanii</i> (Sjöstedt, 1911) <i>formosanus</i> (Shiraki, 1909)
			I	<i>Psammotermes</i> (Desnux, 1902)	<i>allocerus</i> (Silvestri, 1908)
Rhinotermitinae		I	<i>Schedorhinotermes</i> (Silvestri, 1909)	<i>lamanianus</i> (Sjöstedt, 1911)	
Termitidae		Macrotermitinae	IIf	<i>Allodontermes</i> (Silvestri, 1914)	spp. <i>rhodesiensis</i> (Sjöstedt, 1914) <i>schultzei</i> (Silvestri, 1908) <i>tenax</i> (Silvestri, 1912)
	IIf		<i>Ancistrotermes</i> (Silvestri, 1912)	<i>latinotus</i> (Holmgren, 1912)	
	IIf		<i>Macrotermes</i> (Holmgren, 1909)	<i>falciger</i> (Gerstäcker, 1891) <i>michaelseni</i> (Sjöstedt, 1914) <i>natalensis</i> (Haviland, 1898) <i>subhyalinus</i> (Rambur, 1842) <i>ukuzii</i> (Fuller, 1922) <i>vitrialatus</i> (Sjöstedt, 1899)	

**Supplementary Table 1:** List of termite species included in study (continued)

Family	Subfamily	Feeding Group	Genus	Species
Termitidae	Macrotermitinae	Ilf	<i>Microtermes</i> (Wasmann, 1896)	spp.
				<i>albopartitus</i> (Sjöstedt, 1911)
				<i>etiolatus</i> (Fuller, 1922)
				<i>haviglandi</i> (Holmgren, 1913)
				<i>lounsburyi</i> (Fuller, 1922)
		<i>occidentalis</i> (Fuller, 1922)		
		Ilf	<i>Odontotermes</i> (Holmgren, 1912)	spp.
				<i>angustatus</i> (Rambur, 1842)
				<i>badius</i> (Haviland, 1898)
				<i>cafrariae</i> (Sjöstedt, 1897)
				<i>capensis</i> (De Geer, 1778)
				<i>lacustris</i> (Harris, 1960)
				<i>latericius</i> (Haviland, 1898)
				<i>monodon</i> (Gerstäcker, 1891)
				<i>okahandjae</i> (Fuller, 1922)
	<i>tragardhi</i> (Holmgren, 1913)			
	<i>transvaalensis</i> (Sjöstedt, 1902)			
	<i>vulgaris</i> (Haviland, 1898)			
	Ilf	<i>Pseudacanthotermes</i> (Holmgren, 1912)	<i>militaris</i> (Hagen, 1858)	
	Apicotermitinae	III	<i>Adaiphrotermes</i> (Sands, 1972)	<i>choanensis</i> (Fuller, 1925)
				<i>moretelae</i> (Fuller, 1925)
				<i>oryctes</i> (Sands, 1972)
		III	<i>Alyscotermes</i> (Sands, 1972)	<i>kilimandjaricus</i> (Sjöstedt, 1907)
				spp.
		IV	<i>Apicotermes</i> (Holmgren, 1912)	<i>rimulifex</i> (Emerson, 1956)
				<i>tragardhi</i> (Holmgren, 1912)
		III	<i>Astalotermes</i> (Sands, 1972)	<i>aganus</i> (Sands, 1972)
<i>brevior</i> (Holmgren, 1913)				
<i>comis</i> (Sands, 1972)				
<i>empodius</i> (Sands, 1972)				
<i>muricatus</i> (Sands, 1972)				
III	<i>Skatitermes</i> (Coaton, 1971)	<i>psammophilus</i> (Coaton, 1971)		
		<i>watti</i> (Coaton, 1971)		
Cubitermitinae	IV	<i>Basidentitermes</i> (Holmgren, 1912)	spp.	
			<i>monachus</i> (Uys, 1994)	
	IV	<i>Crenetermes</i> (Silvestri, 1912)	spp.	
			<i>Cubitermes</i> (Wasmann, 1906)	spp.

**Supplementary Table 1:** List of termite species included in study (continued)

Family	Subfamily	Feeding Group	Genus	Species		
Termitidae	Cubitermitinae			<i>anatruncatus</i> (Fuller, 1925)		
				<i>bilobatus</i> (Haviland, 1898)		
				<i>conjenii</i> (Fuller, 1925)		
				<i>duplex</i> (Holmgren, 1913)		
				<i>microduplex</i> (Fuller, 1925)		
				<i>pallidiceps</i> (Sjöstedt, 1913)		
				<i>pretorianus</i> (Silvestri, 1914)		
				<i>sanctaeluciae</i> (Fuller, 1925)		
				<i>transvaalensis</i> (Fuller, 1925)		
				<i>truncatoides</i> (Fuller, 1925)		
				<i>undulatus</i> (Fuller, 1925)		
			IV	<i>Euchilotermes</i> (Silvestri, 1914)	spp.	
			IV	<i>Lepidotermes</i> (Sjöstedt, 1924)	spp.	
					<i>amydrus</i> (Uys, 1994)	
					<i>goliathi</i> (Williams, 1954)	
					<i>lounsburyi</i> (Silvestri, 1914)	
					<i>mtwalumi</i> (Fuller, 1925)	
					<i>planifacies</i> (Williams, 1954)	
					<i>pretoriensis</i> (Sjöstedt, 1914)	
					<i>scalenus</i> (Uys, 1994)	
					<i>simplex</i> (Holmgren, 1913)	
					<i>vastus</i> (Uys, 1994)	
			IV	<i>Noditermes</i> (Sjöstedt, 1924)	spp.	
			IV	<i>Okavangotermes</i> (Coaton, 1971)	<i>giessi</i> (Coaton, 1971)	
			IV	<i>Ovambotermes</i> (Coaton, 1971)	spp.	
					<i>sylvaticus</i> (Coaton, 1971)	
			IV	<i>Unguitermes</i> (Sjöstedt, 1924)	spp.	
					<i>unidentatus</i> (Ruelle, 1973)	
			IV	<i>Unicornitermes</i> (Coaton, 1971)	<i>gaerdesi</i> (Coaton, 1971)	
			Termitinae	llw	<i>Amitermes</i> (Silvestri, 1901)	spp.
					<i>braunsi</i> (Fuller, 1922)	
					<i>hastatus</i> (Haviland, 1898)	
			<i>messinae</i> (Fuller, 1922)			
			<i>obtusidens</i> (Mjöberg, 1920)			
		III	<i>Angulitermes</i> (Sjöstedt, 1924)	spp.		
			<i>braunsi</i> (Wasmann, 1908)			
			<i>elsenburgi</i> (Fuller, 1925)			
		llw	<i>Microcerotermes</i> (Silvestri, 1901)	spp.		


**Supplementary Table 1:** List of termite species included in study (continued)

Family	Subfamily	Feeding Group	Genus	Species		
Termitidae	Termitinae			<i>apricitatis</i> (Fuller, 1925)		
				<i>choanensis</i> (Fuller, 1925)		
				<i>collinsi</i> (Fuller, 1925)		
				<i>dumisae</i> (Fuller, 1925)		
				<i>hypaenicus</i> (Fuller, 1925)		
				<i>ilalazonatus</i> (Fuller, 1925)		
				<i>limpopoensis</i> (Fuller, 1925)		
				<i>malmesburyi</i> (Fuller, 1925)		
				<i>mzilikazi</i> (Fuller, 1925)		
				<i>parvus</i> (Haviland, 1898)		
				<i>pondweniensis</i> (Fuller, 1925)		
				<i>psammophilus</i> (Fuller, 1925)		
				<i>sanctaeluciaae</i> (Fuller, 1925)		
				<i>thermarum</i> (Fuller, 1925)		
				<i>zuluensis</i> (Holmgren, 1913)		
				III	<i>Pericapritermes</i> (Silvestri, 1914)	spp.
				III	<i>Promirotermes</i> (Silvestri, 1914)	spp.
						<i>bechuana</i> (Fuller, 1922)
						<i>dumisae</i> (Fuller, 1925)
						<i>rotundifrons</i> (Silvestri, 1914)
				III	<i>Termes</i> (Lineé, 1758)	<i>boultoni</i> (Coaton & Sheasby, 1978)
			Nasutitermitinae	IIw	<i>Baucaliotermes</i> (Sands, 1965)	<i>hainesi</i> (Fuller, 1922)
				IIw	<i>Fulleritermes</i> (Coaton, 1963)	spp.
						<i>coatoni</i> (Sands, 1965)
						<i>contractus</i> (Sjöstedt, 1913)
						<i>mallyi</i> (Fuller, 1922)
				IV	<i>Mimeutermes</i> (Silvestri, 1914)	spp.
				IIw	<i>Nasutitermes</i> (Dudley, 1890)	<i>infuscatus</i> (Sjöstedt, 1902)
						<i>kempae</i> (Harris, 1954)
				IIw	<i>Rhadinotermes</i> (Sands, 1965)	<i>coarctatus</i> (Sjöstedt, 1902)
				IV	<i>Spatulitermes</i> (Coaton, 1971)	spp.
						<i>coolingi</i> (Coaton, 1971)
		IIw	<i>Trinervitermes</i> (Holmgren, 1912)	spp.		
				<i>dispar</i> (Sjöstedt, 1902)		
				<i>rapulum</i> (Sjöstedt, 1904)		
				<i>rhodesiensis</i> (Sjöstedt, 1911)		
				<i>trinervius</i> (Rambur, 1842)		
				<i>trinervoides</i> (Sjöstedt, 1911)		



# To be or not to be a protected area: a perverse political threat

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**Background:** On 15 January 2021, a South African Member of the Executive Committee (MEC) for the Environment amended the Mabola Protected Environment's (MPE) boundaries to remove legal impediments preventing coal mining in this protected area. This decision came in the wake of the MPE being declared a protected area and a series of court cases ending at the Constitutional Court.

**Objective:** The objectives of this paper were: (1) evaluate the potential consequences of the MEC's decision for South African protected areas; (2) speculate on the possible impact on South Africa's reputation in terms of its commitment to safeguarding its protected areas; (3) identify possible weaknesses in the National Environmental Management: Protected Areas Act 57 of 2003 (NEMPAA); and (4) make recommendations to strengthen this Act so that it can reduce the vulnerability of protected areas to arbitrary and prejudicial decision-making.

**Methods:** This study involved an evaluation of NEMPAA and the notice in the Provincial Gazette declaring and giving effect to the MEC's decision, and of the various High Court judgments leading up to and following the publication of this notice.

**Conclusion:** The decision by the MEC highlights the vulnerability of protected areas and the importance of the conservation of biodiversity, particularly in a context of parochial or partisan objectives and profit-vested interests that are of a limited (at least in the medium- to long-term) public benefit. It is concluded that the discretionary clauses in NEMPAA may need to be amended to limit or refine the discretion politicians may apply.

## Introduction

Protected areas are deemed to be the bastions of biodiversity conservation and the core of the natural environment held in trust for the benefit and enjoyment of current and future generations (Blackmore 2020; Lubbe 2019; Radeloff et al. 2010). It is therefore not unreasonable to assume – at least from a principle perspective – that protected areas, once established, would persist *ad infinitum* and that their biodiversity would be protected from at least human-induced harm (Hoffmann & Beierkuhnlein 2020; Qin et al. 2019). The corollary is that each generation would, in turn, inherit a network of protected areas that contains viable components of the country's biodiversity (Mogale & Odeku 2018; Zurba et al. 2020). Thus, in addition to being a custodian or trustee, there is an expectation that each generation would increase the number and size of the existing protected areas to a point where, as a minimum, the network of protected areas contains a viable representation of the country's biodiversity. Thus, the decisions taken in one generation have a direct consequence not only for that generation, but also for future generations (Lubbe 2019). The longevity of a protected area is, therefore, founded on the trustee's ability to safeguard (protect) the area.

While the meaning of a protected area has been defined in many texts, the concept of being protected is rarely, if at all, defined. Consequently, the common interpretation of the term is used. Collins online dictionary defines protected as ‘forbidden by law to be harmed’, while the Merriam-Webster online dictionary defines the term as ‘to cover or shield from exposure, injury, damage, or destruction, or to maintain the status or integrity of especially through financial or legal guarantees’. It is reasonable, therefore, to assume that in the context of this paper, ‘protected’ means that the protected area must be safeguarded from being damaged, diminished, attacked, stolen, injured, lost, and the like. Furthermore, strict application of this interpretation would, in principle, result in the protected area persisting and fulfilling the purpose for which it was established over time.

Despite this understanding, regulatory bodies have not embraced the need of a protected body to persist *ad infinitum*. For instance, the International Union for Conservation of Nature (IUCN) defines a protected area as ‘a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the *long-term conservation* of nature with associated ecosystem services and cultural values’ (author’s emphasis).

The inclusion of the term ‘[in] the long-term’ suggests that the IUCN envisioned that the life of a protected area, although unknown, is finite but persists beyond the foreseeable future (or beyond the short to medium term) (Blackmore 2020). It is, therefore, conceivable that the IUCN conceptualised, for whatever reason, that a protected area may be established for an extended period, during which time the integrity of the biodiversity (and other values therein) is shielded from, at least, anthropogenic harm and with a future possibility of it being discontinued. The corollary is that while the protected area is in existence, it is maintained and protected in a fit state – i.e., it fulfils the purpose for which it was set aside as a protected area by its trustee or trustees. Here the trustee would comprise the state and, if different, the management authority.

The trustee role of the state would be to provide the necessary governance instruments (legal and policy framework) for the establishment and management of the protected area. In contrast, the trustee role of the management authority would be to give effect to day-to-day management of the protected area in accordance with, at least, these governing instruments (Goosen & Blackmore 2019). Thus, on establishing a protected area and following the assignment of a management authority, the state assumes an oversight role to ensure that the integrity of the protected area is reasonably safeguarded in the public interest by the management authority (Atmiş 2018). In a South African context, the oversight role would be primarily exercised

in accordance with the National Environmental Management: Protected Areas Act 57 of 2003 (NEMPAA).

NEMPAA provides for several of kinds of protected areas that may be established in South Africa. This array extends from giving protection to one or more natural or cultural features (e.g., a protected environment) to prohibited access by people save for that required under exceptional and necessary circumstances (e.g., a special nature reserve). A summary of the kinds of protected areas in South African law is provided in Fuggle and Rabie (Strydom & King 2009). The origin of a ‘protected environment’ is rooted in the Protected Natural Environment (PNE) in the Environment Conservation Act 73 of 1989 (ECA)(RSA, 1989). This component of the Act was repealed by the NEMPAA, which redefined the ‘Protected Natural Environment’ to ‘Protected Environment’(PE) to cater for cultural attributes needing protection. Nonetheless the erstwhile PNE and current PE purpose remained unchanged. This being to ‘enable private landowners to take collective action to protect one or more attributes of their properties’ (Blackmore 2022).

## Discussion

### The plight of protected areas

Despite the legislative instruments, protected areas and the biodiversity therein suffer from many threats that extend from unsustainable use of natural resources to mismanagement or improper conservation management, to encroachment by incompatible land-use change and development, and to climate change (Coppa et al. 2021; Hoffmann & Beierkuhnlein 2020; Mascia & Pailler, 2011; Prato & Fagre 2020). These threats, either individually or cumulatively, may lead to the loss of a protected area function (viz. a paper park) or the loss of part or all of the protected area through deregistration or degazettement (De Vos et al. 2019; Mascia & Pailler 2011; Qin et al. 2019).

The need for a protected area to at least be downsized or degazetted in recent protected area jurisprudence and statute law, has twinned the need for the establishment of new protected areas and the expansion of existing ones. Such provisions provide the relevant state authority – particularly the political head – with the powers to act and make decisions in the State’s and therein the public’s (current and future generations) best interests. The establishment and formalising of a protected area in law are generally conditional: the parcel of land needs to meet particular biodiversity or ecosystem standards or requirements. In contrast, the withdrawal of a parcel of land from the protected area estate invariably occurs without any significant limitation or challenging legal restriction (see, for instance, Mascia & Pailler 2011).

## Protected area downgrading, downsizing, and degazettement (PADDD)

In South Africa, the withdrawal of a protected environment, special nature reserve, national park or nature reserve belonging to the state requires the oversight and a resolution of the relevant national or provincial legislature. In contrast, a boundary of a marine protected area may be amended, or the declaration may be withdrawn at the sole discretion of the (national) Minister responsible for the environment. A similar circumstance applies to private nature reserves or where private land has been incorporated into a national park. In this instance, the relevant political head (the national Minister – the Minister; or the Member of the Executive Committee, also commonly referred to as the ‘provincial minister’ – the MEC) for the environment must, without consideration, degazette the private land on receipt of a notice from the landowner requesting this (See Chapter 5 – RSA 2004). Thus, the long-term security of these protected areas must be questioned in that the persistence of the protected area is vulnerable to the discretion of a political head or landowner.

While the politicians involved in the degazetting of a parcel of land or sea are obligated to act as a trustee of South Africa’s protected areas (see Section 3 – RSA 2004), the NEMPAA is silent on the consequences should this obligation be disregarded. Furthermore, while the Act is explicit on the circumstances and criteria that need to be met for either a terrestrial or marine protected area to be declared, it is silent on the circumstances under which degazetting may occur. Thus, other than the obligation to act as a trustee of protected areas – a provision of NEMPAA that is possibly the least understood (Blackmore 2018; Van der Schyff 2010) – there is no explicit provision in NEMPAA that binds the political head and the relevant legislature to ensure that the downsizing or degazetting of a protected area does not compromise the objective and intent of this Act. Nonetheless, the fulfilment of the trustee obligations with respect to downsizing or degazetting of a protected area and maintaining the integrity of the public trust entity (the network of protected areas in South Africa) has taken place in in this country’s recent conservation history. For example, the Vaalbos National Park was degazetted to grant successful land claimants’ beneficial occupation of the properties that comprised that protected area. To compensate for or offset this loss to the public trust entity, the Minister gazetted the establishment of the Mokala National Park (SANParks 2021).

As with the marine protected areas and private nature reserves, the amendment of the boundaries or withdrawal of a protected environment is not overseen by the national or provincial legislature. The political head

for the environment may, therefore, notwithstanding the public trust obligation:

- a. ‘withdraw the declaration [...] of an area as a protected environment or as part of an existing protected environment; or
- b. exclude any part of a protected environment from the area’ (Section 29 of NEMPAA).

These provisions in NEMPAA provide the foundation in South African protected area law, as argued below, for decisions of what de Marques and Peres (2015) described as a ‘pervasive legal threat to protected areas’ in Brazil. In this instance, de Marques and Pere (2015) discovered that the Brazilian legal system was correctly being used, in a disingenuous manner, to ‘degazette, downsize or downgrade’ several the country’s protected areas. Furthermore, de Marques and Peres (2015) discovered that the underlying reasons for such actions were to accommodate state infrastructure, relax restrictions on land use or the use of natural resources by people, or as a result of ‘conflicting interests with the wider private sector’ (de Marques & Peres 2015). Invariably, the degazetting, downsizing or downgrading of a protected area results in environmental degradation and a concomitant irreversible loss of the protected area’s values (Mascia & Pailler 2011). In the absence of physical compensation (biodiversity and protected area offsetting), the protected area public trust entity would be diminished by the loss of part or all of the protected area (Blackmore 2020).

Continuing with the protected environment example, and with reference to the Mabola Protected Environment near Wakkerstroom in Mpumalanga, South Africa; section 48(1)(b) of NEMPAA renders it illegal to either prospect or mine in this type of protected area without, among other things, the written permission granted by the Minister for the Environment having consulted the Minister for Mineral Resources. Furthermore, the Minister responsible for the environment may refuse permission or grant such subject to any condition or set of conditions that would be required to reduce the potential impacts of the proposed prospecting or mining on the protected environment to a reasonably acceptable level. Thus, depending on the sensitivities of the protected environment and the effectiveness of mitigation, an application for either a prospecting or mining activity may be refused or burdened with conditions, including securing an offset for both the residual damage to biodiversity and the integrity of the protected area estate (Blackmore 2020).

## The MEJCON Judgment

In 2014, the Mabola Protected Environment (MPE), located in the Enkangala–Drakensberg Strategic Water Source Area, was established to protect grasslands deemed to be of exceptionally high biodiversity value.

This Strategic Water Source Area is one of 22 such areas in South Africa and provides water to two metropolitan areas and several towns and agricultural regions in three provinces. Notwithstanding this irreplaceable biodiversity status of the MPE and its critical water provision function, together with the apparent irreversible damage that may be caused, the then Minister of Environmental Affairs, on 21 November 2016, issued the environmental authorisation for Uthaka Energy (PTY) Ltd to undertake coal mining activities. The following day, a mining right was granted by the then Minister of Mineral Resources (Davis 2021). The decisions taken by both these Ministers were later set aside on the grounds, among others, that the Ministers failed to fulfil the requirement of section 48 of NEMPAA as discussed above (MEJCON Judgment 2018).

The litigants (appellants) were a consortium of non-governmental organisations (NGOs) comprising the Mining and Environmental Justice Community Network of South Africa, Groundwork, Birdlife South Africa, Endangered Wildlife Trust, Federation for a Sustainable Environment, Association for Water and Rural Development, and the Bench Marks Foundation.

Whereas the respondents were Uthaka Energy (PTY) Ltd the MEC for Agriculture, Rural Development; the Minister of Mineral Resources and Energy; the Acting Chief Director for Environmental Affairs; the Mpumalanga Department of Agriculture, Rural Development, Land and Environmental Affairs; Gert Sibande District Municipality; Dr Pixley Ka Isaka Seme Local Municipality; the Water Tribunal; Estate Late Pierre William Bruwer Uys; Occupiers Of Portion 1 of The Farm Yzermyn 96 HT; the Voice Community Representation Council; the Mabola Protected Environment Landowners Association; the Mpumalanga Land and Environmental Affairs and the Minister of Forestry, Fisheries and the Environment. This interdict focussed primarily on preventing Uthaka Energy (PTY) Ltd from undertaking any mining activities. The remainder of the respondents are those parties the litigants believed may be able to provide information to the court should the need arise and need to be bound by the judgement. These respondents may also oppose the interdict and hence may, vis-à-vis be liable to pay the litigants legal costs.

Uthaka Energy (PTY) Ltd followed the issuing of the MEJCON Judgement with a series of court applications for leave to appeal the MEJCON Judgment, which ended up being refused on 9 July 2019 by the President of the Supreme Court of Appeal. A similar dismissal with costs was issued by the Constitutional Court on 6 November 2019, ending the efforts of Uthaka Energy (PTY) Ltd to have the MEJCON Judgment set aside. The sequential consequence of these judicial endeavours is that the six orders in the judgment stand and would be binding on, among others, Uthaka Energy (PTY) Ltd and (importantly) the Mpumalanga MEC for Agriculture,

Rural Development, Land and Environmental Affairs. The orders of the MEJCON Judgment are:

1. 'The decision of the first respondent [Minister of Environmental Affairs] on 20 August 2016 to grant the third respondent [Atha-Africa Ventures (Pty) Ltd – predecessor to Uthaka Energy (PTY) Ltd] written permission to conduct commercial mining in the Mabola Protected Environment in terms of section 48(1)(b) of the National Environmental Management: Protected Area Act 57 of 2003 ('NEMPAA') is reviewed and set aside.
2. The decision of the second respondent on 21 November 2016 to grant the third respondent written permission to conduct commercial mining in the Mabola Protected Environment in terms of section 48(1)(b) of NEMPAA is reviewed and set aside.
3. The third respondent's application for written permission to conduct commercial mining in the Mabola Protected Environment in terms of section 48(1)(b) of NEMPAA is remitted to the first and second [Minister of Mineral Resources] respondents for reconsideration.
4. In reconsidering the third respondent's application for written permissions to conduct commercial mining in the Mabola Protected Environment in terms of section 48(1)(b) of NEMPAA, the first and second respondents are directed to consider all relevant considerations and:
  - 4.1. to comply with section 2 and 4 of the Promotion of Administrative Justice Act 3 of 2000;
  - 4.2. to take into account the interests of local communities and the environmental principles referred to in section 2 of the National Environmental Management Act 107 of 1998 ('NEMA');
  - 4.3. to defer any decision in terms of section 48(1)(b) of NEMPAA until after the decision of
    - 4.3.1. the applicants' statutory appeal to the Director General: Department of Mineral Resources in terms of the Mineral and Petroleum Resources Development Act 28 of 2002 against the approval of the third respondent's environmental management programme; and
    - 4.3.2. the applicants' statutory appeal to the Water Tribunal in terms of the National Water Act 36 of 1998 against the decision to issue a water use licence to the third respondent;
  - 4.4. not to consider the granting of permission to conduct commercial mining in the Mabola Protected Environment in terms of section 48(1)(b) of NEMPAA until a management plan

for the MPE has been approved by the fifth respondent in terms of section 39(2) of NEM-PAA and to consider the contents thereof.

5. In the event that, prior to the completion of the reconsideration contemplated in paragraphs 3 and 4, the fifth respondent [MEC for (the political head for the Department of) Agriculture, Rural Development, Land and Environmental Affairs, Mpumalanga] decides in terms of section 29(b) of the National Environmental Management: Protected Areas Act 57 of 2003, to exclude the farms referred to in Provincial Notice 127 of 2018 ('Gazette notice'), from the Mabola Protected Environment, any party may apply to Court on the same papers, duly supplemented, on notice to the other parties, for an order varying paragraphs 3 and 4 or granting such alternative, further or interim relief as may be just and equitable in the circumstances.
6. The first, second and fifth respondents are directed to pay the applicant's costs of this application, jointly and severally on the attorney and client scale, the one paying the other to be absolved, such costs to include the costs of two Counsel.' (Davis 2021).

In the arguments leading up to the above six orders, Justice Davis recognised the potential of the mine creating economic benefits that, amongst others, include the employment opportunities for the neighbouring communities. While economic employment remains a key consideration, it must be viewed within the context of the environmental right discussed below (Davis 2021). Justice Davis further argued, while economic hardship is tragic, the interdict is 'temporary in nature' and hence would not add to the economic hardship that has been in place for many years, and the mine would not 'miraculously' create instant economic relief and therein immediately 'solve or alleviate' the community's problems (Davis 2021). Thus, the granting of the interdict merely suspends the potential of the economic benefits the proposed mine may create, until such time the rule of law has run its course.

## The Shongwe Notice

With these orders in place and binding on the MEC (and despite Order 5 enabling aggrieved parties to take the MEC's decision on judicial review), the MEC elected on 8 December 2020 to amend the boundaries of the MPE to exclude four of the six properties from the MPE. This boundary amendment was published in the Provincial Gazette (PG 3225 of 15 January 2021 – the 'Shongwe Notice'). Furthermore, the four properties excluded from the MPE coincided with those listed in the mining application (Davis, 2021).

In the Shongwe Notice, the MEC cited the following rationale for the decision to amend the MPE boundaries:

1. *'To ensure balance towards use of natural resources for socio-economic benefits of all the citizens/community of Pixley Ka Seme Local Municipality and the country, while promoting environmental protection and sustainability;*
2. *To ensure/promote economic growth of the country and the community of the area;*
3. *To promote co-existence of mining activities and conservation within the area on the properties, the boundaries of which are as indicated on addendum 1 and 2 hereto.'* (Shongwe Notice 2021).

An analysis of the Shongwe Notice is moot in many respects. The entire environmental application and the granting of the mining rights (including a plethora of yet to be considered environmental, mining and municipal appeals) are subject to judicial review. At the time of writing this paper, these cases had not been heard by the High Court.

The rationality and reasonableness of the Shongwe Notice can only be confirmed by the courts when taken under judicial review, which has been set in motion as a consequence of the interdict granted on 30 March 2021 by Justice Davis (Davis 2021). To make a determination that sets the Shongwe Notice aside, the High Court will need to be convinced that the decision to issue the Notice was unreasonable given the circumstances, was founded on an improper purpose or motive, or was irrational, arbitrary or capricious. Until such time a determination is made, any evaluation of the integrity of the Shongwe Notice is speculative.

It is an enigma why the MEC did not use the opportunity to include in the notice information germane to the justification of the rationale. This information would be available, at least, in the social component of the environmental impact assessment and associated application documentation. Despite having ready access to this information, the challenge facing the MEC would be to demonstrate that the benefits alluded to in the Notice significantly outweigh the potential social, water, biodiversity and other impacts the proposed mine is likely to cause. Having not done so, unfortunately renders the Shongwe Notice vague and unsubstantiated, which brings into question whether it is reasonable and justifiable. Nonetheless the notice needs to be read as it is published and in so doing cannot be given any greater status than an 'opinion' (Alison et al. 2003; Watson 1984).

Furthermore, the rationale provided by the MEC presupposes, in some respects, the outcome of the reconsideration of the mining application by both the Ministers, and particularly the Minister for Environment, as well as the various appeals and judicial reviews. The outcome of these processes may conclude that the mining activity, as applied for, is sustainable and in the

country's best interests. Thus, by issuing the notice, the MEC appears to have displayed significant apprehension that this outcome is unlikely.

## A perverse threat to protected areas

Given the judgements discussed above and the absence of detail justifying the rationale, the *prima facie* conclusion one draws from the publication of the Shongwe Notice is that it was impulsive with the intention to remove the restrictions preventing Uthaka Energy (PTY) Ltd from mining within the MPE by:

1. evading or circumventing the need for the permissions that are to be granted by both the Minister for the Environment and the Minister for Mineral Resources, for Uthaka Energy (PTY) Ltd to mine the Mabola Protected Environment, and
2. ameliorating the judicial failures of Uthaka Energy (PTY) Ltd to appeal the MEJCON Judgement (CER, 2021).

Should the High Court come to the same conclusion, and taking into consideration that the notice, in its current form, is insubstantial, it is highly likely that the Shongwe Notice will be set aside, at least, on the grounds of being irrational, arbitrary and/or capricious (Watson 1984). Moreover, this consideration, in combination with the vague and unsubstantiated nature of the Notice, dispels the notion that PADD was used in a manner it was intended to be used. This argument is amplified below.

Nonetheless, the question that arises is whether the MEC, by issuing the Shongwe Notice, acted logically and in accordance with the provisions of NEMPAA? The MEC drew on section 29 of NEMPAA, which granted, when viewed in isolation from the remainder of the Act, unfettered powers to amend the boundary of a protected environment. Thus, the MEC's action from this perspective is compliant with this section of the Act. However, this strategy is precarious in that the decision taken must be in the context of the intent and purpose of the Act, and therein the roots of the Act in the Constitution. The context of the Act is established primarily in the preamble, followed by section 2 (Objectives of the Act) and section 3 (State trustee of protected areas). Simply put, the preamble and the objectives to the NEMPAA provide for: (1) an appropriately governed system of protected areas for the protection of 'ecologically viable areas representative of South Africa's biological diversity and its natural landscapes and seascapes,' and (2) these areas to be sustainably used 'for the benefit of people, in a manner that would preserve the ecological character of such areas'. The plurality of 'people' infers that the benefits derived from a protected area cannot be arbitrarily limited to one person (or entity), a limited group of people, or one generation – to the exclusion of the next.

The benefit of protected areas cumulating to all people is further embraced by section 3(a) of NEMPAA, where the State, in this instance the MEC, is to act as the trustee of Mpumalanga's protected areas. In establishing and safeguarding a protected area, the MEC would be contributing to the progressive fulfilment of section 24 (the 'Environmental Right') in the Bill of Rights of the Constitution. The role of a 'trustee' in this context is similar to a trustee administering common law trusts. The duty of trustees is centred on the obligation to administer the trust solely in the interest of the trust's beneficiaries. It is, therefore, the obligation of the trustees to, as a minimum, safeguard the integrity of what is held in trust – the trust entity. Any decision taken by the trustees that can harm the trust entity must, therefore, be cautiously taken and with prudence. For circumstances where a decision results in a loss in value or integrity, the trustees must, to the best of their abilities, ensure that the trust entity is compensated for the loss.

The Environmental Right in the Constitution reads as follows:

*Everyone has the right—*

- a. *to an environment that is not harmful to their health or well-being; and*
- b. *to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that—*
  - i. *prevent pollution and ecological degradation;*
  - ii. *promote conservation; and*
  - iii. *secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.*

It, thus, makes sense that the three points in the MEC's rationale must, at least, reflect the common law duties placed on trustees and, therein, fulfil the intention and purpose of NEMPAA and the Constitution.

## Catapulting South Africa into the negative realm of PADD

It is recognised that there are valid circumstances where PADD is necessary. For instance, to remove redundancy or where a portion or all of the protected area does not meaningfully contribute to the conservation of biodiversity, or where greater accuracy of the contribution of protected areas to biodiversity conservation is required (Cook et al. 2017). PADD may also be required where the loss of part or all the protected area is required for justifiable and critically important development or land use change that is (at least in the medium- to long-term) overridingly in the public's best interests. In these circumstances, the loss

of biodiversity and the protected area estate would need to be compensated or offset in a manner that is equally overriding in favour of biodiversity conservation (Blackmore 2020). These conditions for the use of PADDD do not fit comfortably, if at all, with the amendment of the MPE boundaries.

By issuing the Shongwe Notice, it is evident that the MEC, *inter alia*:

- a. attempted to circumvent the National Ministers' consent obligations,
- b. ignored his public trust and other obligations bestowed on him by the NEMPAA,
- c. attempted to nullify the MEJCON judgment – an outcome Uthaka Energy (PTY) Ltd was not able to achieve by approaching the Senior Court of Appeal and the Constitutional Court,
- d. undermined the pending judicial and appeal processes that are yet to be finalised, and
- e. following on from the above two points, displayed a lack of confidence in the rule of law.

In view of this, it may be easily concluded that the action taken by the MEC was an inappropriate use of his powers – perverse in that the MEC used a discretionary provision in NEMPAA to set aside the intent and purpose of the Act.

Should this be the case, the MEC may have catapulted South Africa into the ranks of Brazil and other countries where protected areas are purposefully being downgraded, downsized and degazetted to pave the way for achieving, what appears to be, parochial or partisan objectives and profit-vested interests (Blackmore 2015; de Marques & Peres 2015; Qin et al. 2019; Treves et al. 2019).

## Conclusion

In 2014, the then Minister of Environmental Affairs and the Minister for Mineral Affairs gave their individual permissions for mining to take place in Mabola Protected Environment and did so in non-compliance with the provisions of the National Environmental Management: Protected Areas Act 57 of 2003 (NEMPAA). This is the principal statute that safeguards, *inter alia*, protected environments. Drawing primarily on this non-compliance, Justice Davis, in the High Court, set both these approvals aside and instructed the Minister of Environmental Affairs to reconsider the application to undertake mining in the Mabola Protected Environment once the provisions of this statute had been complied with.

Following the Senior Court of Appeal's and the Constitutional Court's refusal of the mining company's request to appeal the Justice Davis decision, the Member of the Executive Committee (MEC), the provincial political head for the environment, in 2020, surprisingly, elevated his authority above that of the Courts and the responsibilities of the national Minister.

Furthermore, by using a discretionary clause in NEMPAA in isolation to the other key provisions of the Act, the MEC amended, in what appears to be an arbitrary and capricious decision, the boundaries in a protected environment to circumvent a statutory prohibition of mining, as well as a series of orders issued by the High Court. Other than South Africa being seen to be pushed into the negative realm of 'protected area downgrading, downsizing, and degazettement' (PADDD), it is concluded that this country's protected areas, in the absence of the Courts, are vulnerable to prejudicial, politically based decision-making in favour of short-term parochial gains. It is further concluded that this potential outcome arose out of disregarding the public trust duties the MEC is obligated to apply.

Finally, it is recommended that the legislation providing for protected areas be amended to restrict the scope of discretionary clauses providing PADDD. Here the scope should be limited to the rare circumstance where the protected area cannot reasonably be avoided, and the development is unquestionably in the public's long-term best interest, and where the residual loss to biodiversity and the protected area estate is appropriately compensated or offset.

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## Disclaimer

The ideas, arguments and opinions expressed in this article are the author's own and do not necessarily represent those of Ezemvelo KZN Wildlife or the University of KwaZulu-Natal.

## Competing interests

None.

## Authors' contributions

AB conceptualised, researched and wrote this article.

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# A taxonomic revision of the *Othonna auriculifolia* Less. group (Asteraceae: Senecioneae: Othonninae)

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A taxonomic revision is presented for the two geophytic species of *Othonna* L. (Asteraceae: Senecioneae: Othonninae) distinguished by a condensed caudex without evident internodes. These species are morphologically and phylogenetically distinct from the remaining geophytic species. This account includes descriptions, complete nomenclature and typification, illustrations and geographical distribution. We recognise the following two species: *O. auriculifolia* with radiate capitula and mature pappus 3–25 mm long, and *O. taraxacoides* (DC.) Sch. Bip. with disciform capitula and mature pappus 3–8 mm long. Both species are vegetatively variable.

**Keywords:** geophytes; *Othonna auriculifolia*; *O. taraxacoides*; nomenclature; southern Africa; synonyms; succulent.

## Introduction

The genus *Othonna* L. (Asteraceae, Senecioneae, Othonninae) comprises ± 90 species of succulent or sub-succulent perennial herbs or shrubs with more-or-less dorsiventrally flattened leaves and radiate or disciform capitula with female-sterile disc florets and female marginal florets with a beige or reddish pappus that is sometimes accrescent (Leistner 2001; Nordenstam 2007, 2012; Magoswana et al. 2019). The genus is concentrated in the Greater Cape Floristic Region of South Africa but extends into southern Namibia, southern Angola and Zimbabwe (Manning & Goldblatt 2012; Manning 2013; Magoswana et al. 2019, 2020).

The genus was last revised in its entirety by Harvey (1865) and is in urgent need of a modern taxonomic revision, although the preliminary floristic treatments by Manning and Goldblatt (2012) and Manning (2013), as well as the recent taxonomic revision of the geophytic species of the genus by Magoswana et al. (2019), constitute a valuable contribution to a complete revision of the genus in the Greater Cape Floristic Region.

Phylogenetic and biogeographic relationships within *Othonna* have not yet been adequately analysed, although the monophyly of the genus and its systematic position in the tribe Senecioneae have been established (Pelser et al. 2007). Preliminary molecular analyses (Magoswana 2017, unpubl.) retrieved the species with a tuberous rootstock and well-developed stem with cauline leaves in a clade comprising the majority of the geophytic species but excluding the remaining few geophytic species with a rosulate habit and condensed caudex.

The geophytic species with an aerial stem (the *O. bulbosa* group) were recently monographed by Magoswana et al. (2019). The present account serves to complete the taxonomic treatment of the geophytic species of the genus *Othonna*, viz. with a rosulate habit (hereafter termed the *O. auriculifolia* group). Members of the *O. auriculifolia* group are deciduous geophytes with the crown at or near ground level and the annual stem highly condensed without evident internodes, thus appearing unbranched. The leaves and branches originate directly from the crown of the subterranean tuberous root, and the capitula are sub-scapose. The flowering capitula are erect or suberect, but the scapes become decumbent in fruit, with the capitula flexed upwards. In contrast, the *O. bulbosa* group have the crown or growth point of the subterranean rootstock with its renewal buds buried well below the soil surface, thus with the lower portion of the annual flowering stem underground and the exposed portion usually well developed. The fruiting peduncles remain erect in fruit (Magoswana et al. 2019).

We provide complete nomenclature and typifications, detailed descriptions and illustrations, and geographical distribution for both species of the *O. auriculifolia* group. Two species are recognised (*O. auriculifolia* Less. and *O. taraxacoides* (DC.) Sch. Bip.), and five names are reduced to synonymy.

## Research methods and materials

### Procedures

All relevant types were examined, as well as all collections from BOL, NBC, PRE and SAM (acronyms following Thiers 2022), the primary collections of southern African species. If the collecting number was not cited in the protologue but is present on the actual specimen then we have included this number in square brackets following the collector's name. Measurements of vegetative and reproductive structures were taken from specimens across the distribution range of each species to account for variation between the subpopulations. For leaf characters, only well-developed lower leaves were measured, as upper leaves may grade into bracts. Leaf width was measured at  $\pm$  the middle of the leaf and leaf length did not include the petiole (if the species has a petiole).

The capitula were initially rehydrated for an hour in pre-boiled water and subsequently the involucre bracts and florets (ray and disc), anthers and stigmas were excised and studied under an Olympus SZ61 stereomicroscope and photographed using an Olympus SC30 camera with Olympus analysis getIT soft imaging

software (Informer Technologies, Inc.). Species localities are cited following the Quarter Degree Reference System (Edwards & Leistner 1971; Leistner & Morris 1976). Both species were also studied in the field in both the Northern and Western Cape provinces of South Africa over the winter and spring growing periods. During these field visits, photographs and detailed field notes were taken to capture any features lost when specimens were pressed, as well as information on habitat, flowering time and species associations.

## Taxonomic treatment

**Othonna** L., Species Plantarum 2: 924. (1753). Type: *O. coronopifolia* L., lecto., designated by Green: 184 (1929).

*Doria* Thunb., Nova Genera Plantarum 12: 162. (1800). Type: Not designated.

Shrubs, subshrubs, or geophytes with underground tuber or herbs,  $\pm$  succulent, crown and leaf axils cobwebbed. Leaves alternate, sometimes crowded basally, linear to ovate or obovate-spatulate or lyrate to pinnatisect, sub-succulent or leathery. Inflorescence terminal, pedunculate, capitula solitary or laxly cymose or paniculate. Capitula heterogamous, radiate or disciform. Involucre campanulate, bracts uniseriate, free and adherent or connate up to  $\frac{1}{2}$ , lanceolate to oblong, glabrous, green with scarious margins. Receptacle conical, punctate, glabrous, epaleate. Marginal florets female-fertile, usually yellow or sometimes white, rarely pink to mauve, filiform or ligulate; ovary glabrous or appressed-puberulous with white twin hairs; style branches with discrete lateral stigmatic areas, apices oblanceolate and shortly papillate. Cypselas ellipsoid to obovoid, 10-ribbed, dark brown, densely appressed-puberulous with myxogenic or non-myxogenic white twin hairs, rarely glabrous; pappus bristles many, basally united, barbellate, persistent, beige or sometimes banded deep red. Disc florets functionally male, numerous, yellow or white to blue or pink, corolla tube funnel-shaped, 5-lobed; anthers obtuse at base with ovate apical appendages, filament collar balusteriform; ovary glabrous; style simple and cone-tipped, rarely with short branches but then without lateral stigmatic zones; pappus of  $\pm$  10 barbellate bristles, sometimes reduced to one or two bristles and lacking in one species, united basally, white.

*Distribution and ecology*:  $\pm$  90 spp., largely restricted to the Greater Cape Floristic Region, with a few species in the eastern summer rainfall regions of South Africa and some extending to southern Angola and Zimbabwe; usually on sandy flats or rocky slopes, rarely seasonally damp sandy flats.

Key to the species of the *Othonna auriculifolia* group

- 1a. Shrubs or shrublets, succulents without tuberous rootstock . . . . . remaining species of *Othonna*
- 1b. Geophytes with thickened or tuberous rootstock:
  - 2a. Crown or growth point buried well below the soil surface, lower portion of annual stem underground and exposed portion usually well-developed; leaves emerge from the aboveground portion of stem . . . . .  
. . . . . *O. bulbosa* group (Magoswana et al. 2019)
  - 2b. Crown at or near ground level, annual stem highly condensed without evident internodes, appearing unbranched; leaves originate directly from crown of subterranean tuberous root:
    - 3a. Capitula disciform; pappus of marginal florets 3–8 mm long . . . 1. *O. taraxacoides* (DC.) Sch. Bip.
    - 3b. Capitula radiate; pappus of marginal (ray) florets 6–25 mm long . . . . . 2. *O. auriculifolia* Less.

## Species treatments

1. ***Othonna taraxacoides* (DC.) Sch. Bip.** in Flora 27(2): 769 (1844). *Doria taraxacoides* DC., Prodrum 6: 471 (1838); Harv. in Flora Capensis. 3: 325 (1865). Type: South Africa, [**Northern Cape**]: ‘in Africæ Capensis regione Gariepinâ [Zwischen Zilwerfontein, Kooperbergen und Kaus in Drège (1843)], *Drège* [2887] [Sept.–Oct. 1838] (G-DC-G00473781, holo.–image!; K-000307012–image!, P-0010014–image!, iso.).

Deciduous geophyte, to 150 mm, stem subterranean, condensed, appearing unbranched, felted at crown; rootstock cylindrical to oblong. Leaves emergent or fully developed at flowering, crowded basally, erect to spreading, base narrowed and petiole-like, blade obovate-spatulate or rarely lyrate-pinnatifid, 10–35 × 5–25 mm, undulate-incised or crenate, glabrous, glaucous, petiole 5–50 mm long. *Inflorescence* cymose but appearing sub-scapose, one or more capitula per plant; scapes erect at flowering but decumbent in fruit, 20–100 mm long, glabrous, ebracteate or sometimes with one or two bracteoles near base. *Capitula* disciform, involucre 10–20 mm diam., involucre bracts 13 or 14, lanceolate to elliptic, 5–15 × 2–4 mm, glabrous-penicillate. *Marginal florets* 13 or 14, corolla tube reduced, collar-like, 0.5–1.5 mm long, pale to deep yellow; ovary ellipsoid-ovoid; style bifid, greatly exerted, 4–6 mm long. *Cypselas* ellipsoid-ovoid, 2–4 × 1–2 mm, densely appressed-puberulous on ribs with white myxogenic twin hairs; pappus of numerous barbellate bristles, 3–8 mm long, beige or sometimes deep red. *Disc*

*florets* numerous, yellow, corolla funnel-shaped, tube ± as long as limb, 0.5–2.0 mm long; filaments 1–2 mm long; ovary narrowly ellipsoid, 3–8 mm long, glabrous; style simple and cone-tipped; pappus of ± 10 barbellate bristles united basally. Figure 1A, B.

*Distribution and ecology*: a local endemic of the winter-rainfall region of Northern Cape, South Africa, distributed along the western escarpment from the Richtersveld to the Kamiesberg Mountains; usually in patches of gravelly quartz or sometimes in quartz outcrops, rarely on granite substrates. Flowering from July to September (Figure 2).

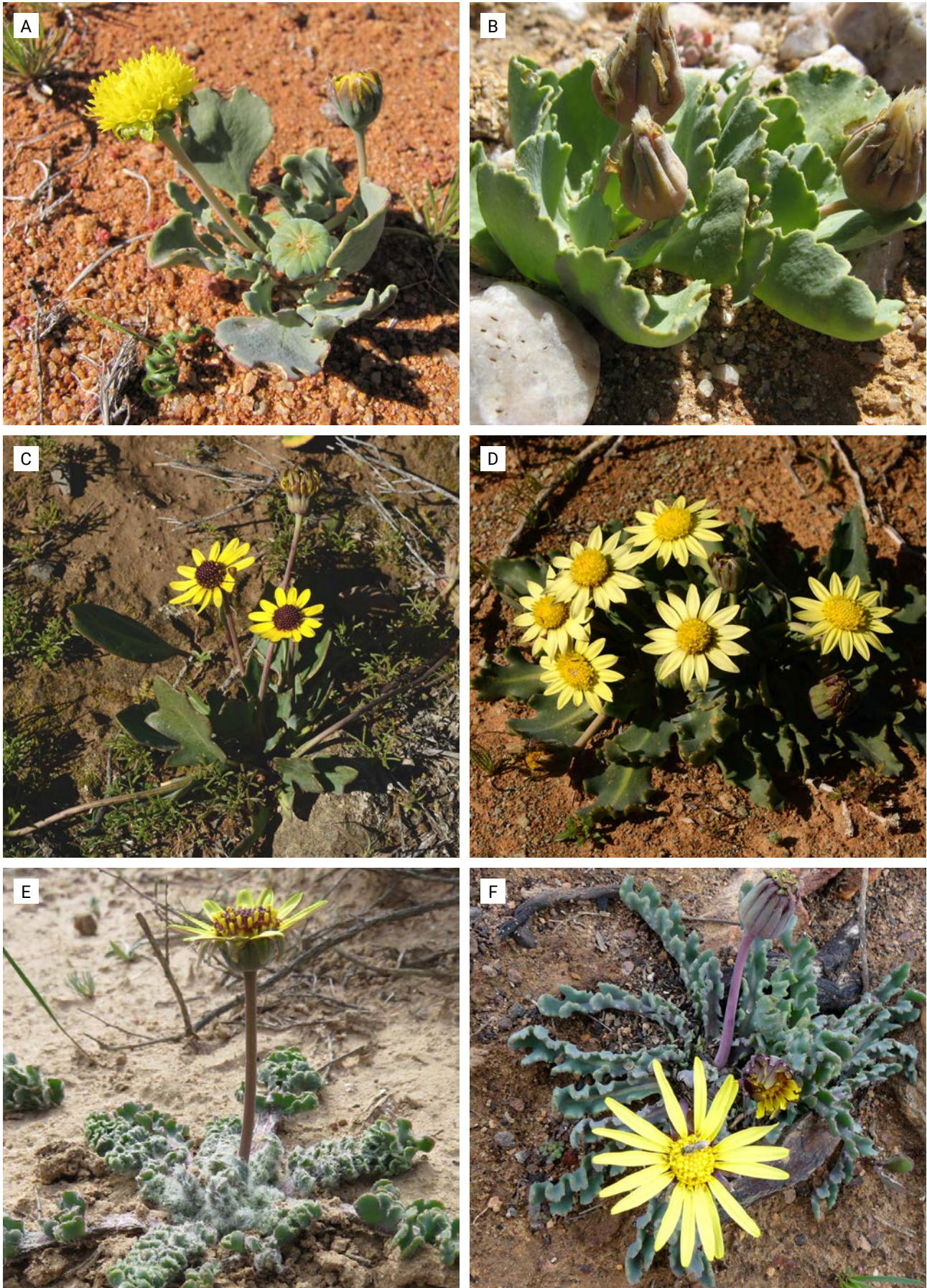
*Diagnosis*: *Othonna taraxacoides* is an acaulescent geophyte with obovate-spatulate or lyrate-pinnatifid leaves 10–35 mm long, and sub-scapose, disciform capitula (Figure 1A, B). The pappus of the cypselas is invariably short, 3–8 mm long.

*Conservation status*: The species is classified as Least Concern (LC) in the SANBI Red List of South African Plants (Von Staden 2016).

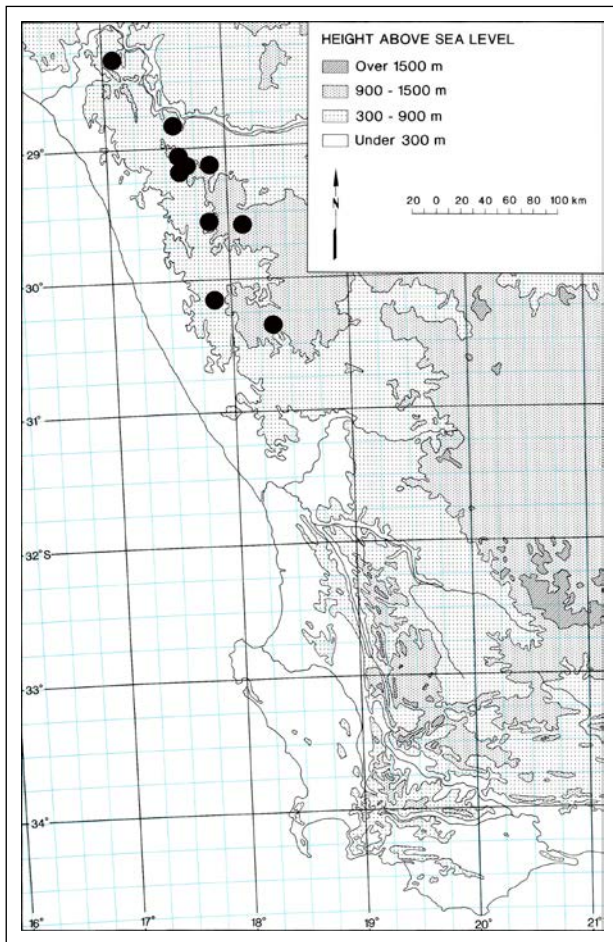
## Additional specimens examined

SOUTH AFRICA. **Northern Cape**: **Vioolsdrif** (2817): Richtersveld (–AC), Sept. 1933, *Herre s.n.* (NBC); base of Umdaus (–DC), 1 Aug. 1988, *Williamson 3915* (NBC). **Springbok** (2917): Steinkopf, W of town along highway (–BA), 22 Aug. 2015, *Deacon 4448* (NBC); 15 km N of Steinkopf (–BA), Sept. 1995, *Williamson 5699* (NBC); 3 miles (5 km) W of Steinkopf (–BA), Aug. 1949, *Hall s.n.* (NBC); ± 10 km E of Jakkalswater (–BB), 8 Jul. 2008, *Bruyns 11116* (NBC); 12 miles (19 km) E of Springbok (–DB), 25 Aug. 1954, *Barker 8382* (NBC). **Gamoep** (2918): Kweekfontein (–CA), 2 Aug. 2000, *Bruyns 8239* (NBC). **Hondeklipbaai** (3017): Kamieskroon (–BB), 4 Aug. 1952, *Hall NBC 462/52* (NBC). **Kamiesberg** (3018): eastern Kamiesberg between Paulshoek and Platbakkies (–AD), 8 Sept. 2006, *Snijman 2088* (NBC).

2. ***Othonna auriculifolia* Less.** in Linnaea 6: 93 (1831) [as ‘*auriculaefolia*’]; DC., Prodrum 6: 481 (1838); Harv. in Flora Capensis 3: 340 (1865). Type: South Africa, [**?Northern Cape**]: ‘Roggeveld Majo’, without date, *Lichtenstein s.n.* in Herb. Willdenow 16734 (B-W 167340–10, holo.–image!). [Note: The name has until now been cited as ‘Licht. ex Less.’ based on Lessing’s (1831) citation of the taxon as ‘*O. auriculaefolia* Lichtenstein in herb. W. No. 16734’ but we find no evidence that Lichtenstein used this name and interpret this entry as merely a citation of the type specimen.]



**Figure 1.** General morphology. A, B, habit of *O. taraxacoides* showing obovate-spatulate or lyrate-pinnatifid leaves and disciform capitula; C–F, *O. auriculifolia*, note the leaves densely covered with long tangled hairs (E), and capitula with 17 ray florets (F). Photographs: A,B: J. Manning; C, E. Marinus; D, F. Linde; E,F: N. Helme.



**Figure 2.** Distribution of *O. taraxacoides*.

*Othonna cyanoglossa* DC., Prodrômus 6: 481 (1838). Type: South Africa, [Western Cape]: 'Carro, Pietermeintjefontein' [Matjiesfontein], June 1838, *Drège* [6078] (G-DC, holo.—microfiche!, P-0004607—image!, syn.).

*Othonna lactucifolia* DC., Prodrômus 6: 482 (1838) [as '*lactuæfolia*']. Type: South Africa, [Eastern Cape]: 'in Africâ Capensi ad Graf-Reynet' [Graaff-Reinet], Aug. 1838, *Drège* [6077] (G-DC, holo.—microfiche!, P-000460—image!, syn.).

*Othonna picridioides* DC., Prodrômus 6: 482 (1838). Type: South Africa, 'in Africâ Capensi deserto Carro', Aug. 1838, *Drège* [6077] (G-DC-00498513, holo.—image!, P-0004605—image!, syn.).

*Othonna auriculifolia* var. *arctotoides* Harv. in *Flora Capensis*. 3: 340 (1865), *syn. nov.* Type: South Africa, 'Wolve River', May [?1842], *Burke s.n.*, (K-0003037010, lecto., designated here; K-0003037009, isolecto!). [Other original material: South Africa, without locality, *Zeyher* 992 (?TCD, not located, P-0004616—image!, syn.).]

[*Othonna pimulina* Schltr, *nom. inval. ms.*, non. DC., Prodrômus 6: 479 (1838): Associated specimens: South Africa, [Northern Cape] 'Onder-Bokkeveld, Oorlogkloof', 21 Aug. 1897, *Schlechter* 10962 (BR-0000008876379 image!, BR-0000008877390, K-306927 image!, PH-20047 image!, S-08-8797)].

Deciduous geophyte, to 250 mm, stem subterranean, condensed, appearing unbranched, felted at crown; rootstock cylindrical to turnip-shaped. Leaves emergent or fully developed at flowering, crowded basally, prostrate or spreading to sub-erect, base narrowed and petiole-like or evidently petiolate, blade narrowly oblong to obovate or suborbicular, flat or concave with lobes curled up, 20–120 × 5–25 mm, serrate or pinnatisect with quadrate to rounded lobes, or rarely entire, leathery to sub-succulent, usually glabrous, sometimes ciliate basally, or rarely sparsely to densely lanate or stiffly setose on both surfaces, glaucous or spotted or streaked with purple, petiole 10–80 mm long. *Inflorescence* cymose, appearing sub-scapose, one to several capitula per plant; scapes erect at flowering but decumbent in fruit, 20–180 mm long, glabrous or rarely sparsely lanate and glabrescent, bracteate basally with 1 or 2 lanceolate to elliptic or sometimes leaf-like bracts. *Capitula* radiate, involucre 10–30 mm diam., involucre bracts 11 to 14, lanceolate to elliptic, 7–15 × 2–5 mm, glabrous-penicillate or rarely lanate. *Marginal florets* 11 to 14(17), corolla tube reduced, collar-like or cylindrical, 0.5–2.0 mm long, limb lanceolate to elliptic, 7–15 mm long, unicolorous or discolorous, pale to deep yellow above, usually flushed purple or blue beneath; ovary ellipsoid to obovoid; style bifid, included, branching below mouth of tube. *Cypselas* ellipsoid-ovoid, 2–6 × 1–3 mm, densely appressed-puberulous on ribs with white myxogenic twin hairs; pappus of numerous barbellate bristles, 3–25 mm long, united basally, beige. *Disc florets* numerous, yellow or lobes sometimes mauve to purple, corolla funnel-shaped, tube ± as long as limb, 0.5–2.0 mm long, lobes lanceolate to ovate, 0.5–1.0 mm long; filaments 1–2 mm long; ovary narrowly ellipsoid, 2–6 mm long, glabrous; style simple and cone-tipped; pappus of ± 10 barbellate bristles united basally. Figure 1C–F.

*Distribution and ecology:* a well-collected species that is widely distributed through the drier interior parts of southwestern and western South Africa, where it is best known from the Hantam and Roggeveld in Northern Cape but as far north as Springbok, extending along the drainage basin of the Orange River into Bushmanland, and south through the interior Cape Floristic Region of Western Cape to Willowmore in Eastern Cape, with scattered records from the interior parts of Eastern Cape and southern Free State; occurring on a wide variety of substrates, usually on shale flats in open karroid scrub, rarely on sandy flats or on sandstone rock sheets at high altitudes in arid fynbos. Flowering from May to September (rarely early October at high altitude) (Figure 4).

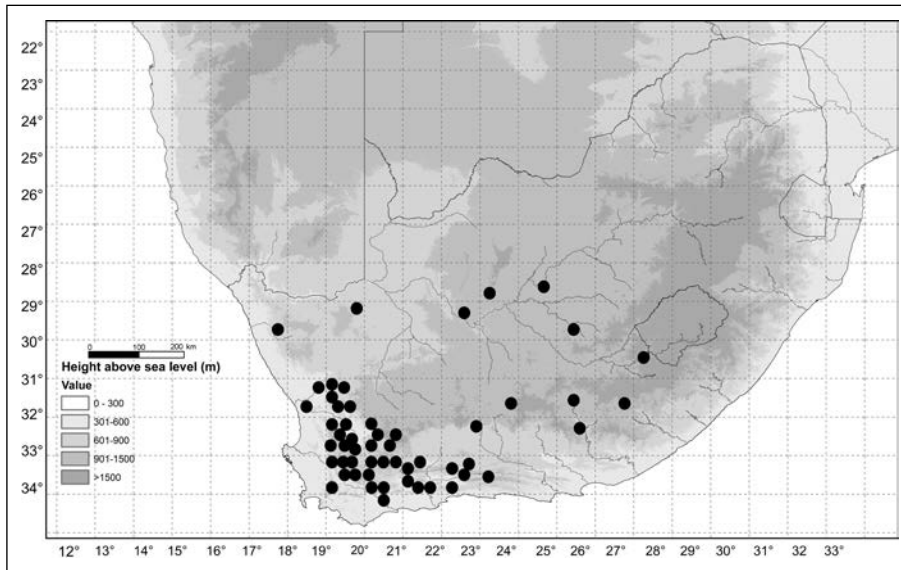


Figure 3. Distribution of *O. auriculifolia*.

**Diagnosis:** *Othonna auriculifolia* is an acaulescent geophyte with entire or serrate to pinnatisect leaves and scapose, radiate capitula with 11 to 14 involucre bracts and often discoloured ray florets, and disc florets sometimes with mauve to purple lobes. The species is vegetatively variable, the leaves ranging from narrowly oblong to obovate and pinnatisect to serrate or sometimes entire and suborbicular (Figures 1C–F & 4). The leaves of *O. auriculifolia* are usually glabrous but a few populations between Clanwilliam and Calvinia [Coetzee CJ1 (NBG), Koopman DK049 (NBG) and Schlechter 10836 (BOL)] are distinctive in having the leaves densely covered with long, tangled hairs. We considered the possibility that these populations represent a separate species but additional populations from Worcester [Tyson s.n. (SAM)] are sparsely lanate-glabrescent and thus intermediate between the glabrous and densely hairy plants, and populations on the Hex River Mountains have the leaves stiffly setose. We therefore conclude that *Othonna auriculifolia* is also variable in leaf vestiture.

Candolle (1838) treated a number of these vegetative variants as distinct species. *Othonna cyanoglossa* DC., based on a collection from Matjiesfontein in Western Cape, was distinguished by ovate to sub-rotund leaves with sinuate-dentate margins, and scapes  $\pm$  as long as the leaves; *O. lactucifolia* DC., from Graaff-Reinet in Eastern Cape, by ovate leaves with sinuate, mucronate-dentate margins and peduncles as long as the leaves; and *O. picridioides* DC. from the 'Karoo' by pinnatifid leaves with subrotund lobes with serrate-dentate margins, and peduncles shorter than the leaves. These taxa were synonymised by Harvey (1865), a decision that is supported by our observations of the  $\pm$  continuous variation in leaf shape among collections and sometimes even individual plants, as well as observations in the field. Harvey (1865), however, segregated plants from Wolve River near Calvinia in

Northern Cape with petiolate, cuneate-obovate leaves with entire or repand, or sometimes variably incised or pinnatifid margins, as var. *arctoides* Harv. Specimens matching this form occur throughout the range of the species among more typical individuals, and evidently represent extreme or juvenile variants, and we do not recognise the variety.

**Conservation status:** The species is classified as Least Concern (LC) in the SANBI Red List of South African Plants (Raimondo et al. 2009).

#### Additional specimens examined

**SOUTH AFRICA. Free State: Jagersfontein** (2925): Fauresmith Botanical Reserve (–CB), 1 Sept. 1925, Smith 398 (PRE); 2 Sept., 1925, Smith 418 (PRE); 27 Jul. 1930, Potter 2022 (PRE); 1 Sept. 1925, Pole-Evans and Smith 841 (PRE).

**Northern Cape: Griekwastad** (2823): Griquatown (–CC), Jun. 1895, Marloth s.n. (PRE); Jul. 1914 (PRE). **Kimberley** (2824): 7 miles [11 km] NE of Kimberley on Samaria Road (–DA), 24 Aug. 1961, Leistner and Joynt 2649 (PRE); 3 miles (5 km) N of Kimberley (–DA), 17 Jun. 1959, Leistner 1421 (PRE). **Springbok** (2917): Hester Malan Nature Reserve (–DB), 1 Jul. 1975, Rosch and Le Roux 1167 (PRE). **Pofadder** (2919): Farm Gannapoort, 26 miles [42 km] east of Pofadder (–BC), 21 May 1961, Schlieben 8952; Leistner 2470 (PRE). **Prieska** (2922): Prieska (–BC), Jun. 1935, Bryant 1130 (PRE). **Calvinia** (3119): Bokkeveld, Farm Meulsteenvlei (–AC), 13 Sept. 1926, Marloth 12945 (PRE); Nieuwoudtville (–AC), 11 May 1983, Perry and Snijman 2093 (NBG); 15 Jun. 1983, Perry and Snijman 2112 (NBG, PRE); 8 Sept. 1983, Perry and Snijman 2356 (PRE); 15 Sept. 2000, Koekemoer and Funk 1949 (PRE);  $\pm$  3 km S of Nieuwoudtville (–AC), 4 Jun. 2010, Helme 6584 (NBG); Glen Ridge Farm, Nieuwoudtville (–AC), 19 Jul. 1962, Barker s.n. (NBG); Nieuwoudtville, Hantam National Botanical Gardens (–AC), 13 May 2015, Coetzee CJ1 (NBG); 23 May 2016, Koopman DK049 (NBG); Willem's River (–AC), without date, Leipoldt 754 (SAM); Karigaboschfontein S of Calvinia (–AD), 20 Aug. 1975,



**Figure 4.** Leaf variation in *Othonna auriculifolia*. A, suborbicular blade with entire margins; B, obovate blade with sparsely serrate margins; C, pinnatisect leaves; D–G, serrate leaves with quadrate lobes; H, densely or stiffly setose, pinnatisect leaves. Scale bar: 2 cm.

Thompson 2473 (NBC); foot of Hantam Mountains (–BC), Jul. 1948, Lewis 2586 (SAM); Hantamsberg, summit of plateau above Ambralshoek (–BD), 18 Aug. 1975, Thompson 2336, 2338 (NBC); Menzieskraal 816, 35 km SE of Nieuwoudtville on Botterkloof Road (–CA), 11 Aug. 2009, Helme 6450 (NBC); Nieuwoudtville Nature Reserve (–CA), 8 Sept. 1983, Perry and Snijman 2356 (NBC); 7 Aug. 1986, Steiner 1243 (NBC); Kareeboomfontein (–DA), 5 Sept. 1974, Hanekom 2398 (PRE); Riepjoeni [Rebunie] Mountains (–DA), Aug. 1921, Marloth 10301 (PRE). **Victoria West** (3123): Groot Boschmanspoort, NE

of Victoria West (–AC), 14 May 1976, Thompson 3078 (NBC). **Sutherland** (3220): Roggeveld, Soekop (–AA), 8 Aug. 2006, Rösch 461 (NBC); Voëlfontein Farm (–AA), 10 May 1969, Hall 219A (NBC); Tankwa Karoo National Park, top of Gannaga Pass (–AA), 5 Aug. 2006, Koekemoer 3205, 3210, 3213 (PRE); Tankwa Karoo National Park, between Quaggasfontein and Uitkyk (–AD), 7 Sept. 2013, Koekemoer 4423 (PRE); Tankwa Karoo, Quaggasfontein (–AD), 27 Sept. 1998, Desmet 1856 (NBC); Koedoesbergpas on Ceres–Sutherland Road (–CC), 20 May 1976, Hugo 398 (NBC); between Laingsburg and

Sutherland near Komsberg Pass (–DB), 3 Jul. 1983, *Vlok 609* (NBG, PRE); 3 km W of top of Komsberg Pass (–DB), 19 Jul. 2006, *Bruyns 10506* (NBG).

**Western Cape: Vanrhynsdorp** (3118): near Vanrhynsdorp (–DA), 6 May 1965, *Barker 10193* (NBG). **Wupper-tal** (3219): Pakhuisberg, 17 km from Clanwilliam on road to Pakhuis (–AA), 25 Aug. 1995, *Rodriguez-Oubina and Cruces 2101* (PRE); Pakhuis, Heuningvlei (–AA), 24 Jul. 1983, *Hockey 1* (NBG); Farm Lamkraal (–AA), 14 Aug. 1987, *Schlechter 10836* [2 sheets] (BOL); top of plateau, Algeria (–AC), 3 Aug. 1937, *Martin NBG 1294* (NBG); Middelberg hut (–AC), Jun. 1980, *Hugo 2372* (NBG); SE slopes of Bloukop (–CB), 13 Sept. 2002, *Burgoyne 9340* (PRE); foothills of Bloukop on the Luiperdskloof 4 × 4 route (–CB), 11 Sept. 2002, *Koekemoer 2411* (PRE); 13 Sept. 2002, *Koekemoer 2425, 2430* (PRE); Breekkrans (–CB), 22 Jun. 1984, *Taylor 10961* (NBG); Gonnafontein (–CB), 8 Jul. 2000, *Pond UP98* (NBG); Koue Bokkeveld (–CC), 13 Aug. 1979, *Miros s.n.* (NBG); Groenfontein, on road to Kaggakamma (–DC), 10 Jul. 1991, *Van Zyl 4205* (PRE); Knolfontein, 60 km NE of Ceres (–DC), 14 May 2008, *Jardine and Jardine 870* (NBG); 26 Aug. 2012, *Jardine 1818* (NBG); 29 Jul. 2009, *Jardine and Jardine 1153* (NBG); 6 Sept. 2011, *Jardine 1593* (NBG); 17 Aug. 2011, *Jardine 1573* (NBG); 15 Jul. 2005, *Jardine and Jardine 17* (NBG); 12 Sept. 2008, *Jardine and Jardine 928* (NBG); 19 Jun. 2006, *Jardine and Jardine 314* (NBG), 26 Jul. 2010, *Jardine 1489, 1490* (NBG); 18 May 2010, *Jardine 1494, 1495, 1496, 1497* (NBG); Groenfontein, Zeekoegat 137, W of Rietriver (–DC), 16 Jun. 2000, *Stobie 4* (NBG). **Beaufort West** (3222): Courland's Kloof, Nelspoort (–DB), Jul. 1907, *Pearson 1486* (SAM). **Worcester** (3319): Matroosberg summit (–AC), 26 Sept. 1981, *Kotze 100* (NBG); Mostersthoek (–AD), 2 Aug. 1926, *Stokoe 697* (PRE); Doornriver (–AD), 9 Jul. 1991, *Van Zyl 4197* (NBG); Farm Tweeriviere along the Ceres–Patatsrivier Road (–BB), 25 Jun. 1979, *Van Breda 4463* (PRE); Karrooport (–BC), Aug. 1919, *Marloth 9010* (PRE); 27 Jul. 1941, *Compton 11159* (NBG); NW of Worcester, 16 May 1948, *Bayer 4142* (NBG); Hex River Mountains, N slopes of Rooiberg (–BC), 19 Aug. 1999, *Oliver 11310* (NBG); 1.5 miles [2.4 km] W of Verkeerdevele dam (–BD), 17 Jun. 1965, *Acocks 23665* (PRE); Verkeerdevele (–BD), 13 Jun. 1975, *Durand 27* (PRE); 12 Jul. 1954, *Barker 8287* (NBG); Matroosberg (–BD), 30 Sept. 1928, *Andrea 1157* (PRE); Zachariashoek, La Motte Forest Station (–CC), 3 Jun. 1982, *Viviers 386* (PRE); near Nuy (–DA), 8 Jul. 1970, *Barker 10702* (NBG). **Montagu** (3320): Tweedside (–AB), 1 Jun. 1925, *Marloth 12058, 12073* (PRE); Pieter Meintjies (–AD), 28 Apr. 1946, *Barker 4023* (NBG); Klein Roggeveld (–BA), 8 Jul. 1938, *Compton 7275* (NBG); Matjiesfontein, Whitehill (–BA), 7 Aug. 1933, *Humbert 9726*; 7 Sept. 1983, *Van Zyl 3567* (PRE); Whitehill (–BA), 7 Jul. 1941, *Compton 10881* (NBG); 17 Aug. 1942, *Compton 13385* (NBG); Waboomsberg main kloof E of Brakleege (–CB), 14 Jul. 1994, *Oliver 10484* (NBG); Touws River (–DA), Jul. 1903, *Marloth 3230* (PRE); Fonteinskloof (–DC), 14 Jul. 1954, *Rycroft 1590* (NBG); Barrydale (–DC), 5 Aug. 1949, *Barker 5463* (NBG); 6 Aug. 1949, *Barker 5400* (NBG). **Ladismith** (3321): N of Klein Swartberg (–AD), 24 Jul. 1957, *Warts 1508* (NBG); Gamka Mountain (–BC), 20 Aug. 1975, *Boshoff P223* (NBG); Witteberg (–CA), 11 May 1941, *Compton 10813* (NBG); top of Witteberge, Matjiesfontein (–CA), 29 Sept. 1983, *Van Zyl 3566* (NBG);

Derde River (–CD), 8 Jun. 1925, *Muir 3624* (PRE); N of Garcia's Pass (–CC), Sept. 1923, *Muir 2951* (PRE); Farm Phisante Kraal 166, top of Witteberg (–CC), 9 Aug. 1988, *Pool 57* (NBG); ± 1 km along road from Dwars in die weg to Rietkuil (–DA), 5 Aug. 2015, *Manning and Magoswana 3507* (NBG); Gamka Mountain Reserve, Bakenskop (–DB), 16 Apr. 1998, *Rourke 2127* (NBG, PRE); Gamka Mountains between Calitzdorp and Oudtshoorn (–DB), 22 Jul. 1980, *Taylor 10209* (PRE); Gamka Mountain Reserve (–DB), 16 Apr. 1998, *Rourke 2127* (NBG); Mountain Zebra Reserve, between Calitzdorp and Oudtshoorn (–DB), 22 Jul. 1980, *Taylor 10209* (NBG). **Oudtshoorn** (3322): Farm Frisgewaagd, Swartberg Mountains (–AD), Jun. 1986, *Vlok 1486* (PRE); Vrolikheid (–BC), Jul. 1976, *Merwe 2837* (PRE); Oudtshoorn commonage (–CA), Jul. 1925, *Marloth 12180* (PRE); Farm Kleinvlakte, 10 miles [16 km] from Barrydale (–DC), 3 Jun. 1974, *Van Breda 4240* (PRE). **Bredasdorp** (3420): Rietvallei, on boundary of four farms and Suurbraak (–BA), 17 Aug. 2008, *Von Witt CR3209* (NBG).

**Eastern Cape: Lady Grey** (3027): Fontein's Kloof, near Driefontein (–CD), 14 Jul. 1954, *Lewis 4497* (SAM). **Victoria West** (3123): Murraysberg (–DD), Apr. 1879, *Tyson 390* (PRE). **Steynsburg** (3125): Conway farm (–CB), Aug. 1899, *Gilfillan 5552* (PRE). **Queenstown** (3126): N slopes of Andriesberg (–DA), 23 May 1899, *Galpin 2611* (PRE). **Cradock** (3225): National Bergkwagga Park [Mountain Zebra National Park] (–AD), 5 May 1963, *Liebenberg 7214* (PRE). **Willowmore** (3323): Uniondale, Vettevlei (–CA), 8 Jul. 1935, *Markötter s.n.* (NBG).

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## Author contributions

S.L.M. and J.M. were the project leaders, A.M. and J.S.B. made conceptual contributions.

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# Ecological factors determining the distribution patterns of *Cyrtanthus nutans* R.A.Dyer (Amaryllidaceae) in northwestern KwaZulu-Natal, South Africa

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**Background:** *Cyrtanthus nutans* R.A.Dyer is a range-restricted species occurring in northwestern KwaZulu-Natal, South Africa and in Eswatini, and is currently classified as Vulnerable in accordance with the IUCN criteria. Land transformation and disturbance of natural habitats have resulted in an ever-increasing fragmentation of the species' range.

**Objectives:** This manuscript provides a description of some of the abiotic and biotic factors associated with the remaining natural populations of *C. nutans* in the Sour Sandveld and Moist Tall Grassland Bioresource Groups of northwestern KwaZulu-Natal.

**Methods:** An investigation was conducted in the northwestern KwaZulu-Natal region to determine the effect that key ecological and anthropological determinants have in influencing the distribution and survival of the species. Data collected included sites of occurrence, estimated population numbers, elevation, ecological factors (soils/geology, climate, veld composition), and human/animal activities.

**Results:** The northwestern KwaZulu-Natal *C. nutans* populations were found to occur primarily in untransformed veld within the Moist Tall Grassveld, Dry Highland Sourveld and Sour Sandveld Bioresource Groups. It occurs largely on gradients of < 10% on mid- to lower terrain slopes and predominantly within an altitude range of between 1 100 and 1 300 m a.m.s.l.

**Conclusion:** *C. nutans* occurs in a narrow altitudinal range and has a preference for soils with high nitrogen and organic carbon and low phosphorus and acidity levels.

**Keywords:** autecology, Dundee fire lily, plant species distribution.

## Introduction

Almost a quarter of the ± 20 700 vascular plant taxa indigenous to the Republic of South Africa are threatened with extinction or are of conservation concern (Von Staden et al. 2013; SANBI 2020). Almost all ecosystems in southern Africa have been modified or transformed by human activity (Macdonald 1989), and southern African plant diversity faces several pressures and multiple threats from both sustainable and unsustainable agricultural practices, urbanisation and mining in addition to the uncontrolled spread of alien invasive plants and illegal plant harvesting (Macdonald 1989; Scott-Shaw 1999). The east coast province of KwaZulu-Natal (KZN) is home to 5 261 vascular plant taxa, of which almost 14% are categorised as threatened or of conservation concern (SANBI 2020).

*Cyrтанthus nutans* R.A.Dyer (Amaryllidaceae), is a deciduous geophyte that reproduces vegetatively or by seed after a short spring flowering period. It is currently classified as Vulnerable B1ab(iii), according to the National Red List categories, with an extent of occurrence (EOO) of 6 067 km<sup>2</sup> in only four locations (SANBI 2020).

The first documentation of *C. nutans* in KZN was by Dr L.E. Codd in 1952, who collected the plants for cultivation. He found the plants and described them as abundant in an area of approximately 8 km<sup>2</sup> in the Vants Drift area (latitude 28° 10'S and longitude 30° 31'E), near Dundee. Two years later, Dyer (1954) formally recorded the presence of the plants and taxonomically described the species. The area of occurrence fell within what is now known as the Umzinyathi District Municipality (DM), and were subsequently found in a small area in the adjoining Uthukela DM. This comprises the study area, which extends over some 1 450 km<sup>2</sup>.

Ten years later the species was located in Eswatini [Swaziland], on the hills around Mbabane above the Komati River, Piggs Peak, by Gordon McNeil (McNeil 1967; Reid & Dyer 1984) and has recently been documented as occurring in the mountains above Barberton, Mpumalanga, South Africa (SANBI 2020).

Distribution patterns of *C. nutans* were briefly described in the Dundee area in 2011 (Scott-Shaw 2011: pers. comm.). Indications were that the species was not as abundant as described in the 1952 Dyer report. The probable causes or factors for a reduction in population are not known. Furthermore, in 2006, the unsuccessful translocation of a *C. nutans* population from a housing development project in the Umzinyathi DM emphasised the lack of information on the specific habitat preferences of the plants. Following these events, informal observations of *C. nutans* were noted, which eventually led to annual Spring recordings of flowering plants, from 2012 onwards, of distribution sites in Dundee, KZN and surrounding areas. A formal re-evaluation of the Dundee *C. nutans* distribution was undertaken from 2014 onwards, which form the current study (Ruddle 2018).

## Materials and methods

### Study area description

The study area is characterised by relatively high elevations, sandy soils, sourveld grasslands and sparsely scattered paperbark thorn trees (*Vachellia sieberiana*). The Bioresource Groups (BRG) that occur in the area are Dry Highland Sourveld, Moist Tall Grassveld, Sour Sandveld and Mixed Thornveld (Camp 1999). The area is typically a summer rainfall region (October to March) with a long-term mean annual rainfall of 749 mm annum<sup>-1</sup>.

Long term annual rainfall records for the period 1968 to 2016 indicated that the highest and lowest annual recorded rainfall during this period occurred during 2012/2013 and 2014/2015 respectively and occurred during the study period (Agrometeorology 2019).

### Data collection

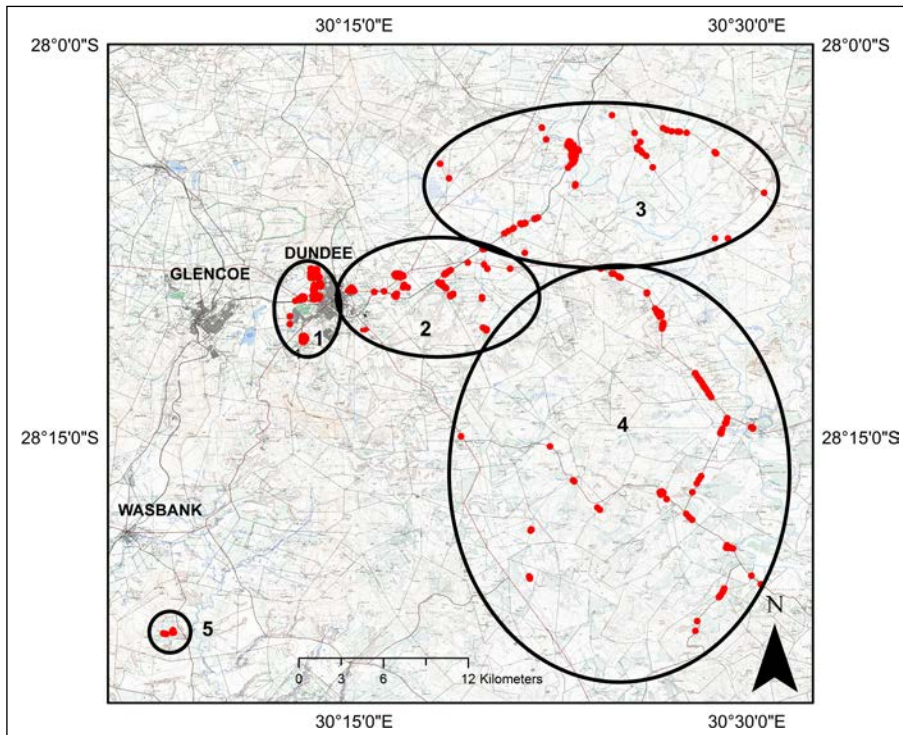
Over a four-year period (2013–2016) during the spring months of September to mid-December, which covers the flowering period of *C. nutans*, areas within the district municipalities were randomly traversed by motor vehicle and on foot, identifying sites of occurrence. The number of flowering plants, latitude/longitude co-ordinates, altitude and gradient were recorded, and the presence or absence of fire/herbivores or human activities and land use were documented.

Vegetation species composition surveys were carried out at *C. nutans* sites according to a method described by Camp and Hardy (1999). A 50 × 50 m square was marked at each site. Within the square, a W-shaped path was traversed, using a sharp stick, of approximately 1.2 m in length, 50 spike-point observations were made. The nearest grass species to the point was identified and recorded.

Soil samples were taken at sites on the basis that no evidence of historical disturbance was noted but were a good representative of the known geology of the area. Using a Dutch auger, samples were taken at a depth of 0–30 cm (Sample A: topsoil, excluding organic material) and depth 30–60 cm (Sample B: sub-soil). The chemical soil analyses were carried out in accordance with standard practices (Manson & Roberts 2001) at the Cedara Feed and Soil Laboratory of the KwaZulu-Natal Department of Agriculture, Environmental Affairs and Rural Development, which is an accredited laboratory.

### Data analysis

Co-ordinates of sites of *C. nutans* occurrence were mapped onto a 1:50 000 digital topographical map and Bioresource Group vegetation map (Ezemvelo KZN Wildlife 2009). The condition of the herbaceous component survey per site was compared with that of a benchmark site to calculate a veld condition per site (Camp & Hardy, 1999). A benchmark site is the most productive of its kind in terms of the highest possible sustained animal production within the Bioresource Groups (BRG) and are pre-described by Camp and Hardy (1999). Climatic data for the study were sourced from the Agricultural Research Council (ARC) (Agrometeorology 2019) weather station, based at the Dundee Research Station (Comp 30109).



**Figure 1.** Range and distribution of *C. nutans* in five main areas within northwestern KwaZulu-Natal (Area 1 = Dundee central; Area 2 = eastern Dundee; Area 3 = northeastern Dundee; Area 4 = Rorkes Drift and Area 5 = Wasbank).

## Results and discussion

### Sites of occurrence

During the study period, a total of 27 sites, where *C. nutans* plants occurred, were found over an area of approximately 1 450 km<sup>2</sup>. In Umzinyathi DM, plants were only located in two of the four Local Municipalities (LM); namely, Endumeni LM and Msinga LM. In Uthukela they were only located in the adjoining Indaka LM near Wasbank. The sites of occurrence were classified into five main groups, according to population densities and basic land use type; namely, Area 1 – urban; Area 2 – semi-urban/industrial/agriculture; Area 3 – semi-urban and agriculture; Area 4 – commercial agriculture; and Area 5 – mixed wildlife/cattle rangeland (Figure 1).

### Description of sites of occurrence

#### Topography

The *C. nutans* populations were recorded at an altitude range of between 1 031 and 1 459 m a.m.s.l. in an area extending over 1 450 km<sup>2</sup>. The great majority of plants (97.98%) occurred within the 1 100–1 300 m altitude range (Figure 2).

#### Slopes and gradients

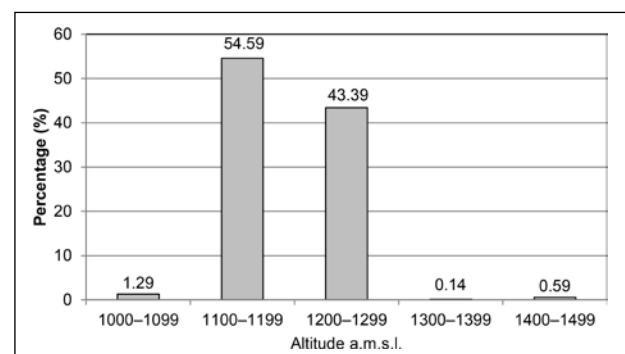
Most of the *C. nutans* populations were found on relatively flat grassveld areas with gradients of less than 15° overall (mid- to foot slopes); 75% of the *C. nutans*

populations were found on gradients of less than 10% with no preference for a particular facing slope.

Gradients play a fundamental role in water drainage and the subsequent formation of soils and nutrient deposits on the lower slopes (Gordon 2017; pers. com.). The soil fertility environment of *C. nutans* is not currently known, however established populations at certain sites may indicate its favourability for the species. Soil acidity levels, clay percentages and nutrient levels based on the soil sample readings, provide an indication of a favourable soil environment (Gordon 2017; pers. com.).

### Geological and soil data

Soil sampling was undertaken in four of the five main areas indicated in Figure 1. The dominant parent rock at the sites was dolerite, with only two sites underlain with shale or sandstone (Table 1). Nitrogen levels



**Figure 2.** Percentage of *C. nutans* plants per 100 m a.m.s.l. altitude range.

**Table 1.** Site geological and soil data

Area		1	2	3	4	Mean values
Number of flowering plants counted		3 039	5 428	11 416	1 433	
<b>Parent material</b>	<b>Soil layer</b>	Dolerite/ shale	Dolerite/ shale	Dolerite sandstone	Sandstone	
<b>Nitrogen N%</b>	Topsoil	0.19–0.20	0.16–0.21	0.09–0.16	0.10	0.16
	Subsoil	0.10–0.15	0.11–0.12	0–0.050	0.03	0.1–0.22
<b>Phosphorous P (mg L<sup>-1</sup>)</b>	Topsoil	6–7	5–7	5–7	7	6
	Subsoil	5	3–5	5	5	5
<b>Potassium K (mg L<sup>-1</sup>)</b>	Topsoil	92–100	164–228	136–172	172	154
	Subsoil	36–55	118–133	109–113	133	102
<b>Calcium Ca (mgL<sup>-1</sup>)</b>	Topsoil	642–745	539–1 625	303–1 919	355	866
	Subsoil	553–757	488–1 901	175–2 738	245	953
<b>Magnesium Mg (mg L<sup>-1</sup>)</b>	Topsoil	249–278	185–836	102–1 496	136	481
	Subsoil	259–284	274–1106	71–1 867	115	627
<b>Total Cations (cmol L<sup>-1</sup>)</b>	Topsoil	5.97–6.43	5.13–15.46	2.88–22.31	3.47	8.86
	Subsoil	5.34–6.39	5.05–18.93	1.92–29.38	2.79	10.33
<b>Acid saturation (%)</b>	Topsoil	4–7	0–6	0–3	4	3.1
	Subsoil	2–6	0–1	0–9	10	3.5
<b>pH (KCl)</b>	Topsoil	4.1–4.5	4.1–5.2	4.6–5.1	4.3	4.5
	Subsoil	4.3–5.0	5.0–5.8	4.2–5.3	4.0	4.9
<b>Clay (%)</b>	Topsoil	22.0–50.0	20.5–29.5	15.0–34.5	18.5	27.3
	Subsoil	22.5–52.5	25.5–35.5	9.0–39.0	21.5	29.1
<b>Organic Carbon (%)</b>	Topsoil	2.05–2.86	1.68–2.63	1.77–1.78	0.9	1.98
	Subsoil	0.87–2.37	0.73–1.60	0.08–0.96	0.52	1.01

were high (>0.16%) in all except one site in Area 3, where subsoil nitrogen levels were too low to measure due to low organic carbon percentages. Low acidity (< 10% acid saturation), high organic carbon percentages (>1.8%) and tolerance of a wide range of textures (15 to 50% clay) and low phosphorous levels appears to be adequate for *C. nutans* plants.

## Vegetation data

*Cyrtanthus nutans* were primarily found within the Moist Tall Grassveld (20% of plants counted) and Sour Sandveld (79% of plants counted) with minimal occurrence in Dry Highland Sourveld (1% of plants counted) (Figure 3).

The veld condition assessment for Area 5 was not conducted as further access to the property was unattainable. No clear picture arises from veld conditions compared with number of flowering plants counted since

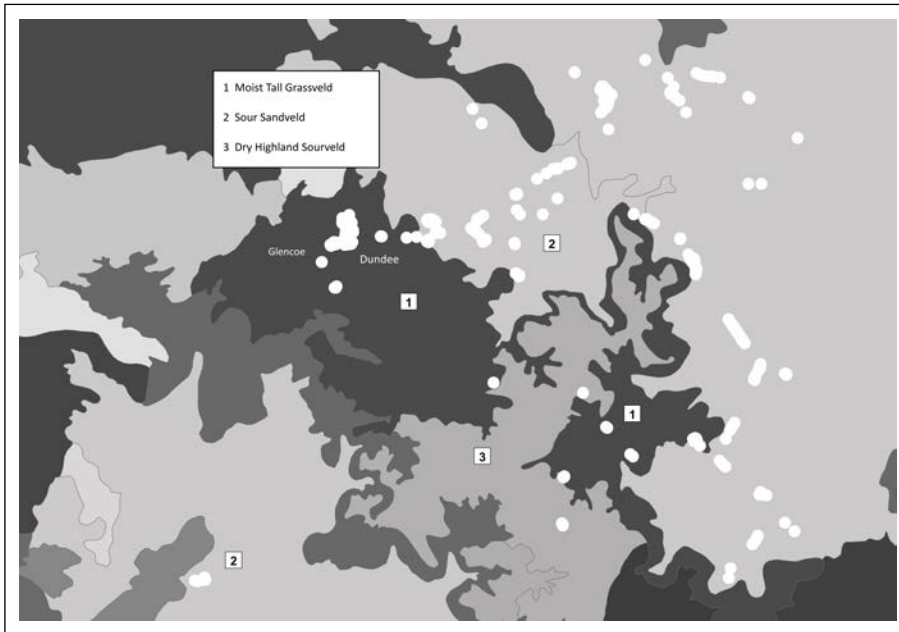
*C. nutans* was found in areas where veld conditions ranged from relatively low (22%) to relatively high (one site indicated a veld condition of 100%). A high percentage of sites (40–100%) had been burnt or grazed prior to plant emergence (Table 2).

## Population size

Most of the flowering plants were located in Area 3 (53%) and Area 2 (25%), with fewer populations in Area 1 (14%), Area 4 (7%) and Area 5 (1%). As the study progressed, fewer new sites plant populations and flowering plants were identified (Table 3).

## Anthropological influences

Large scale fragmentation of an already restricted range was evident with the distribution of *C. nutans*. Population sites were distributed primarily on the periphery



**Figure 3.** *C. nutans* sites located within the Bioresource Groups.

of arable land, in natural veld situated outside of fenced agricultural properties, along road reserves that had not been graded/cleared, and in the narrow band of railway reserves; these areas were not conducive to land transformation. Areas utilised for low intensity grazing over long-term periods were predominantly well populated with *C. nutans*. Only sites situated in Areas 1 and 2 (urban and semi-urban) indicated some form of human activity in terms of pedestrian and vehicular thoroughfares, dumping of building materials, graded road reserves and the subsequent damage to

plants and habitat fragmentation resulting in smaller isolated pockets of plants.

## Conclusions

Abiotic and biotic factors associated with the geographical distribution of *C. nutans* in the Sour Sandveld and Moist Tall Grassland Bioresource Groups of northwestern KwaZulu-Natal have been documented.

**Table 2.** Site vegetation information

Area	1	2	3	4	5
<b>Number of flowering plants counted</b>	3 039	5 428	11 416	1 433	92
<b>Number of sites</b>	7	8	6	5	1
<b>Mean altitude (m.a.m.s.l)</b>	1 253	1 234	1 195	1 233	1 036
<b>Parent material</b>	Dolerite/shale	Dolerite/shale	Dolerite/sandstone	Sandstone	—
<b>Bio-Resource Group</b>	Moist Tall Grassveld	Moist Tall Grassveld	Sour Sandveld	Dry Highland Sourveld	Sour Sandveld
		Sour Sandveld		Moist Tall Grassveld	
				Sour Sandveld	
<b>Veld condition (%)</b>	40–100	22–60	40–62	44–63	—
<b>Decreaser (%) range</b>	3.8–70.6	0–29.8	0–29.1	0–24	—
<b>Burnt (% of sites)</b>	86%	63%	40%	80%	100%
<b>Grazing activity (% of sites)</b>	86%	75%	60%	40%	100%

**Table 3.** Population numbers and sites during the study period

Year	Number of population sites identified						Number of flowering plants identified					
	Area					Total	Area					Total
	1	2	3	4	5		1	2	3	4	5	
<b>2013</b>	7	6	1	2	0	16	2 987	1 467	2 146	126	0	6 726
<b>2014</b>	0	2	3	4	1	10	0	1 353	8 123	1 073	92	1 0641
<b>2015</b>	0	2	3	1	0	6	0	2 474	447	111	0	3 032
<b>2016</b>	1	2	1	2	0	6	52	134	700	123	0	1 009
<b>Total</b>	<b>8</b>	<b>12</b>	<b>8</b>	<b>9</b>	<b>1</b>	<b>38</b>	<b>3 039</b>	<b>5 428</b>	<b>11 416</b>	<b>1 433</b>	<b>92</b>	<b>21 408</b>

The species occurs within a narrow altitudinal range on relatively flat grasslands on predominantly dolerite parent rock in soils with moderate nitrogen and organic material, and low phosphorus and acidity levels. Land transformation in the Dundee area has resulted in the fragmentation of *C. nutans* populations

into smaller isolated pockets. According to Von Staden (2013), the expansion of both urban and agricultural areas in the Dundee area has resulted in a 9% loss of habitat in the past 24 years and *C. nutans* is threatened by habitat degradation due to crop cultivation and overgrazing.

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# New identifications of Lamiaceae (Lamioideae and Scutellarioideae) from D.R. Congo, Rwanda and Burundi

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**Background:** The Lamiaceae family is one of the largest still not covered by the Flore d'Afrique centrale (except Premnoideae and Viticoideae) and many specimens are left unidentified in collections.

**Objectives:** To prepare the treatment of subfamilies Lamioideae and Scutellarioideae, herbarium materials have been revised.

**Methods:** Herbarium material from BR, BRLU and POZG was studied.

**Results:** Ten taxa (9 species and 1 variety) are reported as new to The Democratic Republic of the Congo (D.R. Congo) and Burundi: *Achyrospermum africanum*, *A. axillare*, *A. oblongifolium*, *A. tisserantii*, *Leucas deflexa* var. *kondowensis*, *L. fulvipila*, *L. songeana*, *Stachys pseudohumifusa* subsp. *minutiflora*, *S. pseudonigricans*, *Tinnea gracilis*. For several species, the new localities are remarkably distant from the species' previously known distribution area. New localities of five rare taxa are also included (*Achyrospermum micranthum*, *Leucas nyassae*, *L. stormsii* var. *parviflora*, *Tinnea coerulea* var. *linearifolia*, *T. platyphylla*). Many new localities are situated in regions subject to strong anthropogenic pressure.

**Conclusion:** The new records increase the number of accepted species of Lamioideae and Scutellarioideae in Central Africa by 27%.

**Keywords:** *Achyrospermum*; *Leucas*; *Stachys*; *Tinnea*; tropical Africa, flora; conservation; distribution; Haut-Katanga; Labiatae.

## Introduction

Lamiaceae comprise thirty-five genera and  $\pm$  200 species in Central Africa (D.R. Congo, Rwanda, Burundi) (Paton & Meerts 2020). So far, only two subfamilies have been covered by the Flore d'Afrique centrale i.e., Premnoideae (6 species) and Viticoideae (17 species) (Paton & Meerts 2020). Regional treatments of the Lamiaceae have been published for different parts of that territory i.e., Rwanda (Troupin & Ayobangira 1985), and the Virunga National Park (Robyns 1947). The whole family is now covered by standard floras in neighbouring regions, noticeably Flora of Tropical East Africa (Paton et al. 2009) and Flora Zambesiaca (Paton et al. 2013). The preparation of the treatment of subfamilies Lamioideae and Scutellarioideae for the Flore d'Afrique centrale is now underway. During the revision of the herbarium materials, a number of new records have come to my attention, which I publish here. New localities are also included for five taxa with restricted distributions.

## Materials and methods

The study was conducted in BR (Meise Botanic Garden Herbarium, Belgium) and BRLU (Free University of Brussels Herbarium, Belgium), and is based upon

the examination of specimens either collected after the most recent revision of the relevant genus, or more ancient specimens that had remained unidentified so far. Digitized images of specimens from POZG (Adam Mickiewicz University Herbarium, Poland) have also been obtained. Herbarium acronyms are according to Thiers (2021). Other specimens have been retrieved from GBIF (<https://www.gbif.org/fr/occurrence/>). The nomenclature of accepted species names follows the African Plant Database (version 3.4.0). The specimens cited are grouped according to the phytogeographic regions following Robyns (1948). Geographic coordinates are those reported by collectors, or, when missing, retrieved with Bamps (1982). A map of the study region can be found online (<https://www.floredafriquecentrale.be/#/en/phytogeographical>).

## Results

New records for D.R. Congo and Burundi are documented below. These comprise ten additions to the flora of D.R. Congo and Burundi (based on Govaerts et al. 2021) (marked ‘\*’) (*Achyropermum africanum*, *A. axillare*, *A. oblongifolium*, *A. tisserantii*, *Leucas deflexa* var. *kondowensis*, *L. fulvipila*, *L. songeana*, *Stachys pseudohumifusa* subsp. *minutiflora*, *S. pseudonigricans*, *Tinnea gracilis*).

New records of five rare taxa are also included (marked ‘!’) (*Achyropermum micranthum*, *Leucas nyassae*, *L. stormsii* var. *parviflora*, *Tinnea coerulea* var. *linearifolia*, *T. platyphylla*).

The specimens in BR have been annotated online with our new identifications.

### \**Achyropermum africanum* Hook.f. ex Baker

**Distribution:** Cameroon, D.R. Congo, Guinea, Ivory Coast, Nigeria, Sierra Leone, Togo.

**Habitat:** Understory of dense forests, rainforests; alt. 800–1300 m in D.R. Congo, alt. 900–2380 m elsewhere.

**Specimens examined:** D.R. CONGO. **Kasaï:** Masapo, 06°56’S, 17°20’E, alt. ± 750 m, sous-bois, 14 Apr. 1953, *Callens 1190* (BR). **Lac Albert:** Kilo, 01°50’N, 30°09’E, forêt vierge, 28 Jun. 1914, *Bequaert 4869* (BR). **Lacs Edouard et Kivu:** Parc National Albert [Parc des Virunga], rivière Mulili, affl. droit Byangolo, 00°26’N, 29°46’E, alt. 1300 m, forêt ombrophile équatoriale, 23 Apr. 1952, *de Witte 7641* (BR).

**Discussion:** *A. africanum* was previously known from the Guinean region and the Sudanian region only. The new records in D.R. Congo represent a remarkable extension of the species’ range to the southeast. Interestingly, the three new records originate from different regions of

D.R. Congo, suggesting that the species could be more widespread in the Congolian region. In the materials from D.R. Congo, the corolla is white, while it is either purplish or white in W African materials.

**Bibliography:** Baker (1900), Bruce (1936), Hepper & Keay (1963).

### \**Achyropermum axillare* E.A. Bruce

**Distribution:** D.R. Congo, South Sudan, Uganda.

**Habitat:** Rainforest, dense evergreen forest, swamp forest, gallery forests, fallow fields; alt. 500–1800 m in D.R. Congo.

**Specimens examined:** D.R. CONGO: **Forestier central:** Kivu, Territ, Walikale, env. Mutongo, 52 km NE de Masisi, 01°10’S, 28°37’E, piste Kaseke-Pinga, alt. 1100–1200 m, forêt ombrophile, 22 Jan. 1957, *Troupin 3007* (BR); Mishuli, Mutongo, territ Walikale, 01°10’S, 28°37’E, alt. 1050 m, forêt équatoriale, 6 May 1958, *Gutzwiller 2822* (BR); Lungoma, territ Walikale, 01°06’S, 28°39’E, alt. 1050 m, 11 Jun. 1958, *Gutzwiller 3079* (BR); Bambesa, 03°28’N, 25°43’E, alt. 600 m, forêt, 3 Dec. 1954, *Gérard 1834* (BR); Bambesa, forêt secondaire, 1 Mar. 1961, *Gérard 4860* (BR); Bambesa, recu, 18 Jan. 1963, *Gérard 5519* (BR); Bambesa, jachère, 11 Oct. 1956, *Gérard 2477* (BR); La Kulu, 03°28’N, 23°46’E, alt. 500 m, woud, 3 Feb. 1931, *J.F. Van den Brande 407* (BR). **Ubangi-Uele:** Parc National de la Garamba, env. Bagbele, 04°21’N, 29°17’E, alt. 800 m, partie marécageuse de galerie forestière, sol humifère humide, 20 Jan. 1950, *Demoulin 18* in *De Saeger 068* (BR); Piste frontière vers 68 km, crête Congo-Nil, riv. Mogbwemu, ± 04°20’N, 29°18’E, alt. 800 m, galerie forestière dense, 10 Mar. 1952, *Troupin 388* (BR). **Lac Albert:** Route Gabu-Golu, village Logu, 02°15’N, 30°35’S, alt. 1800 m, galerie forestière, 3 Dec. 1948, *Taton 852* (BR); Ituri District, Mongbwalu Mine Site, 01°58’N, 30°03’E, alt. 1200 m, 23 Oct. 2010, *Luke & Bujo 14535* (BR); Réserve de Djugu, 01°56’N, 30°30’E, en forêt, 28 Nov. 1951, *Smeyers 125* (BR). Lacs Edouard et Kivu: Parc National Albert [Parc des Virunga], riv. Biangolo, 00°26’N, 29°46’E, alt. ± 1300 m, forêt ombrophile dégradée, 28 Apr. 1953, *Frédéricq* in *de Witte 8884* (BR).

**Discussion:** The new records are located in the N and NE of D.R. Congo, markedly expanding the species’ distribution range to the southwest; the westernmost locality (La Kulu) is situated ± 800 km to the west of the previous limit of the distribution range. Many specimens in collections had been previously misidentified as *Achyropermum schimperii* (Hochst. ex Briq.) Perkins ex Mildbr. *A. axillare* is quite distinct,

having a white corolla, pubescent bracts and acute calyx lobes [vs. purplish corolla, subglabrous bracts (except margin) and obtuse calyx lobes in *A. schimperi*].

**Bibliography:** Bruce (1936), Paton et al. (2009).

! *Achyropermum micranthum* Perkins

**Distribution:** Burundi, D.R. Congo, Rwanda.

**Habitat:** Rainforests, mountain evergreen forests, bamboo forests, especially near streams; alt. 1700–2800 m.

**Discussion:** The species was assessed by IUCN as VU (Gereau et al. 2019), based on 12 collections, while GBIF reports 19 localities. Seven new collections have been identified. Even though the new collections do not significantly change the area of occurrence, they indicate that the species is more widespread than previously thought.

**Specimens examined (only newly determined materials):** D.R. CONGO: **Lacs Edouard et Kivu:** Lushasha (Kivu), 02°12'S, 28°47'E, s.d., *Babault* 722 (BR); Dondo, territoire Masisi, 01°25'S, 28°42'E, alt. 1750 m, forêt à *Neoboutonia*, 16 May 1957, *Gutzwiller* 871 (BR); Mont Nyamunono, Terr. Kalehe, 02°04'S, 28°55'E, alt. 2000 m, 4 Mar. 1959, *Léonard* 3290 (BR); Mt Bugulumiza, ± 02°14'S, 28°41'E, alt. 2350 m, forêt dense à *Conopharyngia*, etc. sur sol argileux lourd (basalte à olivine), 26 Jul. 1955, *Pierlot* 663 (BR); Forêt de la Musisi, 21 km route Kavumu-Walikale, Territoire de Kalehe, 02°17'S, 28°37'E; alt. 2270 m, forêt de montagne à *Carapa grandiflora*, pente 40°, 10 Jan. 1959, *Pierlot* 2750 (BR).

RWANDA: **Rwanda-Burundi:** Forêt de Rugege, vallon Buruli (sous le gîte d'Uwinka, au NW de celui-ci), ± 02°28'S, 29°11'E, alt. 2280 m, vallon boisé encaissé, à *Cyathea manniana*, 2 Sep. 1974, *Lambinon* 74/1065 (BR).

BURUNDI: **Rwanda-Burundi:** Prov. Bubanza, Mugeromero (Rugazi), 03°14'S, 29°28'E, alt. 1900 m, sous-bois de forêt de montagne, 01 May 1981, *Reekmans* 10008 (BR).

**Bibliography:** Bruce (1936), Robyns (1947), Troupin & Ayobangira (1985), Bloesch et al. (2009).

\* *Achyropermum oblongifolium* Baker

**Distribution:** Cabinda (Angola), Cameroon, Congo, D.R. Congo, Gabon, Ghana, Guinea, Gulf of Guinea Is., Ivory Coast, Liberia, Nigeria, Sierra Leone, Tanzania (one record).

**Habitat:** Rainforest, secondary forests; alt. 855 m in D.R. Congo, alt. ± 150–900 m elsewhere.

**Specimen examined:** D.R. CONGO: **Forestier Central:** Maniema province, Namoya, lower slopes of Namoya summit, 04°00'59"S,

27°33'51"E, alt. 855 m, overgrown fallow fields and residual forest patches below secondary rainforest, 13 Apr. 2008, *Bytebier* 2867 (BR).

**Discussion:** The species is almost exclusively W African, apart from a single isolated record in Tanzania (material not seen). The new record is situated in a region subjected to increasing anthropogenic disturbance and collecting information indeed reports habitat degradation.

**Bibliography:** Perkins (1921), Bruce (1936), Hepper & Keay (1963), Adam (1975), Morales (2011).

\* *Achyropermum tisserantii* Letouzey

**Distribution:** Cameroon, Central African Republic, D.R. Congo, Equatorial Guinea, Gabon, Republic of the Congo.

**Habitat:** Rainforest; alt. 800–900 m in D.R. Congo, alt. 150–940 m elsewhere.

**Specimens examined:** D.R. CONGO: **Forestier Central** (near the limit of Lacs Edouard & Kivu): Kivu, territoire Walikale, Musenge, 01°38'S, 28°16'E, alt. 800 m, jeune recru, 20 Dec. 1958, *A. Léonard* 1897 (BR); Kivu, territoire Walikale, Tandalukara, 01°33'S, 28°22'E, alt. 850 m, forêt à *Cynometra*, *Julbernardia* et *Staudtia*, 10 Dec. 1958, *A. Léonard* 1927 (BR); Nord Kivu, Irangi, 01°53'S, 28°27'E, alt. 900 m, rive droite de la rivière Luhoho, forêt dense à *Gilbertiodendron dewevrei* et *Uapaca guineensis* sur pentes fortes, 27 Nov. 1988, *Lejoly* 88/730 (BRLU); Kivu, Irangi, gîte IRSAC, ± 01°53'S, 28°27'E, alt. 800 m, forêt dense, sous-bois, 24 Mar. 1967, *Lewalle* 1737 (BR).

**Discussion:** *A. tisserantii* was previously known from the Lower Guinean region only. All new localities are located in Kivu, remarkably isolated > 1000 km in the east of the nearest locations. Collectors do not report the white spots on leaves often found in W African specimens, but the constancy of this trait is uncertain.

**Bibliography:** Letouzey (1967).

\* *Leucas deflexa* Hook.f. var. *kondowensis* (Baker) Sebald

**Distribution:** D.R. Congo, Malawi, Tanzania.

**Habitat:** *Brachystegia* woodlands, streambanks, scrub; in D.R. Congo at alt. ± 1300 m, alt. 800–2150 m elsewhere.

**Specimen examined:** D.R. CONGO: **Haut-Katanga:** Kanfundwa, à environ 6.8 km au nord de Kambove, 10°49'S, 26°36'E, talus de la piste en bordure d'un ruisseau affluent de la Mulungwishi, 8 May 1983, *Schajjes* 1907 (BR, with colour picture).

**Discussion:** This variety is distinguished mostly by its long corolla. Only one collection from D.R. Congo is known, originating from a region that

has been strongly impacted by mining activities in the last decades; the locality could be destroyed.

**Bibliography:** Sebald (1980), Paton et al. (2009).

**\**Leucas fulvipila*** Bramley

*Leucas descampsii* in Angulo (1970) quoad Michel & Reed 2336, non Briq.

*Leucas tettentis* in Sebald (1980) quoad Lewalle 5625, Michel & Reed 2336, Reekmans 536, non Vatke

**Distribution:** Burundi, Tanzania, Zambia.

**Habitat:** *Brachystegia* woodlands; alt. 850–1500 m.

**Specimens examined:** BURUNDI: **Lacs Edouard & Kivu:** Bururi, Rumonge, 03°59'S, 29°26'E, alt. 850 m, forêt claire, 2 May 1971, Reekmans 536 (BR); Rumonge, 03°59'S, 29°26'E, alt. 800 m, forêt claire, 13 May 1952, Lewalle 5625 (BR, WAG). **Rwanda-Burundi:** Kinyinya Mosso, 03°39'S, 30°20'E, forêt de *Cryptosepalum*, 6 Jun. 1952, Michel 2483 (BR); Kinyinya Mosso, 03°39'S, 30°20'E, forêt de *Brachystegia*, 8 May 1952, Michel & Reed 1862 (BR); [Nyamabuye] Mosso, 03°28'S, 30°19'E, forêt de *Cryptosepalum*, 13 May 1952, Michel & Reed 2336 (BR); Bururi, Rubindi, 04°15'S, 29°33'E, alt. 900 m, sous-bois de forêt claire à *Brachystegia*, 16 Apr. 1978, Reekmans 6935 (BR, WAG).

**Discussion:** *Leucas fulvipila* is a recently described species (Paton et al. 2009). The materials from Burundi were previously misidentified as *L. tettentis* Vatke by Angulo (1970) and Sebald (1980), on account of the stiff cilia on bract margins; however, the calyx is quite different. It is closely related to the widespread *L. stormsii* Gürke, from which it is easily distinguished by the 1–2 mm pale yellow cilia on bract margins, much longer than bract width. The new localities extend the species' range  $\pm$  400 km to the north.

**Bibliography:** Paton et al. (2009, 2013).

**! *Leucas nyassae*** Gürke var. *nyassae*

**Distribution:** D.R. Congo, Malawi, Mozambique, Tanzania, Zambia, Zimbabwe.

**Habitat:** Miombo woodlands and shrub savannas; alt.  $\pm$  1300 m, alt. 400–2100 m elsewhere.

**Specimens examined:** D.R. CONGO: **Haut-Katanga:** Territoire de Sakania, environs de Kipushia, env. 5 km au SE de Namapala,  $\pm$  12°54'S, 29°37'E, alt. 1230 m, 28 Apr. 1971, Lisowski 23593 (POZG); Lubumbashi, Kasapa, 11°36'S, 27°38'E, alt. 1230 m, brousse secondaire, 25 Apr. 1971, Lisowski 23594 (POZG).

**Discussion:** The species was previously known from a single old collection [Rogers 21822 (PRE), cited by Sebald (1980)]. Its presence in

D.R. Congo is confirmed here. The new collections are situated in the extreme SE of D.R. Congo, at the northwestern limit of the species' distribution range, at short distance from the nearest localities in Zambia.

**Bibliography:** Sebald (1980), Paton et al. (2009, 2013).

**\**Leucas songeana*** Sebald

**Distribution:** Angola, D.R. Congo, Malawi, Tanzania, Zambia, Zimbabwe.

**Habitat:** Miombo woodlands; alt.  $\pm$  1300 m in D.R. Congo, alt. 1150–1900 m elsewhere.

**Specimens examined:** D.R. CONGO: **Haut-Katanga:** Mont Mukuen, 10 km SE d'Eville [Lubumbashi], 11°46'S, 27°27'E, alt. 1300 m, petite gorge à sol plus profond et frais, 25 Jun. 1948, Schmitz 1704 (BR).

**Discussion:** The species is closely related to the widespread *Leucas martinicensis* (Jacq.) R.Br., from which it differs by the median lobe of the posterior lip of the calyx, which is hardly longer than the other lobes (vs. much longer and erect in *L. martinicensis*), and the calyx tube only weakly curved (vs. strongly sigmoid in *L. martinicensis*). The single collection from D.R. Congo is located in the south of Lubumbashi, in a region that has been subjected to strong urbanization pressure in the last decades.

**Bibliography:** Sebald (1980), Paton et al. (2009, 2013), Vollesen & Merrett (2020).

**! *Leucas stormsii*** Gürke var. *parviflora* Bramley

**Distribution:** D.R. Congo, Tanzania, Zambia.

**Habitat:** *Julbernardia* and *Brachystegia* woodlands; alt. 850–2300 m in D.R. Congo, alt. 850–1000 m elsewhere.

**Specimens examined:** D.R. CONGO: **Haut-Katanga:** Sokele, 09°55'S, 24°36'E, alt. 950 m, Apr. 1950, Desenfans 246 (BRLU); Marungu, Kisinde, 07°21'S, 29°52'E, alt. 2300 m, savane, au bord des chemins, Dubois 1215 (BR); Route Mukoro-Pweto, between 09°10'S, 28°20'E and 08°28'S, 28°54'E, alt.  $\pm$  1000 m, forêt claire à *Julbernardia globiflora*, 24 Jun. 1957, Duvigneaud 3672B (BRLU); Dubie, 08°34'S, 28°31'E, forêt à *Brachystegia bussei* sur colline rocheuse, 24 Jun. 1957, Duvigneaud 3676 (BRLU); Pweto, 08°28'S, 28°54'E, alt. 960 m, savane arborée à sol pierreux, 18 Apr. 1926, Robyns 2027 (BR).

**Discussion:** This variety is characterized by shorter a calyx and corolla and a slenderer habit than the type variety. It was said to occur in D.R. Congo by Paton et al. (2013), but no specimen was cited. Its presence is confirmed here, based on five collections of which four in the E of Haut-Katanga, at short distance from the nearest localities in Tanzania.

**Bibliography:** Paton et al. (2013), Vollesen & Merrett (2020).

\**Stachys pseudohumifusa* Sebsebe subsp. *minutiflora* Y.B.Harv.

**Distribution:** D.R. Congo, Zambia.

**Habitat:** Savannas and dambos, in seasonally waterlogged soil; alt.  $\pm$  1300 m in D.R. Congo, alt. 1000–1300 m in Zambia.

**Specimens examined:** D.R. CONGO: **Haut-Katanga:** Ruashi, 11°37'S, 27°32'E, fond de vallée, terre jaune argileuse, 19 Dec. 1956, *Detilleux 264* (BR).

**Discussion:** The cited collection is only the third one of this subspecies. It is situated  $\pm$  350 and 150 km, respectively, north of the two previous collections (Harvey 1996). The ecology of the species in its Congolese locality is quite similar to both Zambian collections, i.e. herbaceous vegetation on moist soil. The locality is situated in a region that has been under increasing anthropogenic pressure during the last decades due to urbanization and mining activities, and the species could no longer exist there. Two specimens from Tanzania recorded on GBIF [*Bidgood, Congdon & Vollesen 1291* (BR, K), *Bidgood, Congdon & Vollesen 2373* (BR, K)] are actually wrongly databased, being *Stachys pseudonigricans* Gürke. Two other subspecies have been described, i.e. subsp. *saxeri* Y.B.Harv. (Cameroon) and subsp. *pseudohumifusa* (Tanzania); the latter could exist in Haut-Katanga; it is recognized by its longer corolla (10–11 mm).

**Bibliography:** Sebsebe (1993), Harvey (1996), Paton et al. (2009).

\**Stachys pseudonigricans* Gürke

**Distribution:** Angola, Malawi, Mozambique, Tanzania, Zambia, Zimbabwe.

**Habitat:** Miombo woodlands, dambos, on seasonally waterlogged clay soil.

**Specimens examined:** D.R. CONGO: **Haut-Katanga:** Kabanda, 08°42'S, 27°23'E, alt.  $\pm$  1550 m, forêt claire, 19 Mar. 1953, *Desenfans 2489* (BRLU); Kabanda, forêt claire, alt. 1550 m, *Desenfans 2789* (BRLU); Welgelegen, 12°05'S, 27°31'E, alt. 1300 m, forêt dembo à *Uapaca* sur plateau latéritisé à sol hydromorphe, 7 Jan. 1960, *Duvigneaud 4967L* (BRLU); Niamumenda, 11°36'S, 27°18'E, alt. 1300 m, forêt claire à *Brachystegia boehmii* dans une plaine fraîche argileuse, 6 Jan. 1960, *Duvigneaud 4944L* (BRLU); Kamwali, 11°08'S, 27°09'E, alt. 1200 m, forêt claire de plaine à *Brachystegia spiciformis* et *Isobertinia*, 19 Jan. 1960, *Duvigneaud 5118L1* (BRLU); Karavia, 11°39'S, 27°25'E, alt. 1300 m, cultures, anciennes

cultures, bords de sentiers, s.d., *Quarré 1954* (BR); 'Elisabethville' [Lubumbashi], 11°40'S, 27°28'E, alt. 1250 m, 1937, *Salésiens 1060* (BR).

**Discussion:** The new localities fall in two groups, i.e. one group of five collections in the region of Lubumbashi, and another one on the Mitwaba Plateau,  $\pm$  400 km further north. The new localities extend the range to 400 km to the N and to the W of nearest locations in Zambia.

**Bibliography:** Paton et al. (2009, 2013), Vollesen & Merrett (2020).

! *Tinnea coerulea* Gürke var. *linearifolia* (Bamps) Vollesen

**Distribution:** Angola, D.R. Congo, Zambia.

**Habitat:** Miombo woodlands, steppic savannas, sometimes on copper-rich soil.

**Specimens examined (new identifications only):**

D.R. CONGO: **Haut-Katanga:** Parc national de l'Upemba, rive droite de la Lusinga,  $\pm$  8°55'S, 27°12'E, alt. 1700 m, 28 Mar. 1947, *de Witte 2453* (BR); Parc national de l'Upemba, rivière Buye Bala, affluent de la Muye, 8°47'S, 26°56'E, alt. 1750 m, savane herbeuse, 4 Apr. 1948, *de Witte 3637* (BR); Parc national de l'Upemba, savane herbeuse autour de la tête de la source de la rivière Kalumengongo, 8°58'S, 27°06'E, alt. 1830 m, 31 Mar. 1949, *de Witte 5974* (BR); Entre Kisenge (10°42'S, 23°10'E) et Divuma (10°37'S, 22°56'E), alt.  $\pm$  1050 m, 1957, *Duvigneaud 3287T* (BRLU); Dikuluwe, copper hill, 2006, *Lejoly 06/303* (BRLU); Parc national de l'Upemba, 1 km au sud du confluent Wakasinga-Djipwa,  $\pm$  08°47', 27°11'E, alt. 1550 m, 25 Jan. 1956, *P. Vanden Brande 171* (BR, BRLU).

**Discussion:** This variety was initially described at species level by Bamps (1962) on account of its narrow, almost linear leaves; it also tends to have less tomentose inflorescence than the type variety. The new specimens identified show that the variety is widespread in the Upemba region, where the other two varieties [var. *coerulea* and var. *obovata* (Robyns & Lebun) Vollesen] are rare or lacking.

**Bibliography:** Bamps (1962), Vollesen (1975).

\**Tinnea gracilis* Gürke

**Distribution:** D.R. Congo, Tanzania, Zambia.

**Habitat:** Miombo woodlands, especially on rocky outcrops and dry, shallow soil; alt. 1240–1500 m in D.R. Congo, elsewhere alt. 800–1850 m.

**Specimens examined:** D.R. CONGO: **Haut-Katanga:** Kitshinje, 08°24'S, 27°53'E, alt. 1400 m, forêt claire sur affleurement de quartzites, 7 May 1953, *Desenfans 3116* & *Desenfans 3134* (BRLU); Massif de la Luina,

± 12°00'–12°50'S, 27°40'–28°00'E, alt. ± 1250 m, forêt claire à *Brachystegia microphylla* sur conglomérat de base du Roan, 21 Jun. 1957, *Duvigneaud 3614Ti* (BRLU); Entre Welgelegen et Kasumbalesa, ± 12°08'S, 27°40'E, alt. ± 1250 m, forêt claire enrochée à *Brachystegia microphylla*, 29 Jan. 1960, *Duvigneaud 5302T* (BRLU); Près de Kasumbalesa, 100 km S of 'Elisabethville' [Lubumbashi], 12°12'S, 27°48'E, alt. ± 1350 m, crête rocheuse, 27 Mar. 1951, *Schmitz 3517* (BR); Environs de Kasumbalesa, ± 12°12'S, 27°48'E, forêt claire sur pente rocheuse, 20 Mar. 1971, *Lisowski 23785* (POZG); Colline à l'ouest de Kasumbalesa, ± 12°12'S, 27°48'E, alt. ± 1400 m, forêt claire, 20 Mar. 1971, *Lisowski 23789* (POZG).

**Discussion:** The species was previously known from Zambia and Tanzania only. It was first identified in the collections by Paul Bamps in 1985, but that record has apparently remained unpublished. The new collections fall in two groups, i.e. a group located in the SE of Lubumbashi, quite close to the nearest Zambian locality (Ndola), and another one ± 400 km in the north, on the Mitwaba Plateau.

**Bibliography:** Robyns & Lebrun (1930), Vollesen (1975), Paton et al. (2009, 2013), Vollesen & Merrett (2020).

### ! *Tinnea platyphylla* Briq.

**Distribution:** D.R. Congo, (possibly Zambia).

**Habitat:** Miombo woodlands, steppic savannas; alt. 1300–2300 m.

### Specimens examined (new identifications only):

D.R. CONGO: **Haut-Katanga:** Kamatanda, 10°57'S, 26°47'E, alt. 1200 m, forêt claire mixte sur terre rouge et termitières, 9 Feb. 1960, *Duvigneaud 5490* (BRLU); 16 km NW of Likasi, ± 10°52'S, 26°38'E, alt. 1300 m, forêt claire à *Brachystegia boehmii* ceinturant un dembo, 9 Feb. 1960, *Duvigneaud 5486T* (BRLU); Territ. Kasenga, entre Kapama et Kinika, ± 10°27'S, 28°07'E, alt. ± 1000 m, forêt claire sur sable, Jun. 1957, *Duvigneaud 3632T* (BRLU); Mpura, 10 km N Kinika, 10°21'S, 28°06'E (?), alt. 1050 m, steppe arbustive suffrutescente à *Brachystegia nains* sur schiste, 22 Jun. 1957, *Duvigneaud 3639T* (BRLU); Marungu, 2 km S of Lusale Mount, ± 07°36'S, 30°02'E, alt. ± 2200 m, steppe, 27 Jun. 1957, *Duvigneaud 3739* (BRLU); Luiswishi, 11°31'S, 27°27'E, alt. 1208 m, forêt claire, 17 May 1984, *Malaisse 12958* (BR).

**Discussion:** This species is endemic to Haut-Katanga [one collection possibly originating from Zambia (*Bredo 3951*)]; six new collections were found, adding to the ± 11 previously known collections.

**Bibliography:** Robyns & Lebrun (1930), Vollesen (1975).

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# *Arctotis gazanioides* (Asteraceae: Arctotideae), a new species from the Bokkeveld Plateau, Northern Cape Province, South Africa

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**Background:** A taxonomic revision of *Arctotis* L. (Asteraceae) is ongoing. A previous botanical survey of the Avontuur Nature Reserve on the Bokkeveld Plateau, Northern Cape, located a potentially unnamed *Arctotis* taxon associated with seasonally wet sites.

**Objectives:** To compare the morphology of the *Arctotis* from the Avontuur Nature Reserve with morphologically comparable species of *Arctotis* and to determine its taxonomic status.

**Method:** The morphology of fresh collections, herbarium specimens, and relevant type material was examined. All relevant literature was consulted.

**Results:** The Avontuur *Arctotis* is morphologically distinct from *A. acaulis* L. var. *acaulis*, *A. acaulis* var. *undulata* DC. and *A. verbascifolia* Harv.

**Conclusion:** *Arctotis gazanioides* R.J.McKenzie & Helme is described as a new species distinguished by its branching rhizomatous root system with abundant fibrous adventitious roots, and discoloured leaves that are simple lanceolate, lanceolate-ovate to lanceolate-elliptic, or pinnatisect with a lanceolate to lanceolate-elliptic terminal lobe.

**Keywords:** Asteraceae; Arctotideae; *Arctotis gazanioides*; new species; South Africa; morphology; taxonomy.

## Introduction

*Arctotis* L. (Asteraceae, Arctotideae) is the largest genus in the subtribe Arctotideae, comprising approximately 70 species endemic to southern Africa (Karis et al. 2009). *Arctotis* is diagnosed by female ray florets, hermaphrodite outermost disc florets, male or sterile innermost disc florets, smooth filaments, cypselae with the abaxial longitudinal ribs elaborated into two or three wings that create one or two 'cavities' or furrows, and a biseriate pappus of scales. As presently circumscribed, the genus is paraphyletic with *Arctotheca* J.C.Wendl., *Cymbonotus* Cass. and the core elements of *Haplocarpha* Less. (McKenzie & Barker 2008). A taxonomic revision of the genus by the corresponding author is ongoing. In this article, a geographically localised and ecologically specialised species from the Bokkeveld Plateau in the Northern Cape Province of South Africa is described. The species was discovered by the second author in 2012 during botanical surveys of the Avontuur 641 farm, following its purchase by the WWF South Africa and establishment of the Avontuur Nature Reserve. A comparative assessment of all morphologically similar species proved that the Avontuur *Arctotis* was morphologically distinct and supported its recognition at species rank. The species is here formally described and named in accordance with the *International Code of Nomenclature for algae, fungi, and plants* (ICN; Turland et al. 2018).

## Materials and methods

Type material and relevant herbarium specimens housed in BOL, G, G-DC, GRA, K, MEL, NBG, P, PRE, S, SAM, UPS-THUNB and W were examined (herbarium acronyms follow Thiers 2021). Populations were observed in the field and fresh collections made from the Northern Cape Province during the winter–spring growing period. Samples were collected with the permission of the Northern Cape Department of Environment and Nature Conservation (permit no. FLORA 0006/2018) from a maximum of four individuals per population. Vouchers are lodged in GRA, K, NBG and PRE.

Microscopic characters were observed using a SMZ800N stereomicroscope and an Eclipse E200 brightfield microscope (Nikon, Tokyo, Japan). For brightfield microscopic observation, dried plant material was rehydrated in hot water containing a drop of dishwashing detergent and temporarily mounted in water on a microscope slide. Measurements were recorded from fresh or rehydrated material using either a digital vernier caliper (for macromorphological characters) or NIS-Elements D software (for microscopic characters; Nikon). Character measurements reported are derived from 1–6 samples per specimen and from 3–5 specimens. Morphological terminology mostly follows Stearn (1992) and Roque et al. (2009).

## Taxonomy

### Key to species allied to *Arctotis gazanioides*

This key is to the perennial *Arctotis* species with scapigerous shoots and an 'acaulis'-type cypselas in which the cypselas is conspicuously constricted at the base, with three abaxial wings fused above the cypselas base, and crowned with a biseriate pappus of scales. Wherever possible, material from mature (ideally fruiting) plants should be used for reliable identification in *Arctotis*. Young plants of rhizomatous species might appear taprooted but are identifiable from leaf characters.

- 1a. Rootstock taprooted, woody,  $\pm$  turbinate, often lacking secondary roots in upper portion; aerial shoots arising from rootstock crown:
- 2a. Mature leaves discolorous, adaxial surface pilose or glabrescent, not densely lanate, abaxial surface densely lanate, either simple (lamina outline ovate to elliptic) or pinnatisect or lyrate-pinnatisect (lamina outline obovate to elliptic; terminal lobe ovate, rarely ovate-lanceolate or lanceolate-elliptic), with 0–5(–7) pairs of lateral lobes 2–35 mm long,

the longest lobes typically similar in length to terminal lobe width; apical appendage of outer involucre bracts 3.0–8.5(–10.5) mm long, ascending or reflexed . . . . .

. . . . . *Arctotis acaulis* L. var. *acaulis*

- 2b. Mature leaves densely lanate on adaxial and abaxial surfaces, usually simple (lamina outline ovate to subcordate), rarely lyrate-pinnatisect (lamina outline obovate to obovate-elliptic; terminal lobe ovate to subcordate) with 1–2 pairs of lateral lobes 2–15 mm long and considerably shorter than terminal lobe width; apical appendage of outer involucre bracts 0.5–2.5(–7.0) mm long, appressed or ascending or shortly reflexed . . . . .
- . . . . . *Arctotis verbascifolia* Harv.

- 1b. Rootstock rhizomatous, rhizomes stout, woody, branching, with abundant fibrous adventitious roots; aerial shoots terminal on rhizome branches:

- 3a. Leaves simple (lamina outline lanceolate to lanceolate-elliptic), or pinnatisect (lamina outline lanceolate-elliptic or obovate-elliptic; terminal lobe lanceolate, lanceolate-elliptic or lanceolate-ovate), lateral lobes usually longer or of similar length to terminal lobe width, lobe apex frequently curved towards leaf apex; cypselas abaxial and lateral (radial) surfaces sparsely to moderately lanate . . . . .

. . . . . ***Arctotis gazanioides*** sp. nov.

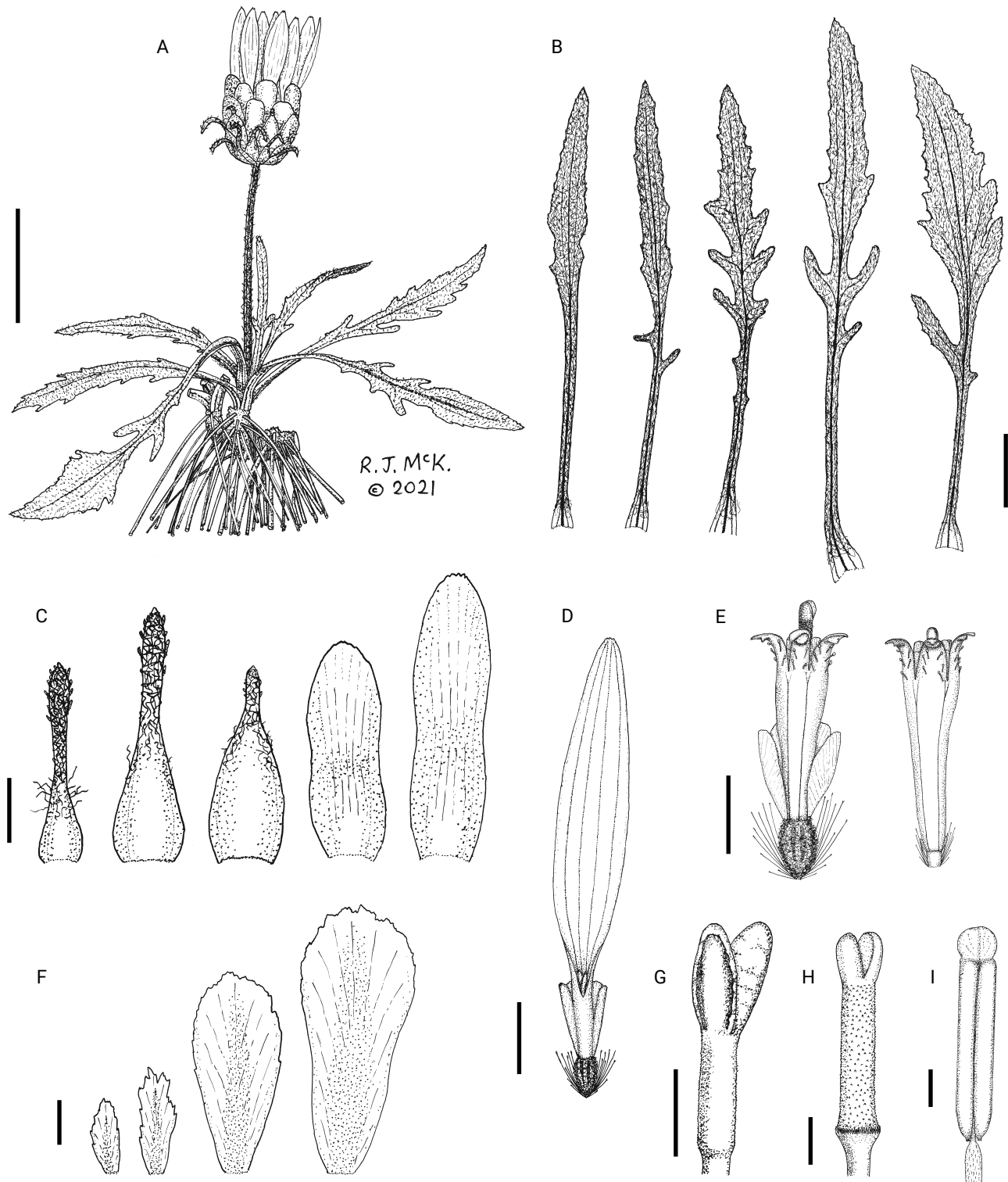
- 3b. Leaves simple (lamina outline ovate to subcordate) or lyrate-pinnatisect (lamina outline obovate to obovate-elliptic; terminal lobe ovate to subcordate), lateral lobes similar in length or shorter than terminal lobe width, lobe apex not curved towards leaf apex; cypselas abaxial and lateral (radial) surfaces glabrous . . . . . *Arctotis acaulis* var. *undulata* DC.

***Arctotis gazanioides*** R.J.McKenzie & Helme, sp. nov. Type: SOUTH AFRICA, **Northern Cape**, Nieuwoudtville (3119): Avontuur Nature Reserve (–AC), 29 Sept. 2019, R.J. McKenzie 3536 (NBG, holo.; GRA, K, PRE, iso.)

*Evergreen herb* initially rosulate, caespitose with age, clumps to  $\pm$  400 mm diameter and 100–200 mm tall. *Rootstock* of young plants taprooted, rhizomatous with age, rhizome cylindrical, stout, branching, woody, to  $\pm$  15 mm diameter, bearing abundant fibrous adventitious roots. *Stems* terminal on rhizome branches, internodes indistinct. *Leaves* crowded basally, spreading to ascending, lamina simple to pinnatisect (typically varying on the same plant), lamina simple (outline lanceolate or lanceolate-elliptic) or pinnatisect (outline lanceolate-elliptic or obovate-elliptic), (40–)60–180  $\times$  (6–)10–27 mm, length:width ratio 1.9–6.7, terminal lobe when present lanceolate, lanceolate-ovate

or lanceolate-elliptic, 20–60(–80) × 6–25 mm, length:width ratio 1.5–7.1, acute to obtuse, lateral lobes 0–4 pairs, longest lobes usually exceeding terminal lobe width, decreasing in length towards leaf base, oblong to oblong-triangular, often antrorse (i.e., lobe

apex curved towards leaf apex), 2.5–15 × 1.5–14 mm wide at base, obtuse, lamina plane or subcanaliculate, margin plane or weakly undulate, dentate-crenate to incised, mucronate, discolorous, adaxial surface with soft short dense pilose pubescence, developing leaves



**Figure 1.** Morphology of *Arctotis gazanioides*. A, flowering shoot and portion of rhizome branch; B, leaves, adaxial surface; C, involucral bracts, abaxial surface, series from outermost (left) to innermost (right); D, ray floret; E, disc florets, peripheral (left) and central (right); F, ray floret pappus scales, smallest and largest scales from outer whorl (left) and inner whorl (right); G, style of ray floret; H, style of peripheral disc floret; I, stamen. Pappus scales and twin hairs on the abaxial side are not depicted in D and E for visual purposes. Scale bars: A, 50 mm; B, 20 mm; C, D, 5 mm; E, 2 mm; F, 1 mm; G–I, 0.5 mm. [R. J. McKenzie 3536/1 (NBG)]. Artist: R. J. McKenzie.

sparsely–moderately lanate becoming glabrescent, abaxial surface densely lanate between major veins, pseudopetiolate, pseudopetiole 20–70 × 2–4 mm, whitish green or reddish purple, adaxial surface sparsely lanate, abaxial surface densely lanate between ribs, often with dense translucent pilose pubescence on both surfaces, base broadened, 3–6 mm wide, semi-amplexicaul, exauriculate, base densely lanate on both surfaces. *Capitulum* terminal, scapose, radiate, 40–55 mm diameter across open rays. *Peduncle* erect, longitudinally ribbed, densely lanate between ribs, dense dark red-purple pilose pubescence along entire length, 90–150 mm long, elongating until fruit maturation, naked. *Involucre* multiseriate, 14–18 × 18–21 mm; outer bracts triangular to triangular-ovate, appendiculate, glabrous to sparsely lanate, margins often flushed red-purple, base 1.5–5.6 × 1.2–4.2 mm, apical appendage linear, reflexed, 2.0–8.8 × 0.5–2.5 mm, obtuse, adaxial surface moderately lanate and pilose, abaxial surface densely lanate, appendage length:base length ratio 1.0–2.0; medial bracts ovate-triangular, margins flushed red-purple, obtuse to rounded, appendage rudimental or lacking, glabrous; inner bracts ovate-oblong to obovate-oblong, glabrous, obtuse to rounded, occasionally retuse, 10–16 × 2–5 mm, margin

entire to erose, usually flushed red-purple, glabrous. *Receptacle* hemispherical, shallowly alveolate, alveolae to 1.25 mm high, fimbriate, fimbria to 4.3 mm long. *Ray florets* 21–27, functionally female, ray limb 18–24 × 4.4–4.9 mm, acute to obtuse, tridentate, limb adaxial surface orange or yellow-orange with black spot at base, adaxial lobe absent, abaxial surface flushed red-purple, abaxial surface with moderate glandular hairs, corolla tube glabrous, 3.9–4.0 × 1.1–1.2 mm; staminodes ovate-lanceolate, blackish; style arms ovate-lanceolate, blackish green, 1.0–1.2 × 0.4–0.5 mm; cypsela obovoid-obconical, base conspicuously constricted below the cavities, 3.0–3.5 mm long × 2.2–2.4 mm wide (tangential) × 2.1–2.5 mm wide (radial), abaxial surface with three wings fused above the base and forming two cavities, medial wing equal in length to or slightly longer than lateral wings, lateral wings hardly incurved, cavities 1.5–1.6 × 0.5–0.6 mm, triangular-linear, obtuse at base, wing margin entire or with incurved acute triangular-linear teeth to 0.5 mm long, partially to ± fully occluding cavity in lower half, medial wing margin entire or rugose-dentate; abaxial surface sparsely lanate, lateral (radial) surfaces moderately lanate, adaxial surface densely lanate; basal whorl of twin hairs ± equal in length to or slightly longer than



**Figure 2.** Morphology of *Arctotis gazanioides*. A, B, Plants in habitat, showing variation in leaf form; C, capitulum, face view; D, capitulum, lateral view; E, ray floret cypsela, abaxial/radial surfaces (note that the basal twin hairs on the abaxial side have been removed for visual purposes). Scale bar: 2 mm. Photographs: A, N.A. Helme; B–E, R.J. McKenzie.



**Figure 3.** Root system of *Arctotis acaulis* and *A. gazanioides*. A, branch of rhizome of *A. gazanioides* (McKenzie 3536/3, NBC); B, rootstock of *A. acaulis* var. *acaulis* (McKenzie 3458, NBC); C, branch of rhizome of *A. acaulis* var. *undulata* (McKenzie 3203/2, NBC). Scale bar: 10 mm.

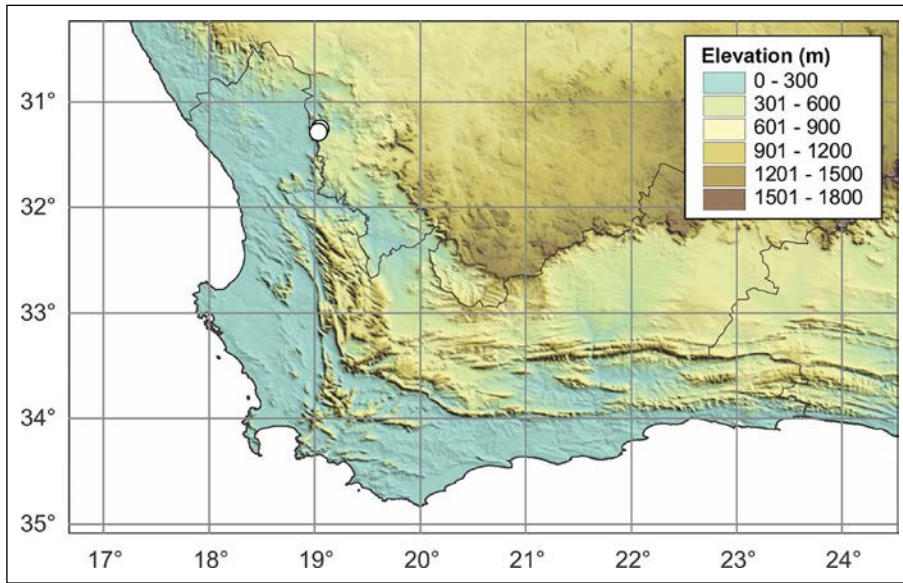
cypsela, to 3.8 mm long, twin hair apex shortly forked (to 0.1 mm) of unequal or equal length; apical plate shortly pubescent, twin hairs to 0.6 mm long; pappus of scales, biseriate, pigmented purple-brown, straw-brown or  $\pm$  translucent, outer whorl  $0.4\text{--}2.1 \times 0.4\text{--}0.8$  mm, longer on adaxial side, lanceolate to obovate-oblong, acute to obtuse, lacerate to erose, inner whorl longer than cypsela,  $3.7\text{--}7.5 \times 1.5\text{--}2.5$  mm, longer on abaxial side, obovate to obovate-oblong, rounded to obtuse, erose, outer surface acutely papillate. *Disc florets*  $\infty$ , outer florets hermaphrodite, inner florets functionally male, corolla funnellform, corolla tube  $4.0\text{--}5.0 \times 1.4\text{--}1.5$  mm, glabrous, corolla lobes abaxial surface black, adaxial surface greenish orange,  $1.2\text{--}1.8 \times 0.7\text{--}0.9$  mm, glandular trichomes sparse-moderate; anthers blackish, apical appendage subrotund-ovate, rounded, pollen orange-yellow; style thickening blackish grey,  $1.9\text{--}2.2$  mm long, arms oblong-ovate, to 0.4 mm long; cypsela of outer florets as for ray florets. Figures 1–3.

### Distribution and habitat

Known only from a small area on the Bokkeveld Plateau north of Nieuwoudtville in the Northern Cape Province of South Africa (Figure 4). The species is associated with seasonally wet loamy sands in the Bokkeveld Sandstone Fynbos (FFs 1) vegetation unit (Rebello et al. 2006).

### Ecology

The species grows in seasonally wet, deep loamy sand at approximately 800 m elevation. The seasonally wet areas constitute discrete localised areas within a matrix of the surrounding fynbos and transitional renosterveld vegetation. Average annual rainfall at Avontuur is approximately 400 mm falling predominantly in winter (March–October), but with a strong rainfall gradient from the edge of the Bokkeveld Escarpment eastwards and marked inter-annual variability in the Nieuwoudtville area (Snijman & Perry 1987; Oetlé et al. 2019). The flowering period is August–October.



**Figure 4.** Distribution of *Arctotis gazanioides*.

### Etymology

The epithet is an adjective derived from the genus name *Gazania* and the suffix *-oides*, indicating resemblance, alluding to the superficial resemblance to certain *Gazania* Gaertn. species in producing dimorphic leaves (simple and pinnatisect forms).

### Illustration

Oettlé et al. (2019): 122 (“*Arctotis* species nova”).

### Diagnosis and relationships

Perennial herb differing from *Arctotis acaulis* L. var. *undulata* DC. in having leaves with a lanceolate to lanceolate-elliptic lamina (when simple) or terminal lobe (when pinnatisect) (versus ovate to subcordate in both cases), and cypselae lanate on all surfaces (versus cypselae glabrous or lanate only on adaxial surface); and from *Arctotis acaulis* L. var. *acaulis* in having a branching rhizome bearing abundant fibrous adventitious roots (versus  $\pm$  turbinata taproot), and leaf lamina lanceolate to lanceolate-elliptic in outline (versus variable in outline but never lanceolate to lanceolate-elliptic).

*Arctotis gazanioides* is hypothesised to be closely allied to *A. acaulis* on the basis of cypselae morphology (see McKenzie et al. 2005). *Arctotis gazanioides* is diagnosable by the combination of a rhizomatous habit, leaves with a lanceolate to lanceolate-elliptic lamina (when simple) or lanceolate to lanceolate-elliptic terminal lobe (when pinnatisect), and cypselae lanate on all surfaces. *Arctotis gazanioides* and *A. acaulis* var. *undulata* are hypothesised to have arisen independently from *A. acaulis*-like progenitors as adaptations to seasonally inundated habitats. *Arctotis gazanioides* is distinguishable from other morphologically similar species by caulescence, lamina shape, pubescence and involucral bract characters (Table 1).

### Conservation status

The species is geographically localised, being currently known from a single property, and is ecologically specialised. It is currently protected within the Avontuur Nature Reserve, which contains the last extensive area of relatively undisturbed Bokkeveld Sandstone Fynbos on the northern Bokkeveld Plateau (Oettlé et al. 2019). Currently, the reserve is partly managed for sustainable agricultural production. Most of the similar habitat on nearby properties in the area has been transformed by cultivation, and it is likely that most other potential subpopulations have thus been lost, but much of this loss probably occurred more than 30 years ago. Predicted climate change as a result of global warming, leading to a warmer and drier regional climate with a shorter rainfall season (Engelbrecht et al. 2009), may impact on the future extent of available habitat. The Extent of Occurrence (EOO) is  $< 10$  km<sup>2</sup> and Area of Occupancy (AOO) is  $< 2$  km<sup>2</sup>. Given the plausible potential threats noted here, a conservation status of VU D2 (IUCN 2012) is warranted.

### Additional specimens examined

SOUTH AFRICA. **Northern Cape:** **Nieuwoudtville** (3119): 20 km NW of Nieuwoudtville, Avontuur 641, 1 km E of Klipvlei (–AC), 9 Sept. 2012, *N.A. Helme* 7620 (NBG); Avontuur Nature Reserve (–AC), 25 Sept. 2019, *R.J. McKenzie* 3524, 3533, 3535 (NBG).

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The curators and staff of the cited herbaria are thanked for allowing access to their holdings or for making digitised images available. The Northern Cape Department: Agriculture, Environmental Affairs, Rural Development and Land Reform is thanked for permission to collect

**Table 1.** Selected morphological differences among *Arctotis gazanioides* and morphologically similar perennial *Arctotis* species

Character	<i>A. gazanioides</i> sp. nov.	<i>A. acaulis</i> L. var. <i>acaulis</i>	<i>A. acaulis</i> var. <i>undulata</i> DC.	<i>A. adpressa</i> DC.	<i>A. campanulata</i> DC.	<i>A. sp. E</i> <sup>1</sup>	<i>A. sp. 2</i> <sup>2</sup>	<i>A. verbascifolia</i> Harv.
Root system	Rhizome	Taproot	Rhizome	Taproot	Rhizome	Rhizome	Taproot	Taproot
Aerial shoot caulescence	Acaulescent	Acaulescent	Acaulescent or shortly caulescent	Shortly caulescent	Shortly caulescent	Shortly caulescent	Shortly caulescent	Acaulescent to shortly caulescent
Leaf lamina shape (simple leaves)	Lanceolate, lanceolate-ovate to lanceolate-elliptic	Ovate to elliptic	Ovate to subcordate	N/A	Ovate to obovate	Linear, oblanceolate	Ovate	Ovate to subcordate
Leaf lamina shape (pinnatisect leaves)	Obovate-elliptic to lanceolate-elliptic	Obovate to obovate-elliptic	Obovate to obovate-elliptic	Obovate to obovate-elliptic	Obovate to obovate-elliptic	Lanceolate-elliptic to obovate-elliptic	Obovate to obovate-elliptic	Obovate
Terminal lobe shape	Lanceolate to lanceolate-elliptic to lanceolate-ovate	Ovate, rarely ovate-lanceolate or lanceolate-elliptic	Ovate to subcordate	Ovate to ovate-elliptic	Ovate	Lanceolate to ovate	Ovate to ovate-elliptic	Ovate to subcordate
Mature leaf pubescence – adaxial surface	Shortly, softly pilose, rarely sparsely lanate	Shortly, softly pilose	Shortly, softly pilose	Densely lanate	Densely lanate	Densely lanate	Densely lanate	Densely lanate
Involucre – outer bract apical appendage	Reflexed or ascending	Reflexed or ascending	Reflexed	Appressed	Reflexed	Absent	Appressed or shortly reflexed	Appressed or shortly reflexed
Involucre – outer bract appendage pubescence	Pilose and lanate	Pilose and lanate	Pilose and lanate	Lanate	Lanate	Absent	Lanate	Lanate
Ray limb colour	Orange	White, yellow, orange, occasionally pastel shades, rarely pale pink	Orange, yellow-orange	Yellow	Orange	White	White, yellow, orange	White, yellow

<sup>1</sup> McKenzie & Herman (2013)<sup>2</sup> McKenzie (2012)  
N/A, not applicable

plant specimens in the Northern Cape Province. Noel Oetlé is thanked for permission to access the Avontuur Nature Reserve. David Gwynne-Evans and Suna Verhoef are gratefully thanked for assistance with field work.

## Competing interests

The authors declare that they have no conflict of interest.

## Authors' contributions

N.A.H. discovered the species in the field, R.J.McK. performed field and experimental work, and both authors wrote the manuscript.

## Ethical considerations

This study followed all ethical standards for research without direct contact with human or animal subjects.

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## Data availability statement


Data sharing is not applicable to this article as no new data were created or analysed in this study.


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# Trends in plant ecology research in Ethiopia (1969–2019): systematic analysis

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**Background:** The current status of plant ecology research in Ethiopia is unknown with the result that it is challenging to judge the impact of existing research on policy development and conservation actions.

**Objectives:** The objective of this paper was to systematically analyse the trends in plant ecological research in Ethiopia over the past 50 years.

**Methods:** The inclusion and exclusion of articles for analysis was carried out using the Reporting Standards for Systematic Evidence Syntheses (ROSES) flow diagram developed for systematic review/meta-analysis.

**Results:** The number of articles published, authors and collaboration has increased dramatically since the 1960s. Most of the research (52.6%) focused on the Dry evergreen Afromontane Forest and grassland complex (DAF) and Moist evergreen Afromontane Forest (MAF) vegetation types. Of the remaining vegetation types, woodlands (14.3%) i.e. *Acacia–Commiphora* woodland and bushland proper (ACW), and *Combretum–Terminalia* woodland and wooded grassland (CTW), desert and semi-desert scrubland (DSS) (2.3%), and the Afroalpine (AA) and Ericaceous Belt (EB) (1.5%) received comparatively little attention. Classical plant ecology themes and descriptive plant community studies were dominant over the last five decades in contrast to the focus on contemporary themes globally. Reproductive and dispersal ecology of invasive plant species and pollination ecology seem to be largely neglected topics. Furthermore, the recommendations forwarded by most of the articles reviewed (38.1%, n = 51) were not result-based.

**Conclusions:** As a future direction, the Ethiopian government should develop a project database for both completed and ongoing projects.

**Keywords:** Afromontane Forest, research syntheses, ROSES, systematic review, vegetation ecology.

## Introduction

Plant ecology as a standalone discipline of botany has a long history with links to the works of Alexander von Humbolt in the early nineteenth century (Hagen 2010). Subsequently, some branches of plant ecology emerged, such as synecology and autecology, which place emphasis on community ecology and individual species respectively. From the early nineteenth century onwards, plant ecologists have studied stands of vegetation, which they considered samples of a plant community (Mueller-Dombois & Ellenberg 1974). Currently, however, traditional ecological terms (e.g., synecology and autecology) are replaced by specialities such as population ecology, community ecology, ecosystem ecology, ecological modelling, global change biology and remote sensing (Hagen 2010; Asselin & Gagnon 2015; Grace 2019).

Even though plant communities were the focus of ecological research during the first half of the twentieth century (Hagen 2010), plant ecology as a discipline

has changed as the scope of the research themes has grown over time. However, there are arguments about the evolution of plant ecological research. For example, Peters (1991) and O'Connor (2000) criticised the state of plant ecological research and argued that ecology as a science has not grown and had just progressed slowly. On their critical response to Peters' criticism and arguments, Grace (2019) and Nobis and Wohlgemuth (2004) countered that ecological research is growing both in scope and citation impact. It is believed that advances in population genetics and evolutionary theory shifted the theme of plant ecological research into a broader scope, which includes population ecology, which combines mathematical modelling and experimentation, to investigate population growth, dispersal and competition from an explicitly Darwinian perspective (Harper 1967, 1977; Hagen 2010; Asselin & Gagnon 2015; Grace 2019). McCallen et al. (2019) identified nearly 50 research topics in ecology over the past four decades.

Like the research topics, the methods employed in plant ecology research also vary depending on the objectives. These might vary in terms of spatial and temporal scale, and organisational levels such as species, population, community and ecosystem. Furthermore, the approaches could be either classical or advanced (Henderson 2012). Although some classical approaches have been retained, plant ecology research methods are evolving. Currently, research in plant ecology is supported by several software systems and is becoming more reputable, which could result in a substantial contribution to vegetation management and biodiversity conservation.

Ethiopia is a country with a very complex topography with elevation varying from about 125 m below sea level to about 4 533 m above sea level (m.a.s.l.) (Gebrehiwot et al. 2020). Two of the 36 biodiversity hotspots, the Eastern Afromontane and the Horn of Africa, are found in Ethiopia (Mittermeier et al. 2004; Hoffman et al. 2016; Gebrehiwot et al. 2020). Thus, Ethiopia is regarded as a major centre of diversity and endemism for several plant taxa though there are extensive anthropogenic disturbances. Taking the complex topography and diverse land use types into consideration, the country has the potential to offer a myriad of research opportunities in plant ecology across a range of themes. Some vegetation surveys were performed across north-eastern Africa (Ethiopia, Eritrea, Djibouti and Somalia) in the late 1950s (Pichi-Sermolli 1957). According to the information extracted from different sources, however, empirical plant ecology research in Ethiopia started only in the late 1960s (Supplementary Table S1).

The objective of, presumably, the first empirical plant ecology research in Ethiopia was to test community ecology hypotheses (Beals 1969). Since Beals' publication, significant numbers of plant ecological studies have been conducted. However, there is no empirical data on the trend in plant ecology research in Ethiopia.

As a result, the progress of plant ecology research in the country is unknown. It is thus challenging to understand the progress made and the impact of the research on policy development and conservation actions. Therefore, a thorough bibliographic analysis of plant ecology research in Ethiopia is necessary to understand whether the discipline is growing as a science in the region. This is also important for documenting what research has been carried out in the past and for highlighting gaps that still exist.

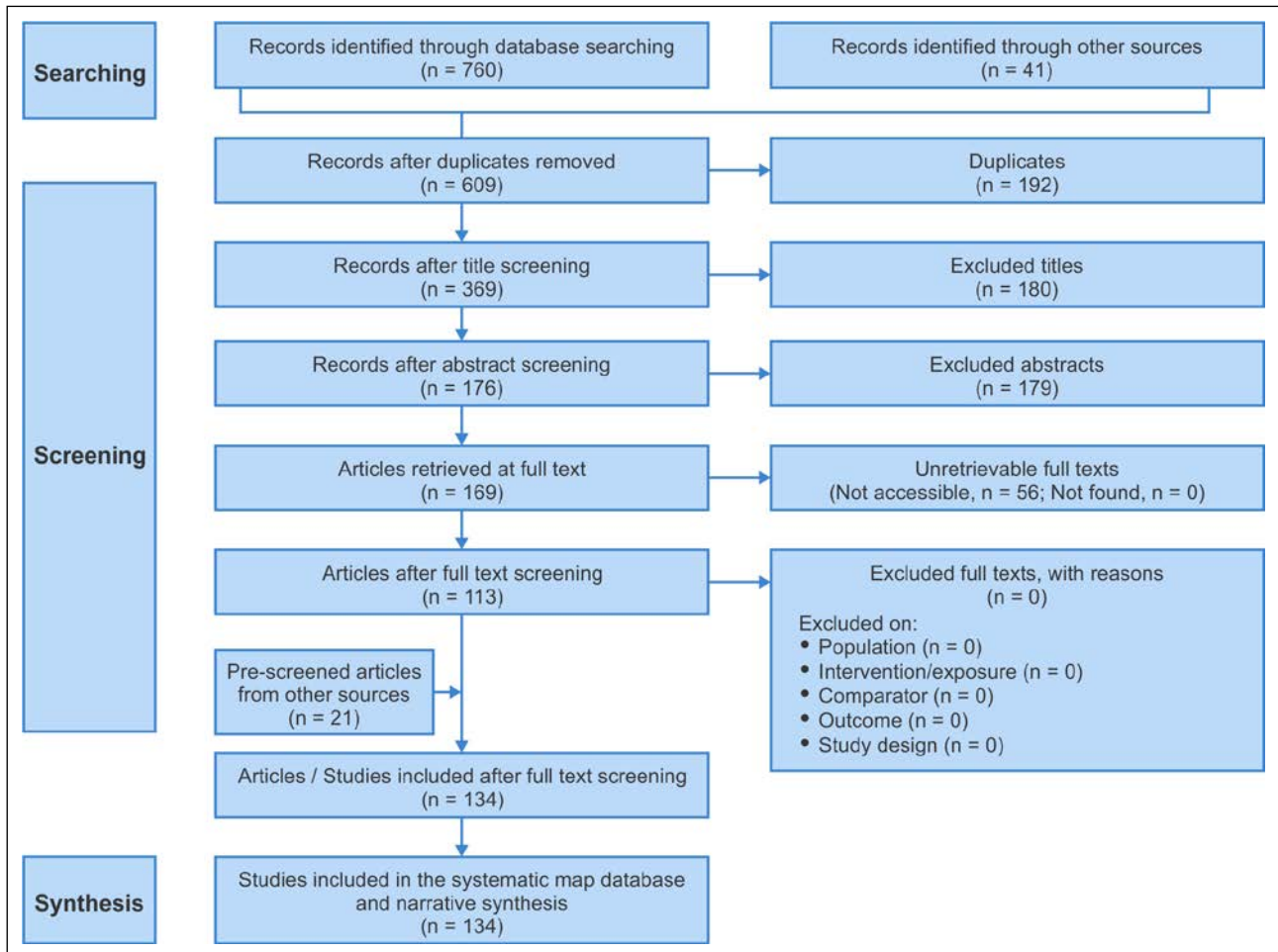
The aim of this paper is to systematically analyse the trends in plant ecological research in Ethiopia in order to answer the following questions: (i) What are the most researched vegetation types (i.e. type of natural ecosystem, such as forests) and land use types (i.e. the purpose for which the land is used, for example farmland?); (ii) What are the most researched domains of plant ecology?; (iii) Is plant ecology research influencing national plant biodiversity conservation policy?; and, (iv) Is there ecological research funding from the government and international sources?

## Materials and Methods

### Data sources and key search terms used

To minimise bias, improve reporting and ensure a better quality and comprehensive systematic review, we followed the Reporting Standards for Systematic Evidence Syntheses (ROSES) flow diagram developed for systematic review/meta-analysis (Haddaway et al. 2018) (Figure 1).

Research publications were filtered and extracted from different sources covering the years between 1969 and 2019. The sources included Scopus, PubMed, African Journals Online (AJOL), Addis Ababa University (AAU) Institutional Repository/Electronic Theses and Dissertations, and Google Scholar. The search covered terms in the articles and in the title, abstract and keywords. The terms included in searching were: ['Floristic' AND 'Ethiopia']; ['woody' AND 'diversity' OR 'structur' AND 'Ethiopia']; ['vegetation' AND 'ecology' AND 'Ethiopia'], ['plant' AND 'communit' AND 'Ethiopia']; ['ordination' AND 'classification' AND 'Ethiopia']; ['invasive AND Ethiopia']; ['species' AND 'distribution' OR 'Model' AND 'Ethiopia']; ['Restoration' AND 'Ecologi'] and ['Elevation' OR 'Altitud' AND 'gradient' OR 'Environment' AND 'Ethiopia']. The combination of terms in the square brackets were entered into the database search bars. The terms used were believed to cover broader plant ecology research themes such as population ecology, community/ecosystem ecology, restoration ecology, and invasive species ecology.



**Figure 1.** ROSES flow diagram for analysis and inclusion of research articles from several databases. Modified from Haddaway et al. (2018).

Six-hundred-and-nine (609) articles from 56 journals were filtered from Scopus, 21 PhD and MSc theses were identified from AAU Institutional Repository/Electronic Theses and Dissertations, and further 20 articles were extracted from AJOL. The articles from Scopus had to pass through a thorough selection procedure. In the first phase, materials that did not follow standard scientific reporting methods such as books and conference papers were excluded. In the second round, articles that focussed only on land use/land cover change although their title includes terms like forest/vegetation cover were excluded. Nevertheless, land use/land cover change that incorporated plant ecological research through GIS and Remote Sensing were included in the analysis. This filtering resulted in 134 articles being included in the study.

## Data analysis

A pre-analysis coding system for the variables was applied (Table 1). The authorship and collaboration, plant ecological research components, descriptive/experimental, vegetation types, community types, methods employed (sampling and analysis), recommendations and funding were coded. Descriptive statistics were employed for the analysis.

## Results

### Authorship and collaboration

Vegetation ecology research in Ethiopia revealed a linear increase in publication (Figure 2A). However, there have been interruptions between the 1960s and 1990s. There has been a dramatic increase after the 1990s, which is illustrated by the figures for 1969 (two articles published) and 2018 (27 articles published). Similarly, the number of authors per publication also showed an increasing trend (Figure 2B). While one author per publication was recorded in several years, the highest number of authors per publication (24) was recorded in 2016. This indicates a trend of increasing collaborative research over the study period.

The author/s affiliation/collaboration involved showed that local authors are dominant and responsible for 83 (62%) of the articles published. International collaborators and foreign authors were responsible for only 48 (35.8%) and three (2.2%) articles respectively. International collaborations started in the late 1990s and grew steadily. Research conducted by foreign nationals only

**Table 1.** Pre-analysis coding system applied to the articles (AAS = Afroalpine and sub-Afroalpine; DAF = Dry evergreen Afromontane Forest; MAF = Moist evergreen Afromontane Forest; CTW = *Combretum–Terminalia* woodland and wooded grassland; ACB = *Acacia–Commiphora* woodland and bushland proper; DSS = Desert and semi-desert scrubland; TRF = Transitional Rain Forest; WGG = Wooded grassland of the Western Gambela region, SSB = Soil seed bank)

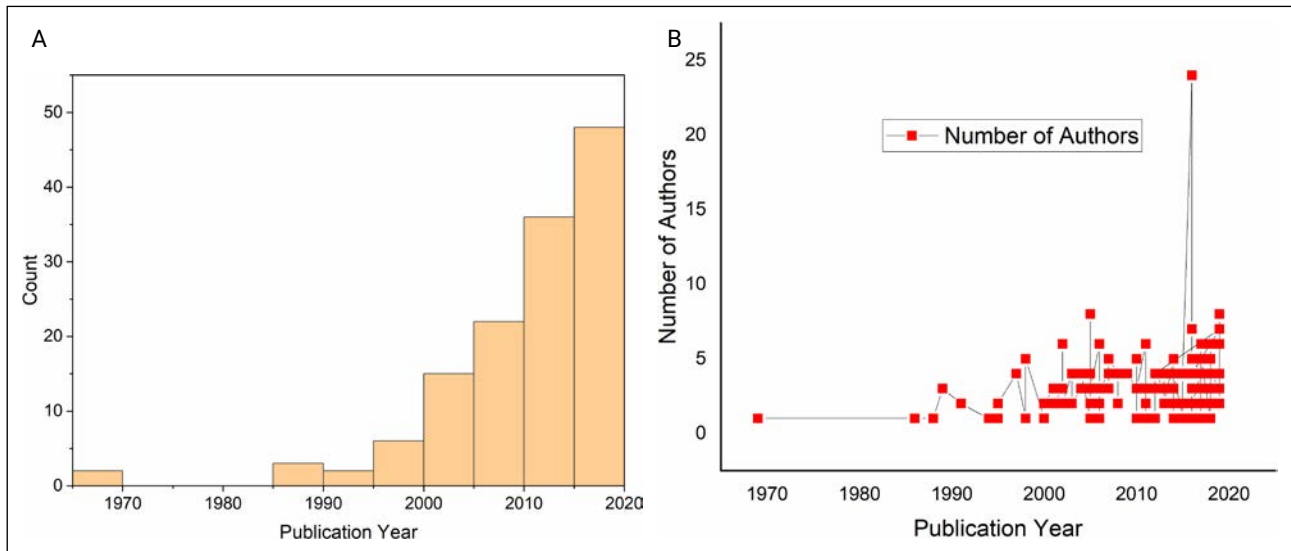
No.	Criteria	Definition	Code
1	Year of publication	The year the publication was published.	
2	Author/s collaboration	The affiliation of the author/s involved in the study.	2.1 = Ethiopian, 2.2 = international collaboration, 2.3 = foreign nationals only
3	Journal quartile	Indicator to evaluate the importance or visibility of a journal.	3.0 = Indexed but journal quartile not indicated, 3.1 = Q1, 3.2 = Q2, 3.3 = Q3, 3.4 = Q4, UI = unindexed, WS = indexed in Web of Science but no quartile yet
4	Objectives	The objectives of the study (indication of the ecological domain).	4.1 = floristic (woody/herbaceous), 4.2 = floristic, structure, regeneration status (count), 4.3 = floristic, structure, soil seedbank, 4.4 = vegetation–environmental–disturbance relationships OR carbon estimation, 4.5 = theory–approach development OR life form/functional traits OR climate change/sustainability, 4.6 = vegetation–environmental disturbance relationships, GIS & remote sensing
5	Land use and vegetation types	The site where the study was conducted. Single species ecology is a study about a particular species that can be performed across land use, vegetation types.	5.1 = AAS, 5.2 = DAF, 5.3 = MAF, 5.4 = CTW, 5.5 = ACW, 5.6 = WGG, 5.7 = DSS, 5.8 = plantation forest, 5.9 = area enclosure/watershed, 5.10 = church forest, 5.11 = TRF, 5.12 = riverine vegetation/wetland, 5.13 = farming landscape, 5.14 = > 1 vegetation types, 5.15 = grasslands/rangelands, and 5.16 = Single species ecology
6	Variables	The biotic and abiotic parameters investigated	6.1 = woody/herbaceous species, 6.2 = floristic, soil seed bank, disturbances, 6.3 = floristic, geographic OR satellite image, 6.4 = floristic soil OR satellite images and aerial images, 6.5 = floristic, geographic, soil, disturbance OR social/sustainability, 6.6 = floristic, geographic, soil, disturbance, soil seedbank 6.7 = floristic, soil, geographic, soil seedbank, remote sensing/allometric equations
7	Sampling method	The data collection design used in the study.	7.0 = not mentioned, 7.1 = random, 7.2 = systematic, 7.3 = preferential, 7.4 = stratified, 7.5 = combination, 7.6 = Plot + GIS, 7.7 = experimental
8	Data analysis method	The data analysis method employed.	8.1 = descriptive, 8.2 = descriptive, community classification, 8.3 = descriptive, classification, ordination, 8.4 = descriptive, classification, ordination plus socio-economic, 8.5 = model, 8.6 = ordination and GIS/ Remote sensing
9	Recommendation	The suggestions made in the article.	9.0 = not available, 9.1 = not result based, 9.2 = shows gap, 9.3 = based on result
10	Funding	The source of funding to run the research.	10.0 = not mentioned, 10.1 = government, 10.2 = international, 10.3 = government & others

is negligible and the only articles published solely by foreign nationals were in 1969 and 2017.

## Plant ecological research components

Results revealed that most of the articles' objectives were descriptive (Table 2). A few articles dealt with some advanced objectives. About 42 (31%) of the articles'

objectives were related to floristic survey, community structure analysis and assessing the regeneration status of a forest based on a seedling, sapling and mature tree count. A theoretical approach development or life form/functional traits and climate change/sustainability themes were covered by only five (3.7%) of the articles. Few articles have been published on invasive plant species distribution and economic impact, and studies on reproductive and dispersal ecology of invasive species



**Figure 2.** Trends in plant ecology research in Ethiopia; A, number of published articles per five-year interval; B, number of authors per publication in each year.

were not found. Furthermore, pollination ecology seems to be a neglected topic in the Ethiopian literature. A few articles have been published on pollination of crops such as coffee (*Coffea arabica*) by honeybees (*Apis mellifera*), but there have been no papers published on pollination ecology of indigenous and wild plants.

### Descriptive/experimental studies

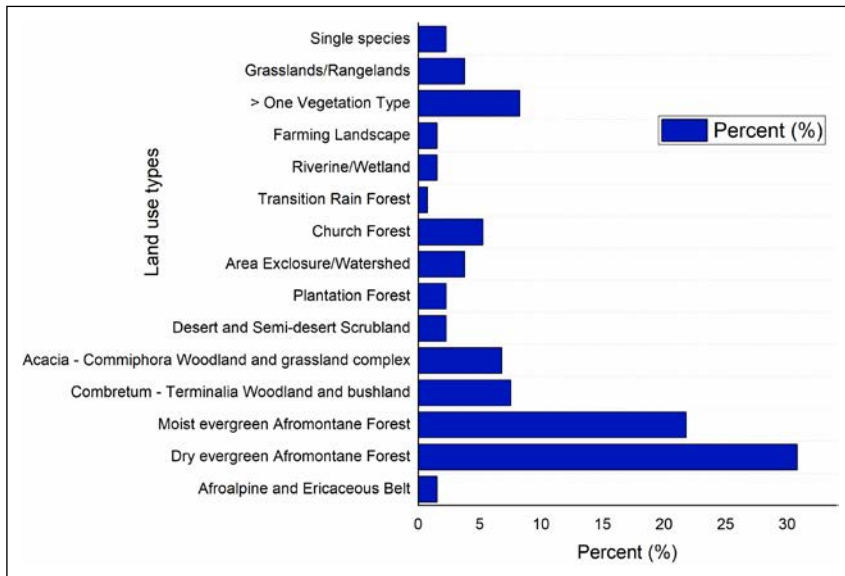
Out of the 134 articles reviewed, only two were experimental while the remainder were descriptive. One of these articles investigated the tree regeneration potential of four species namely *Juniperus procera*, *Ekebergia capensis*, *Prunus africana* and *Olea europaea* subsp. *cuspidata* under three conditions, i.e., along the interior and edge forest gradients, canopy cover, and grazing intensity (Wassie et al. 2009). The other article determined the floristic composition and soil seed bank richness using manure and livestock grazing as treatments (Woldu & Saleem 2000).

### Plant ecological research on vegetation and land use types

Most of the plant ecological research articles in Ethiopia focused on the DAF and MAF vegetation types (Figures 3 & 4). Research on these vegetation types comprised about 52.6% of the articles. However, the woodlands (14.3%) i.e. *Acacia-Commiphora* woodland and bushland proper (ACB), and *Combretum-Terminalia* woodland and wooded grassland (CTW), desert and semi-desert scrubland (DSS) (2.3%), and the threatened Afroalpine (AA) and Ericaceous Belt (EB) (1.5%) received little attention. The Transitional Rain Forest (TRF) vegetation type was represented by only one article (Van Breugel, Friis & Demissew 2016). Nearly 8.3% of the studies covered more than one vegetation type. Church forests, grasslands/rangelands and area exclosures comprised 5.3%, 3.8% and 3.8% respectively. Apart from the natural vegetation types, other land uses have also been an area of plant ecological research. Plant ecology

**Table 2.** The number and percentage of articles published by thematic research topic in Ethiopian plant ecology between 1969 and 2019

Objectives	Number	Percentage of total
Floristic, structure, regeneration (count)	42	31.3
Vegetation–environmental–disturbance relationships OR carbon estimation	35	26.1
Floristic, structure, soil seed bank	28	20.9
Floristic (woody/herbaceous)	16	11.9
Vegetation–environmental–disturbance relationships, GIS & Remote Sensing	8	6.0
Theoretical approach/theory development or life form/functional traits or climate change/sustainability	5	3.7
<b>Total</b>	<b>134</b>	<b>100.0</b>



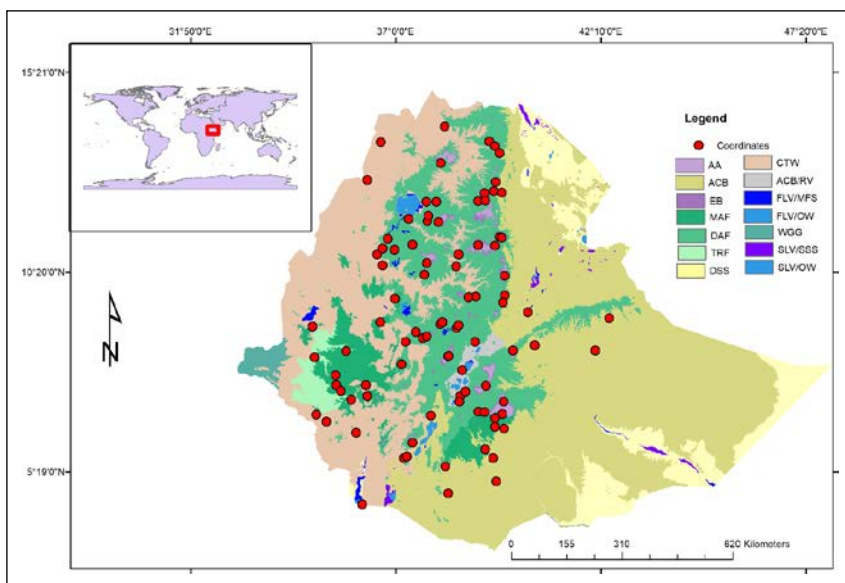
**Figure 3.** Percentage of publications covering different vegetation types or land use types in Ethiopia between 1969 and 2019.

research on farmland landscape and plantation forests comprised 1.5 and 2.3% respectively. About 2.3% of the studies were focused on single species. The absence of appropriate geographical coordinates make tracing some of the study sites challenging.

### Plant community types

About 43% of the studies reported on plant community type analysis. The number of communities varied from two to nine with a mean of five communities per article. However, some articles did not follow

the standard community naming (e.g. *Juniperus–Olea* community) while others showed some deviation in the characteristic species of vegetation types. For example, *Olinia rochetiana* is described as a characteristic species of the DAF (Friis, Demissew & Van Breugel 2010). However, this species was reported as a characteristic species of MAF. Furthermore, although *Erica arborea* is a characteristic species of the Ericaceous Belt, at least two articles reported it as a characteristic species of the DAF (Ayalew, Bekele & Demissew 2006; Yineger et al. 2008). Furthermore, a shrub/tree and herb (for example, *Albizia schimperiana–Hypoestes forskoolii*, *Hyparrhenia filipendula–Combretum molle*) were frequently



**Figure 4.** Map showing localities with coordinates covered by publications on plant ecology in Ethiopia between 1969 and 2019. Vegetation types shown (red dots) and the corresponding vegetation types (AA = Afroalpine Belt; ACB = *Acacia–Commiphora* woodland and bushland proper; EB = Ericaceous Belt; MAF = Moist evergreen Afromontane Forest; DAF = Dry evergreen Afromontane Forest; TRF = Transitional Rain Forest; DSS = Desert and semi-desert scrubland; CTW = *Combretum–Terminalia* woodland and wooded grassland; ACB/RV = *Acacia* wooded grassland of the Rift Valley; WGG = Wooded grassland of the Western Gambela region; FLV/MFS = Freshwater marshes and swamps, floodplains and Lake shore vegetation, FLV/OW = Freshwater Lake Vegetation – Open Water, SLV/SSS = Salt pans, saline/brackish and intermittent wetlands and salt-lake shore vegetation, and SLV/OW = Salt Lake Vegetation – Open Water). Base map from Van Breugel et al. (2015) and the vegetation classification system adapted from Friis, Demissew & Van Breugel (2010).

used to name a plant community. While this is not problematic in the concept of abstract plant communities, naming a plant community after indicator species of different strata (for example, herb (ground herbaceous layer) and tree (canopy)) could be challenging for conservation or management. Furthermore, if the taxa used to name a plant community are from the same stratum they should be separated by a n-dash (–), while those occurring in different strata are separated by a slash (/) and species that may occur with low constancy can be placed in parentheses (Dengler, Chytry & Ewald 2008). Some authors named plant communities after a weed such as *Achyranthes aspera* (Siraj et al. 2017). Overlap of plant community types between vegetation types were also reported in different articles. For example, *Arundinaria alpina* and *Maesa lanceolata*–*Brucea antidysenterica* communities were reported both from DAF and MAF (Bekele 1994; Yeshitela & Bekele 2003; Mewded, Negash & Awas 2019).

## Methods employed by the studies

The selection of data collection and analysis methods were based on the availability of time, funding, expertise and objectives. In the present review 86 (64.2%) of the studies employed systematic sampling while a combination of sampling methods and plot-based data collection supported by GIS only accounted for six (4.4%) studies. The analysis of methods also revealed that more than 50% of the articles were descriptive or largely descriptive (Table 3).

## Journal quartile of the articles published

Almost a quarter of the articles (24.6%) were published in the first quartile (top 25% of journals based

on impact factor or impact index) and second quartile (top 25% to 50%) journals (Figure 5). The articles that were retrieved from African Journals Online (AJOL) and Addis Ababa Dissertation/Theses repository were not indexed although Momona Ethiopian Journal of Science (MEJS) is indexed in Web of Science and tracked for impact.

## Recommendations forwarded by the studies

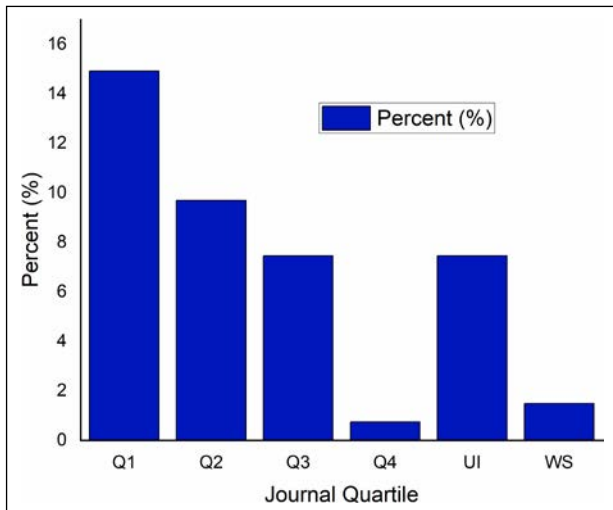
Most of the studies' recommendations were not based on the results of the research (51 articles, 38.1%). For example, some floristic composition studies recommended establishment of a 'Natural Reserve' or 'Biosphere Reserve'. Although floristic study is part of establishing a biosphere reserve, proposing 'Natural Reserve' or 'Biosphere Reserve' based solely on a floristic list is far from the minimum requirement. In only 29 articles (21.6%) were the recommendations based on the results. In 22 articles (16.4%) the recommendations showed the gaps that were not covered by the research reported on. Several studies (32 articles or 23.9%) did not provide any recommendations.

## Funding source reported

The funding for the articles reviewed was predominantly from international funders (58 articles or 43.3%) and the Ethiopian government (47 articles or 35.1%). The remaining articles' funding sources were either collaborative (11 articles or 8.2%) or the funder was not mentioned (18 articles or 13.4%). It is believed that international funding enables researchers to conduct a study with greater scope, but this is not reflected by the articles considered which were mostly descriptive.

**Table 3.** Sampling and analysis methods used in Ethiopian plant ecology publications (1969 to 2019)

Sampling method			Analysis method		
Description	Frequency	Per cent (%)	Description	Frequency	Per cent (%)
Systematic	86	64.2	Descriptive & community classification	34	25.4
Not mentioned	14	10.4	Descriptive	31	23.1
Preferential	14	10.4	ANOVA & Model	25	18.7
Stratified	6	4.5	Descriptive, community classification & ordination	24	17.9
Random	5	3.7	Ordination & GIS/Remote sensing	15	11.2
Combined	5	3.7	Descriptive, community classification, ordination & socio-economic	5	3.7
Plot & GIS	1	0.7			
<b>Total</b>	<b>134</b>	<b>100</b>	<b>Total</b>	<b>134</b>	<b>100</b>



**Figure 5.** Journal quartile of the articles reviewed (Q1 = quartile 1, Q2 = quartile 2, Q3 = quartile 3, Q4 = quartile 4, UI = Unindexed, WS = indexed in Web of Science but no quartile value yet). The journal quartile value is obtained from Scimago (<https://www.scimagojr.com/>).

## Discussion

### Authorship and collaboration

The low number of plant ecological studies in the late 1960s was associated with the lack of trained manpower and political instabilities in the country. Apart from Haramaya and Gondar, which were colleges of agriculture and health science respectively, there has been only one university with a natural science programme, the so-called Haile Selassie I University, which has been known as Addis Ababa University since the early 1970s. Furthermore, most of the experts at the university were foreigners with limited knowledge about the vegetation of Ethiopia, which may explain the low number of plant ecology publications in the early 1970s.

In the early 1980s a flora project was funded by the Swedish International Development Corporation Agency (SIDA) and experts were trained in several disciplines including plant ecology, plant systematics and ethnobotany. A few of those trained are still staff members of Addis Ababa University. Furthermore, the number of universities in the country has increased from one in the 1960s to nearly 50 today. This has tremendously increased the capacity. Concurrently, the number of publications has risen steeply over the last five decades. In addition to the increased number of researchers, there has been an increase in the number of subjects due to new approaches and the development of new technologies from different disciplines which have influenced the increase in plant ecology research publications (Kim, Joo & Do 2018).

Globally, the decline of single-authored articles has been confirmed in various disciplines (Barlow et al.

2018). Similarly, in the present study, single-authored articles showed a declining trend (Figure 2B). This is mainly due to the fact that the research projects are either multidisciplinary or students and staff are included as authors, particularly in the case of publications based on theses or dissertations where the supervisor is included as an author.

### Themes of the research topics

In the 21st century, research is supported by equipment for experiments, software for statistical analysis, and other applications such as GIS and remote sensing, which support field work. As a result of the availability of such technologies, the number of plant ecology articles published and the range of topics has dramatically increased globally (McCallen et al. 2019). In the present review, classical plant ecology themes were dominant over the last five decades in contrast to global contemporary topics such as microscale, macroscale and anthropogenic impacts (McCallen et al. 2019), which employ sophisticated techniques of analysis, including multivariate statistics and mathematical modelling (Kim, Joo & Do 2018). McCallen et al. (2019) identified nearly 50 thematic areas in ecological research. However, less than five thematic areas were covered in the articles reviewed in this study. Descriptive studies on plant community ecology focusing on floristic composition and community structure dominated the studies. However, the few studies on invasive species, fire ecology and species distribution modelling in the 21<sup>st</sup> century reveals that plant ecological research may be changing in Ethiopia. In line with the present study, a co-citation-based analysis study reported the dominance of community ecology research, but this was in the 1970s (Réale et al. 2020). This is, however, in contrast to a report by Carmel et al. (2013) in which single species research found to be dominant.

Ethiopia's natural environment is extremely degraded (Wassie 2020). As a result, most of the environment in the country is likely to be invaded by alien plants. Numerous plant species have been recognised as invasive in Ethiopia. Although most of them are exotic, there are few native plants, which have become invasive. Some of these invasive species appear to have become established in the desert and semi-desert scrubland at elevations lower than 1 000 m a.s.l. (e.g., *Parthenium hysterophorus* and *Prosopis juliflora*) and Afromontane forests at elevation above 2 500 m a.s.l. (personal observation), suggesting that protected areas in the lowlands and highlands are prone to invasive species. However, few studies (Shiferaw et al. 2019a, 2019b) investigated the distribution and impact of invasive species. The study of invasive species distribution and cover as well as reproductive and dispersal ecology is crucial for management or eradication. The impact of invasive species is profound in the Rift Valley.

However, studies on this topic, as well as in this ecosystem are extremely limited. Persistent environmental degradation and climate change are aggravating the impact of invasive species, which means that research in this field is a critical need.

Pollination, an often-mutualistic interaction, is at the core of ecological networks and plays a vital role in maintaining community stability and ecosystem function. Nevertheless, these interactions are threatened due to natural and anthropogenic disturbances leading to a global decline of pollinators. Plant–pollinator networks can potentially modify the population dynamics and the occupied range of a plant species (Pellissier, Alvarez & Guisan 2012). However, the contribution of pollination networks as driver of plant distribution and assemblage of plant communities has received little attention in Ethiopia. Thus, there is a need to characterise plant–pollinator interactions at large spatial scales and especially with respect to dynamic communities, whose compositions and patterns of relative species' abundance vary in time and space (Pellissier, Alvarez & Guisan 2012). In the Anthropocene, global warming is causing changes in species' fundamental and realised environmental niches. As a result, plants are shifting their ranges and phenology. This causes plant–pollinator mismatches, which leads to plant and pollinators diversity decline. Apart from the scant pollination studies on crops (Samnegård et al. 2014, 2016; Geeraert et al. 2020), particularly *Coffea arabica*, research on plant–pollinator networks in natural plant communities are absent in Ethiopia. This is identified as an important gap.

The limited number of articles based on experimental studies and advanced themes could be due to the lack of resources for experimental activities and limited expertise in these fields. Unlike the present study, Carmel et al. (2013) and Asselin and Gagnon (2015) revealed both observation and experimental studies shared almost equal contributions in their systematic reviews.

Although the Swedish organisation (SIDA) contributed to training experts in different fields, these were limited to the basic sciences. Hence, these experts have worked on descriptive research, and they encouraged the students they supervised to do their theses/dissertations on similar topics. Once the graduates are distributed to different universities, they follow the footsteps of their supervisors. As a result, redundancy of research focus occurs throughout the country.

## Vegetation, land use and plant community types

Performing ecological research is not an easy task. Collecting ecological data from the field requires physical fitness as well as the ability to withstand harsh conditions and deal with other challenges associated with

field work. Most of the plant ecological research was in either the DAF or MAF vegetation types. This could be due to forest being considered a high priority and these two vegetation types are dominant. In addition, DAF and MAF are found in an area which has a relatively suitable climate and so has the highest human populations, which means that these vegetation types are easily accessible. The high population does mean that these forests are also the most threatened (Woldu 1999) and so ongoing research is important.

The other important vegetation types attracted little attention, particularly, the Afroalpine and Ericaceous Belt, which are the main sources of freshwater for the downstream population. This could be due to the extreme cold and inaccessibility or the perceived low priority of these vegetation types. Similarly, there were few articles from drylands/lowlands vegetation types.

## Journal quartile of the articles published

Journal Impact Factor (JIF) quartile is among the most widely used indicators to evaluate the importance or visibility of a journal in its field (Liu, Hu & Gu 2015). The reviewed articles were predominantly published in relatively high impact journals. Nevertheless, a significant number of studies were published in undervalued journals, and so it is not possible to track their impact.

## Recommendations and source of funding

Plant ecological research publications often make recommendations based on empirical data and conclusions drawn. The recommendations may serve as guidance for natural resource managers and decision- and policy makers in conservation practices. Furthermore, highlighting research gaps could also have profound benefit. In the present study, most of the recommendations were not made based on the research results despite their relevance to decision makers. This shows either missed opportunities to help the relevant stakeholders or obscure research objectives.

Whether the funding source is governmental or international, the funders might have their own agendas. Often funders are interested in contributing to conservation decisions based on scientific evidence (Burivalova et al. 2019) to maximise the benefits of conservation, given the limited resources available (Game 2018). It is interesting that international funding dominated in the studies reviewed but the research topics investigated using international funding are more-or-less similar to the investigations conducted with Ethiopian government funding.

Monitoring of completed projects and incorporating research recommendations into policy and decision-making is poorly realised. For example, Teketay and Bekele (1995), Hundera and Deboch (2008) and Hundera et al. (2007) recommended Wof-Washa, Gurra Farda and Dodola forests as nature reserves. However, they are not yet designated as protected areas (UNEP-WCMC 2017). Furthermore, forest and woodland cover loss are reported even in protected areas (Nune, Soromessa & Teketay 2016; Arafaine & Asefa 2019), revealing lax policy and decision-making. This disconnect between research findings and recommendations and conservation practice could be due to the following reasons: i) the government is responsible for integrating the research outputs into policies; ii) complexity of socio-ecological systems (Miteva 2012); (iii) lack of funding for conservation operations (Ferraro & Pattanayak 2006); and iv) lack of trustworthy scientific studies.

## Is plant ecology research growing up in Ethiopia?

There are debates on the progress of ecological research. Bringing Grace's (2019) question, 'Is ecology growing up?' to the Ethiopian perspective, if the context is the number of published studies, plant ecology research is definitely growing up. However, the quality of plant ecological research in Ethiopia is not growing up if the criteria applied are the research theme, the use of sophisticated technologies and the depth of study. This is excluding the land use/land cover change domain that focused on the change detection only. Plant community descriptive studies more-or-less dominated the plant ecology research thematically. This topic was the main focus of plant ecological research in the 1960s to 1970s in Europe and Northern America. Hence, although it seems like a negative perspective, plant ecology research in Ethiopia is still stuck in the 1970s.

## Conclusions and future directions

This study systematically synthesised trends in plant ecology research in Ethiopia over the last 50 years. Descriptive plant community ecological studies dominated the plant ecology research thematically – most of them distributed in the DAF and MAF – while the Afroalpine and Ericaceous Belt, woodland (ACB &

CTW), and desert and semi-desert scrubland (DSS) vegetation types got little attention. Hence, the following future directions are suggested to guide and improve plant ecology research in Ethiopia going forward.

Future plant ecology research should include the application of remote sensing in vegetation ecology, climate change and vegetation ecology, and plant functional ecology, vegetation temporal dynamics and experimental approaches should be considered.

Establishing a committee that comprises plant taxonomists, plant ecologists, geologists, geographers and GIS experts is recommended to investigate and map the plant community types at a national level. This is crucial to allocate conservation resources objectively otherwise, fragmented studies of plant community types of a particular sites will make conservation efforts increasingly challenging.

Recommendations from any research study, if available, should be based on empirical information to make policy and decisions justifiable. Funders such as government agencies, non-government organisations and others, including international agencies, are advised to provide resources to cover important topics such as invasive species ecology, application of GIS and remote sensing in vegetation ecology, and community interactions. Supervisors should also play a major role in helping postgraduate students identify contemporary ecological research areas such as pollination ecology.

The Ethiopian Ministry of Science and Higher Education (MoSHE) should establish a database both for completed and ongoing research projects i.e., project registration in addition to what exists at various universities. This would help to avoid project redundancy.

## Competing interests

The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.

## Authors' contributions

KG (Samara University) inception, study design, data collection and analysis, and write-up. SD (Addis Ababa University) contributed to the project inception, data analysis and manuscript writing.

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# Supplementary Material

**Supplementary Table S1.** Studies included in the systematic review and location where the study was carried out

Citation	Study area
Beals (1969). <i>Science New Series</i> 165, 981–985	Bati to Combolcha; Awash to Shashemene
Beals (1969). <i>Journal of Ecology</i> 57, 655–667	Erer-Gota Plain (Southern Afar, Danakil Depression)
Woldu (1986). <i>Vegetatio</i> 67, 3–16	Shewa
Demissew (1988). <i>Mountain Research and Development</i> 8, 243–247	Menagesha Forest
Woldu et al. (1989). <i>Vegetatio</i> 81: 189–198	Harena Forest
Woldu & Backéus (1991). <i>Journal of Vegetation Science</i> 2: 173–180	Shewa
Bekele (1994). <i>Journal of Vegetation Science</i> 5, 87–98	Jibat
Teketay (1995). <i>Mountain Research and Development</i> 15, 183–186	Dakata Valley
Teketay & Bekele (1995). <i>Feddes Repertorium</i> 106, 127–147	Wof Washa
Tekle et al. (1997). <i>Nordic Journal of Botany</i> 17, 48–493	Southern Wello
Demissew (1998). <i>Journal of Ethiopian Studies</i> 31, 159–192	Zonal
Carr (1998). <i>Plant ecology</i> 135: 135–163	Omo Valley
Egziabher et al. (1998). <i>Plant Biosystems</i> 132, 39–51	Adwa
Gebremedhin Hadera (2000). Thesis, AAU	Dess'a Forest
Tekle & Bekele (2000). <i>Biotropica</i> 32, 23–32	Southern Wello
Tekle (2001). <i>Applied Geography</i> 21, 275–300	Southern Wello
Woldu & Saleem (2000). <i>Agriculture, Ecosystems and Environment</i> 79, 43–52	Ginchi
Awas et al. (2001). <i>SINET: Ethiopian Journal of Science</i> 24, 213–228	Gambella
Senbeta & Teketay (2001). <i>Tropical Ecology</i> 42, 175–185	Menagesha Forest
Feoli et al. (2002). <i>Agriculture, Ecosystems and Environment</i> 91, 313–325	Adwa
Gashaw et al. (2002). <i>Nordic Journal of Botany</i> 22, 19–33	Gambella
Senbeta et al. (2002). <i>New Forests</i> 24, 131–145	Munessa-Shashemene Forest
Tesfaye et al. (2002). <i>Flora</i> 197, 461–474	Harena Forest
Yeshitela & Bekele (2002). <i>SINET: Ethiopian Journal of Science</i> 25, 155–175	Sw Ethiopia
Asefa et al. (2003). <i>Land degradation and development</i> 14, 25–38	Hauzien District
Yeshitela & Bekele (2003). <i>Ethiopian Journal of Science</i> 2, 31–48	Masha-Anderacha Forest
Soromessa et al. (2004). <i>Tropical Ecology</i> 45, 209–221	Gamo Gofa Zone
Tesfaye et al. (2004). <i>Mountain Research and Development</i> 24, 354–361	Harena Forest
Abdiitana Tumtu (2005). Thesis. AAU	Awash National Park
Genene Bekele (2005). Thesis. AAU	Magada Forest
Leminih & Teketay (2005). <i>Forest Ecology and Management</i> 218, 60–73	Shashamane Forest Industry Enterprise
Mengistu et al. (2005). <i>Journal of Arid Environments</i> 60, 259–281	Biyokelala and Tiya
Senbeta et al. (2005). <i>Diversity and Distribution</i> 11, 443–452	Berhane-Kontir, Harena, Maji, Yayu
Wassie et al. (2005) <i>Forests, Trees and Livelihoods</i> , 15, 349–373,	Gondar
Aerts et al. (2006). <i>Plant ecology</i> 187, 127–142	Geba Watershed
Ayalew et al. (2006). <i>SINET: Ethiopian Journal of Science</i> 29, 45–56	Denkoro Forest

**Supplementary Table S1.** Studies included in the systematic review and location where the study was carried out (continued)

Citation	Study area
Dereje Denu (2006). Thesis. AAU	Gurra Ferda
Senbeta & Denich (2006). <i>Forest Ecology and Management</i> 232, 68–74	Berhane-Kontir And Harena Forest
Wassie & Teketay (2006). <i>Flora</i> 201, 32–43	Church Forest
Zegeye et al. (2006). <i>Flora</i> 201, 483–498	Islands Lake Ziway
Alelign et al. (2007). <i>Tropical Ecology</i> 48, 37–49	Peninsula Of Zegie
Hundera et al. (2007). <i>SINET: Ethiopian Journal of Science</i> 30, 1–12	Easter Ethiopia
Reubens et al. (2007). <i>Tropicultura</i> 25, 204–214	Dogua Tembien District
Gole et al. (2008). <i>Forest Ecology and Management</i> 255, 2138–2150	Yayu Forest
Hundera & Deboch (2008). <i>Ethiopian Journal of Education &amp; Science</i> 3, 44	Gurra Ferda
Yineger et al. (2008). <i>SINET: Ethiopian Journal of Science</i> 31, 103–120	Bale Mountain
Lulekal et al. (2008). <i>Journal of East African Natural History</i> 97, 165–185	Mana Angetu
Tolera et al. (2008). <i>Agriculture, Ecosystems and Environment</i> 128, 52–58	Beseku-Ilala Peasant Association
Wassie et al. (2009). <i>Forest Ecology and Management</i> 257, 765–772	Gondar (Zonal)
Wassie et al. (2009). <i>Biotropica</i> 41, 110–119	Gondar (Zonal)
Didita et al. (2010). <i>Journal of Forestry Research</i> 21, 395–408	Delo Mana
Feyera Abdena (2010). Thesis. AAU	Chato Forest
Kreyling et al. (2010). <i>Diversity and Distribution</i> 16, 593–605	South Ethiopian Highlands
Schmitt et al. (2010). <i>Applied Vegetation Science</i> 13, 291–304	Bonga
Shambel Bantiwalu Bedanie (2010). Thesis. AAU	Sanka Meda
Wassie et al. (2010). <i>Journal of Vegetation Science</i> 21, 93–948	Gondar
Woldemicael (2010). <i>Momona Ethiopian Journal of Science</i> 2, 27–48	Hugumbirda-Grat-Khassu
Abiyu et al. (2011). <i>Mountain Research and Development</i> 31, 144–154	Tehuledere District
Dinkissa Beche Benti (2011). Thesis. AAU.	Menagesha Forest
Shambel Alemu Chengere (2011). Thesis. AAU.	Angada Forest
Wana & Beierkuhnlein (2011). <i>Journal of Tropical Ecology</i> 27, 289–304	Gughe-Amaro Mountains
Zegeye et al. (2011). <i>Journal of Forestry Research</i> 22, 315–328	Tara Gedam And Abebaye Forests
Adamu et al. (2012). <i>Journal of Forestry Research</i> 23, 599–607	Metema
Adamu et al. (2012). <i>Journal of forestry Research</i> 23, 391–398	Metema
Angassa (2012). <i>Land degradation and development</i> . <a href="http://dx.doi.org/10.1002/ldr.2160">http://dx.doi.org/10.1002/ldr.2160</a>	Yabello And Dirre (Zonal)
Mekbib Fekadu (2012). Thesis. AAU	Awash Melka Kunture
Tessema et al. (2012). <i>Biotropica</i> 44, 211–219	Awash Naional Park
Burju et al. (2013). <i>Ethiopian Journal of Education &amp; Science</i> 8, 11–32	Jibat
Fisaha et al. (2013). <i>African Journal of Ecology</i> . <a href="http://dx.doi.org/10.1111/aje.12071">http://dx.doi.org/10.1111/aje.12071</a>	Wof Washa
Gebrelibanos and Assen (2013). <i>African Journal of Ecology</i> 52, 292–299	Woodland
Gurmessa et al. (2013). <i>Science, Technology and Arts Research Journal</i> 2, 58–69	Komto Forest
Kebede et al. (2013). <i>Journal of Forestry Research</i> 24, 419–430	Wondo Genet
Kebede et al. (2013). <i>Biodiversity Research Conservation</i> 29, 63–80	Wondo Genet

**Supplementary Table S1.** Studies included in the systematic review and location where the study was carried out (continued)


Citation	Study area
Mohammed and Abraha (2013). <i>Ethiopian Journal of Science &amp; Technology</i> 6, 33–45	Yegof Forest
Adem et al. (2014). <i>Journal of Forestry Research</i> 25, 319–328	Omo Valley
Assefa et al. (2014). <i>Ethiopian Journal of Biological Science</i> 13, 117–133	Chilimo
Dale et al. (2014). <i>SINET: Ethiopian Journal of Science</i> 37, 1–12	Borena Rangelands
Dibaba et al. (2014). <i>Momona Ethiopian Journal of Science</i> 6, 70–96	Sire Beggo in Gololcha District
Erenso et al. (2014). <i>International journal of biodiversity and conservation</i> 6, 382–391	Boda Forest
Gebrehiwot & Hundera (2014). <i>Momona Ethiopian Journal of Science</i> 6, 97–101	Belete Forest
Gedefaw & Soremessa (2014). <i>Science, Technology and Arts Research Journal</i> 3, 113–118	Tara Gedam
Mistire Yifru Feleke (2014). Thesis. AAU	Menagesha Forest
Senbeta et al. (2014). <i>SINET: Ethiopian Journal of Science</i> 37, 113–130	Bonga (Zonal)
Sileshi & Abraha (2014). <i>Momona Ethiopian Journal of Science</i> 6, 25–44	Hugumburda
Tadele et al. (2014). <i>Journal of Forestry Research</i> 25, 329–336	Zenegen Forest
Bruk Bedore Amado (2015). Thesis. AAU	Gera Forest
Getaneh Belachew Haile (2015). Dissertation. AAU.	Choke-Koso Ber Mountain Range
Kuma & Shibr (2015). <i>Journal of Botany</i> . <a href="http://dx.doi.org/10.1155/2015/963816">http://dx.doi.org/10.1155/2015/963816</a>	Humbo Carbon Project
Leul Kidane Woldemichael (2015). Dissertation. AAU	Hugumburda
Yirdaw et al. (2015). <i>Journal of Forestry Research</i> 26, 919–931	Rira Forest
Aerts et al. (2016). <i>Science of the Total Environment</i> 551–552, 404–414	Church Forest
Aynekulu et al. (2016). <i>Folia geobotanica</i> . <a href="http://dx.doi.org/10.1007/s12224-016-9247-y">http://dx.doi.org/10.1007/s12224-016-9247-y</a>	Hugumburda
Berhanu et al. (2017). <i>Journal of Forestry Research</i> 28, 343–355	Kundisha
Kebede et al. (2016). <i>Acta Ecologica Sinica</i> 36, 392–400	Gedo Forest
Melese & Ayele (2016). <i>Journal of Forestry Research</i> . <a href="http://dx.doi.org/10.1007/s11676-016-0280-8">http://dx.doi.org/10.1007/s11676-016-0280-8</a>	Ambo Forest
Tamene Yohannes (2016). Dissertation. AAU	Gerged and Anbessa Forests
Van Breugel et al. (2016). <i>Ecosystems</i> 19, 369–386	National
Van Breugel et al. (2016). <i>Applied Vegetation Science</i> . <a href="http://dx.doi.org/10.1111/avsc.12220">http://dx.doi.org/10.1111/avsc.12220</a>	National
Abreham Assefa Madebo (2017). Dissertation. AAU	GibeOmo Watershed
Gebregergis et al. (2017). <i>Journal of Forestry Research</i> . <a href="http://dx.doi.org/10.1007/s11676-017-0512-6">http://dx.doi.org/10.1007/s11676-017-0512-6</a>	Tselemti District
Girma Nigussie Asresu (2017). Thesis. AAU	Guassa
Jara et al. (2017). <i>Agriculture, Ecosystems and Environment</i> 240, 92–100	Farmlandscapes
Mesfin Woldearegay (2017). Dissertation. AAU	Bore-Anferara-Wadera Forest
Scull et al. (2017). <i>Land Degradation and Development</i> 28: 450–458	Debra Tabor (Zonal)
Siraj et al. (2017). <i>Applied Ecology and Environmental Research</i> 15, 245–262	Gamo Gofa Zone
Talemos Seta Shank (2017). Dissertation. AAU	Boter-Becho Forest

**Supplementary Table S1.** Studies included in the systematic review and location where the study was carried out (continued)

Citation	Study area
Tesema and Belay (2017). <i>Journal of Arid Environments</i> 139, 76–84	Babile
Young et al. (2017). <i>Biotropica</i> 0, 1–9	Bale Mountain
Abiyou Tilahun Ayalew (2018). Dissertation. AAU	Wof Washa
Abunie & Dale (2018). <i>International Journal of Forestry Research</i> . <a href="https://doi.org/10.1155/2018/5302523">https://doi.org/10.1155/2018/5302523</a>	Yemrehane Kirstos Church Forest
Abyot Dibaba (2018). Dissertation. AAU	Gerba Dima Forest
Atsbha et al. (2019). <i>Heliyon</i> 5, e01120	Hugumburda
Berhanu et al. (2018). <i>Phytocoenologia</i> 48, 351–367	Awi Zone
Gebre et al. (2018). <i>Agroforest syst.</i> <a href="https://doi.org/10.1007/s10457-018-0226-6">https://doi.org/10.1007/s10457-018-0226-6</a>	Gegera Watershed
Gebrekiros & Tessema (2018). <i>Ecological Processes</i> 7, 9.	Kafta Humera And Tsegede (Zonal)
Gebremedhin et al. (2018). <i>Arid Land Research and Management</i> 32, 236–252	Dejena Sub-District
Girma et al. (2018). <i>Mountain Research and Development</i> 38, 143–152	Arsi Mountain
Habtu Woldu Gebremichael (2018). Dissertation. AAU	Raya Azebo
Johansson et al. (2018). <i>Global change biology</i> 1–13.	Bale Mountain
Meragiaw et al. (2018). <i>PLOS ONE</i> 13, e0204733	Walga River of Wonchi District
Mewded et al. (2019). <i>Journal of Forestry Research</i> . <a href="https://doi.org/10.1007/s11676-019-00894-0">https://doi.org/10.1007/s11676-019-00894-0</a>	Sirso MAF
Seta et al. (2018). <i>Journal of Forestry Research</i> . <a href="https://doi.org/10.1007/s11676-018-0623-8">https://doi.org/10.1007/s11676-018-0623-8</a>	Biteyu Forest
Shiferaw et al. (2018). <i>Journal of Forestry Research</i> . <a href="https://doi.org/10.1007/s11676-018-0782-7">https://doi.org/10.1007/s11676-018-0782-7</a>	Debrelibanos Monastery
Tesfaye & Negash (2018). <i>Journal of Arid Environments</i> . <a href="https://doi.org/10.1016/j.jaridenv.2018.02.004">https://doi.org/10.1016/j.jaridenv.2018.02.004</a>	Liben
Yasin et al. (2018). <i>Ekológia (Bratislava)</i> 37, 380–391	Belete Forest
Reta et al. (2019). <i>Sustainability in Environment</i> 4, 98–123	Kelekal Protected Forest
Shumi et al. (2019). <i>Biological Conservation</i> 232, 117–126	Kebelles (Sites)
Terefe & Gure (2019). <i>Ecosystem Health and Sustainability</i> . DOI: 10.1080/20964129.2019.1593794	Kebelles (Sites)
Gebrehiwot et al. (2019). <i>Plant Diversity</i> 41, 220–228	Abune Yosef Mountain
Gebeyehu et al. (2019). <i>Taiwania</i> 64, 307–320	Awi Zone
Davis et al. (2012). <i>PLOS ONE</i> 7, e47981	<i>Coffea arabica</i>
Shiferaw et al. (2019). <i>Scientific reports</i> 9, 1576	<i>Prosopis juliflora</i>
Noulekoun (2016). <i>African Journal of Ecology</i> . <a href="http://dx.doi.org/10.1111/aje.12345">http://dx.doi.org/10.1111/aje.12345</a>	<i>Faidherbia albida</i>
Abraha et al. (2018). <i>Journal of Sustainable Forestry</i> . <a href="http://dx.doi.org/10.1080/10549811.2018.1494000">http://dx.doi.org/10.1080/10549811.2018.1494000</a>	<i>Juniperus procera</i>

# New combinations in *Drimia* Jacq. ex Willd. (Hyacinthaceae: Urgineoideae) and an updated key to the southern African species

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Five species recently described in the genus *Geschollia* Speta (Hyacinthaceae: Urgineoideae) are transferred to *Drimia* Jacq. ex Willd. as *D. brachyandra* (Mart.-Azorín et al.) J.C.Manning & Goldblatt, *D. globuligera* (Mart.-Azorín et al.) J.C.Manning & Goldblatt, *D. longipedicellata* (Mart.-Azorín et al.) J.C.Manning & Goldblatt and *D. prolifera* (Mart.-Azorín et al.) J.C.Manning & Goldblatt, with the new name *D. zebrinella* J.C.Manning & Goldblatt provided for *G. zebrina* Mart.-Azorín et al. since that epithet is pre-occupied in *Drimia*. *Austronea pater-soniae* Schönk. ex Mart.-Azorín et al. is treated as a synonym of *D. chalumnensis* A.P.Dold & E.Brink. The two names *Urginea amboensis* Baker and *Albuca reflexa* K.Krause & Dinter are formally placed in synonymy under *Drimia zambesiaca* (Baker) J.C.Manning & Goldblatt to accord with the current taxonomy. The recently described monotypic genus *Triandra* Mart.-Azorín et al. is also included in *Drimia* and the necessary transfer of *T. pellabergensis* Mart.-Azorín et al. to *Drimia* is effected, along with the second known locality for the species, representing a significant range extension. A total of 80 species of *Drimia* are now recognised in southern Africa. Updated identification keys to the species in sections *Capitatae*, *Ledebouriopsis*, *Macrocentrae*, *Physodia* and *Thuranthos* are provided.

## Introduction

The most recent taxonomic review of the species of *Drimia* Jacq. ex Willd. in southern African recognised 70 species distributed among 19 sections (Manning & Goldblatt 2018). This work serves a valuable role in summarising the taxonomic knowledge in the genus to that date but is, as the authors themselves make clear, far from complete. At the time that the review by Manning & Goldblatt (2018) appeared, several species were still incompletely known, and others were anticipated to exist. Several of these additional species have since been described or treated in the segregate genera *Austronea* Mart.-Azorín et al. (Martínez-Azorín et al. 2018a, 2019a), *losanthus* Mart.-Azorín et al. (Martínez-Azorín et al. 2019b), *Vera-duthiea* Speta (Martínez-Azorín et al. 2018b), *Zingela* N.R.Crouch et al. (Crouch et al. 2018), and more recently *Geschollia* (Martínez-Azorín et al. 2019c). A simplified phylogeny of Urgineoideae was presented in Martínez-Azorín et al. (2019b), but publication of the full analysis is still pending. Until then it is not feasible to meaningfully assess the available options for circumscribing genera in the subfamily. All of these genera were included in a broadly circumscribed *Drimia* by Manning & Goldblatt (2018) and Manning (2019), where a full discussion of the issues surrounding these two classifications is provided.

Since then, a further monotypic genus *Triandra* Mart.-Azorín et al. has been described for a nocturnal species from northern Namaqualand in Northern Cape that is unique in the family in lacking the outer staminal whorl (Martínez-Azorín

et al. 2021). Aside from the striking loss of the outer stamens, *Triandra pellabergensis* Mart.-Azorín et al. is morphologically similar to *Drimia hesperantha* J.C.Manning & Goldblatt (= *U. revoluta* A.V.Duthie) (sect. *Thuranthos*) from the southwestern winter-rainfall region of Western Cape, although unpublished molecular analyses suggest that the two species may not be immediately related (Martínez-Azorín et al. 2021). Available molecular data (Buerki et al. 2012; Ali et al. 2013) certainly indicate that sect. *Thuranthos* was not monophyletic as circumscribed by Manning and Goldblatt (2018), confirming the suspicions of the authors themselves, who clearly recognised that it reflected a pollination syndrome, defined by a lax raceme of nodding flowers with nocturnal anthesis and narrow, reflexed tepals, filaments that are much longer than the anthers, and a  $\pm$  clavate style. As suggested by them, larger species with caducous bracts and thickened fruiting pedicels such as *D. macrantha* (Baker) Baker, *D. pauciflora* Baker (= *D. basutica* (E.P.Phillips) J.C.Manning & Goldblatt) and *D. zambesiaca* Baker (as *D. indica* (Roxb.) Jessop), likely comprise a clade not immediately related to other species that were included in sect. *Thuranthos*. The southeast Asian species that were included in sect. *Thuranthos* have since been segregated as sect. *Indurgia* (Speta) J.C.Manning & Lekhak (Yadav et al. 2019). More fully sampled and resolved phylogenies will guide the further fragmentation of sect. *Thuranthos*, but until then it serves a purpose in providing a morphological framework for taxonomic study in the group.

Most of the relevant species described by Martínez-Azorín and co-workers since the review of the genus by Manning and Goldblatt (2018) were subsequently transferred to *Drimia* by Manning (2019) (who also synonymised a few), but one additional species of *Austronea* and five species recently described in *Geschollia* have still to be dealt with, as has *Triandra pellabergensis*. In addition, the two names *Urginea amboensis* Baker and *Albuca reflexa* K.Krause & Dinter, formerly treated as synonyms of *Drimia indica* (Roxb.) Jessop, need to be placed in synonymy under *Drimia zambesiaca* (Baker) J.C.Manning & Goldblatt, which is the earliest available name for this sub-Saharan taxon as circumscribed by Manning and Goldblatt (2018). These nomenclatural changes are necessary to integrate the newly described taxa into the classification of *Drimia* that was proposed by Manning and Goldblatt (2018) and which has been adopted by various institutes and checklists. A total of 80 species of *Drimia* are now recognised from southern Africa.

Finally, a few nomenclatural changes were also made by Martínez-Azorín et al. (2019d) and Manning (2019) to the taxa that were recognised by Manning and Goldblatt (2018). In view of both the increase in the number of species and the changes to the nomenclature of others, it seems useful to provide updated sectional keys to the species that have been affected, to facilitate both

their identification and the correlation of the taxa with those enumerated by Manning and Goldblatt (2018). Updated keys to the southern African species of sects. *Capitatae*, *Ledebouriopsis*, *Macrocentrae*, *Physodia* and *Thuranthos* are accordingly provided. The system of numbering of species used in Manning and Goldblatt (2018) is retained, with new species inserted into that system with decimal points.

## Taxonomic treatment

***Drimia* Jacq. ex Willd.**, Species Plantarum 2: 165 (1799). Type species: *Drimia elata* Jacq. ex Willd.

1. Sect. ***Capitatae* J.C.Manning & Goldblatt** in *Strelitzia* 40: 76 (2018). Type: *Drimia marginata* (Thunb.) Jessop

*Austronea* Mart.-Azorín et al. in *Pytotaxa* 365: 105 (2018a). Type: *Austronea marginata* (Thunb.) Mart.-Azorín et al. = *Drimia marginata* (Thunb.) Jessop

***Drimia chalumensis* A.P.Dold & E.Brink** in *South African Journal of Botany* 70: 631 (2004). Type: South Africa, Eastern Cape, Peddie (3327): Cornfields farm, near Chalumna River, (–BA), 25 Oct. 2002, *Dold 4619* (GRA, holo.).

*Austronea patersoniae* Schönl. ex Mart.-Azorín, A.P.Dold & M.B.Crespo in Martínez-Azorín et al. in *Phytotaxa* 427: 94 (2019c), *syn. nov.* Type: South Africa, Grahamstown (3326): Alicedale, (–AC), 1 Jul. 1919, *Cruden 300* (GRA, holo.; PRE, iso.).

*Note:* *Drimia chalumensis* is an Eastern Cape endemic described from two populations near Chalumna east of Grahamstown and diagnosed in sect. *Capitatae* by the loose bulb scales and several subterete or linear-channelled leaves with papillate margins. Two additional populations, from Alicedale west of Grahamstown and from Port Elizabeth respectively, were provisionally included in *D. chalumensis* by Manning and Goldblatt (2018) on the basis that they differed from that taxon essentially only in their taller inflorescences (60–110 mm vs 15–50 mm) and slightly longer pedicels (4–6 mm vs 2–6 mm). Plants matching these populations have now been recorded from further locations along the Eastern Cape coast between Jeffrey's Bay and Alicedale, and have been segregated from *D. chalumensis* under the name *Austronea patersoniae* (Martínez-Azorín et al. 2019c). The cited differences between the two taxa remain essentially the mostly slightly longer, erect foliage (exposed portion 30–45 vs 15–30 mm long) and the longer peduncle (80–150 vs 10–20 mm), all of which are consistent

with a more mesic habitat. Purported minor differences in the length of the lower bract spur and tepals are not consistent. In addition, Martínez-Azorín et al. (2019c) record a second locality for smaller plants consistent with *D. chalumnensis* from Aberdeen far to the northwest of the original material. As there do not appear to be any additional substantive differences between the Jeffrey's Bay–Alicedale plants and those from Aberdeen and Peddie it seems reasonable to regard them as representing a single species as suggested by Manning and Goldblatt (2018). Following this interpretation, *Drimia chalumnensis* is now known to occur more widely along the Eastern Cape coast from Jeffrey's Bay to Peddie and inland near Aberdeen.

2. Sect. **Ledebouriopsis** (Baker)  
*J.C.Manning & Goldblatt* in *Strelitzia* 40: 24 (2018). *Ornithogalum* subg.  
*Ledebouriopsis* Baker in J. Linn. Soc., Bot. 13: 284 (1873). Type: *Drimia anomala* (Baker) Baker, lecto., designated by Manning & Goldblatt (2018: 24).

*Geschollia* Speta in *Stapfia* 75: 169 (2001); Martínez-Azorín et al. in *Phytotaxa* 427: 88 (2019c). Type: *Geschollia anomala* (Baker) Speta = *Drimia anomala* (Baker) Baker

- Drimia brachyandra*** (Mart.-Azorín et al.) *J.C.Manning & Goldblatt*, comb. nov. *Geschollia brachyandra* Mart.-Azorín, A.P.Dold & M.B.Crespo in Martínez-Azorín et al. in *Phytotaxa* 427: 94 (2019c). Type: South Africa, Eastern Cape, Grahamstown (3326): 19 km from Grahamstown on Cradock road, (–AD), 27 Nov. 1993, *Dold* 438 (GRA, holo.).

Note: This species is distinguished from *D. calcarata* (Baker) Stedje by the more heavily barred cataphylls and the slightly smaller, reddish flowers. These differences are very slight and its status may need to be revised.

- Drimia globuligera*** (Mart.-Azorín et al.) *J.C.Manning & Goldblatt*, comb. nov. *Geschollia globuligera* Mart.-Azorín, A.P.Dold & M.B.Crespo in Martínez-Azorín et al. in *Phytotaxa* 427: 101 (2019c). Type: South Africa, Eastern Cape, Port Elizabeth (3325): Thornhill, Van Stadens Wildflower Reserve, (–CC), 20 Jan. 2018, *Dold* 16021 (GRA, holo.; ABH, iso.).

- Drimia longipedicellata*** (Mart.-Azorín et al.) *J.C.Manning & Goldblatt*, comb. nov. *Geschollia longipedicellata* Mart.-Azorín, Wetschnig, M.Pinter & M.B.Crespo in Martínez-Azorín et al. in *Phytotaxa* 427: 103 (2019c). Type: South Africa, Eastern Cape, Willowmore (3323): Willowmore, ± 1 km E

of town, (–BC), 4 May 2015 (fl. ex hort in Austria), *Wetschnig & Huber* 494 (GRA, holo.; ABH, iso.).

- Drimia prolifera*** (Mart.-Azorín et al.) *J.C.Manning & Goldblatt*, comb. nov. *Geschollia prolifera* Mart.-Azorín, A.P.Dold & M.B.Crespo in Martínez-Azorín et al. in *Phytotaxa* 427: 107 (2019c). Type: South Africa, Eastern Cape, Fort Beaufort (3226): Fort Fordyce Reserve, (–DA), 25 Nov. 2017, *Dold* 16026 (GRA, holo.).

- Drimia zebrinella*** *J.C.Manning & Goldblatt*, nom. nov. pro *Geschollia zebrina* Mart.-Azorín, A.P.Dold & M.B.Crespo in Martínez-Azorín et al. in *Phytotaxa* 427: 109 (2019c), non *D. zebrina* (Oberm. ex Mart.-Azorín et al.) *J.C.Manning & Goldblatt* in *Manning* in *Bothalia* 49: 5 (2019). Type: South Africa, Western Cape, Oudshoorn (3322): Grootkop Nature Reserve, (–CA), 4 May 2015, *Martínez-Azorín et al.* 893 (GRA, holo.; ABH, iso.).

3. Sect. **Thuranthos** (C.H.Wright)  
*J.C.Manning & Goldblatt* in *Strelitzia* 40: 62 (2018). *Thuranthos* C.H.Wright in *Kew Bull.* 1916: 233 (1916). Type: *Thuranthos macrantha* (Baker) C.H.Wright = *Drimia macrantha* (Baker) Baker

*Triandra* Mart.-Azorín, M.B.Crespo, M.Á.Alonso, N.R.Crouch & M.Pinter in *Phytotaxa* 487: 66 (2021), syn. nov. Type: *Triandra pellabergensis* Mart.-Azorín et al. = *Drimia pellabergensis* (Mart.-Azorín et al.) *J.C.Manning & Goldblatt*

- Drimia pellabergensis*** (Mart.-Azorín, M.B.Crespo, M.Á.Alonso, N.R.Crouch & M.Pinter) *J.C.Manning & Goldblatt*, comb. nov. *Triandra pellabergensis* Mart.-Azorín, M.B.Crespo, M.Á.Alonso, N.R.Crouch & M.Pinter in *Phytotaxa* 487: 68 (2021). Type: South Africa, Northern Cape, Pofadder (2919): Pella se Berge, 29 Jun. 2018 [fl. ex hort. Spain], *Martínez-Azorín et al.* 671b (GRA, holo.; ABH, K, PRE, iso.).

Note: This extraordinary species was known only from the type locality Pella se Berge in Bushmanland in Northern Cape. A collection of an unidentified *Drimia* that was collected in leaf on the Koesdoesberge near Touwsrivier in Western Cape has subsequently flowered in cultivation at Kirstenbosch National Botanical Gardens and clearly represents the same species, viz. 2 or 3 filiform leaves that are dry at flowering; diminutive inflorescence 30–90 mm tall with obscurely flecked, minutely striate-puberulous scape; nodding pedicels 4–6 mm long at flowering [the dimensions of 12–15 mm long at anthesis given in the protologue are clearly a mistake and refer to the elongated fruiting pedicels as is evident from Fig. 2 in the protologue]; pendulous buff-coloured flowers with nocturnal anthesis and

linear, revolute tepals  $\pm$  5 mm long, connate at the base; only the three inner stamens developed, with filiform filaments  $\pm$  4 mm long closely appressed to the ovary and style, and minute yellow anthers; narrowly subclavate style  $\pm$  2 mm long and as long as the ovary; small subglobose capsules  $\pm$  4 mm long; and elliptic, peripherally winged seeds  $\pm$  2.0–2.5  $\times$  1 mm. This collection represents a range extension of some 200 km south of the type locality.

*Additional specimen seen*

South Africa, Western Cape, Sutherland (3220): Pienaarsfontein-se-Berge, Koedoesberge, (–CD), 17 Feb 2022 [fl. in cult], Harrower 6188 (NBG).

***Drimia zambesiaca*** (Baker) J.C. Maning & Goldblatt in Manning et al. in *Edinburgh Journal of Botany* 60: 557 (2004); Manning in *Bothalia* 49: 4 (2019) [superfl. comb. nov.]. Type: Mozambique, Expedition Island, without date, Kirk s.n. (K, holo.).

*Urginea amboensis* Baker in *Bull. Herb. Boissier, sér.* 2, 3: 665 (1903), syn. nov. *Vera-duthiea amboensis*

(Baker) Mart.-Azorín, M.B. Crespo, M. Pinter & Wetschnig in Martínez-Azorín et al. in *Phytotaxa* 397: 296 (2019d). Type: Namibia, Ondangua (1715): Ondonga, Rautanen 773 (Z, holo.)

*Albucca reflexa* K. Krause & Dinter in *Bot. Jahrb. Sys.* 51: 445 (1914), syn. nov. *Vera-duthiea reflexa* (K. Krause & Dinter) Mart.-Azorín, M.B. Crespo, M. Pinter & Wetschnig in Martínez-Azorín et al. in *Phytotaxa* 397: 296 (2019d). Type: Namibia, Tsumeb (1917): Nord-Hereroland bei Tsumeb, without date, Dinter 2694 (SAM [2 sheets], lecto., designated by Manning & Goldblatt, 2018: 67).

Note: These three names were treated as synonyms of *Drimia indica* (Roxb.) Jessop by Manning and Goldblatt (2018) following conventional usage but since the realisation that *D. indica* is restricted to the Indian subcontinent (Martínez-Azorín et al. 2018b; Yadav et al., 2019), the earliest available name for the African taxon as currently circumscribed is *Drimia zambesiaca* and the other two names are accordingly placed in synonymy.

## Updated keys to species in selected sections

### Sect. **Capitatae**

- 1a. Leaf margins thickened and cartilaginous, either papillate/colliculate or scabridulous:
  - 2a. Bulb scales loose; leaves linear-channelled, 2.0–2.5 mm wide; pedicels 2–6 mm long; plants from Eastern Cape . . . . . 37. *D. chalumnensis*
  - 2b. Bulb scales closely packed; leaves plane, 4–25 mm wide; pedicels 5–10 mm long; plants from Western and Northern Cape:
    - 3a. Leaf blades obtuse; margins colliculate; plants from Western Cape Fold Mtns . . . . . 31. *D. ecklonii*
    - 3b. Leaf blades acute-apiculate; margins partly or entirely scabridulous on upper surface; plants not from Western Cape Fold Mtns:
      - 4a. Leaf margins simple, densely retrorsely scabridulous along upper surface . . . . . 32. *D. marginata*
      - 4b. Leaf margins duplex, narrowly colliculate along edge with submarginal band of erect or retrorse trichomes along upper surface . . . . . 33. *D. pulchromarginata*
- 1b. Leaf margins not thickened and cartilaginous, sometimes pubescent or scabridulous:
  - 5a. Leaves usually 2 or more, plane or channelled above, with narrow hyaline margins:
    - 6a. Leaves glabrous but minutely scabridulous along margins, at least distally . . . . . 28. *D. virens*
    - 6b. Leaves pubescent or scabridulous on one or both surfaces:
      - 7a. Leaves in a rosette, (15–)20–30 (–70)  $\times$  (3–) 5–7 (–9) mm, margins with long cilia and softly pubescent on one or both surfaces; tepals not fringed . . . . . 29. *D. barkerae*
      - 7b. Leaves in a loose tuft, 12–26  $\times$  1.0–1.5 mm, margins glabrous, upper surface recurved-scabridulous; inner tepals fringe . . . . . 30. *D. fimbrimarginata*
  - 5b. Leaf solitary (rarely two), without a distinct hyaline margin:
    - 8a. Leaf glabrous, fleshy and semiterete to terete or clavate:
      - 9a. Dwarf plants, inflorescence 15–30 mm long . . . . . 38. *D. acarophylla*
      - 9b. Taller plants, inflorescence 40–100 mm long:
        - 10a. Aerial portion of leaf 35–70  $\times$  2–6 mm . . . . . 34. *D. vermiformis*
        - 10b. Aerial portion of leaf 15–25 (–40)  $\times$  5–9 mm . . . . . 34.1. *D. pinguis*
    - 8b. Leaf plane, ciliolate or pubescent:
      - 11a. Leaf retrorsely ciliolate along margins only with hairs  $\pm$  0.5 mm long . . . . . 35. *D. ciliolata*
      - 11b. Leaf softly retrorsely pubescent on one or both surfaces and along margins with hairs  $\pm$  1.0–2.5 mm long:
        - 12a. Leaf plicately grooved adaxially, with soft spreading trichomes 2.5 mm long on upper surface only . . . . . 35.1. *D. hispidoplicata*
        - 12b. Leaf not grooved, with scattered retrorse trichomes  $\pm$  1 mm long on both surfaces. . . 36. *D. trichophylla*

Sect. **Ledebouriopsis**

- 1a. Floral bracts 1.5–7.0 mm long;
- 2a. Plants evergreen with leaves synanthous; leaf blades concave above, the margins narrowly hyaline and smooth; bulb scales never fibrous, dark red below ground . . . . . 9. *D. delagoensis*
- 2b. Plants deciduous with leaves hysteroanthous or emergent at flowering; leaf blades canaliculate, the margins slightly thickened and papillate; bulb scales  $\pm$  fibrous, white to pink:
- 3a. Bulbs with a conspicuous collar of stiff, apical fibres . . . . . 7. *D. multisetosa*
- 3b. Bulbs with at most a weak collar of fine, pale fibres. . . . . 6. *D. echinostachya*
- 1b. Floral bracts mostly up to 1 mm long:
- 4a. Raceme 1- to 3-flowered; plants from southern Namibia. . . . . 13. *D. occultans*
- 4b. Raceme > 3-flowered; plants from South Africa:
- 5a. Raceme congested, ellipsoid to subglobose with flowers mostly 0.5–2.0 mm apart:
- 6a. Scape longitudinally colliculate-scabridulous basally; perianth cup puberulous within; plants from Richtersveld . . . . . 16. *D. barbata*
- 6b. Scape glabrous; perianth cup glabrous within; plants from extreme southwestern Western Cape:
- 7a. Leaf terete or clavate, 1–2 mm diam. . . . . 15. *D. salteri*
- 7b. Leaf lorate-oblong, 10–16 mm wide. . . . . 15.1. *D. densiflora*
- 5b. Raceme elongate, laxly cylindrical with flowers mostly more than 3 mm apart, rarely 1-flowered:
- 8a. Leaf solitary and stiffly erect, (2–)3–5 mm diam., sheathing base with wide, chestnut brown, papery margins; bulb often with a thick papery collar. . . . . 8. *D. anomala*
- 8b. Leaves 1 to 5, either solitary and erect but then less than 2 mm diam., or flexuous to drooping, sheathing bases with pale-papery margins, not forming a thick papery collar:
- 9a. Capsules ellipsoid to fusiform (rarely ovoid), usually more than twice as long as wide, 2–3 mm diam.; plants from southwestern South Africa . . . . . 14. *D. dregei*
- 9b. Capsules ovoid, up to twice as long as wide, 3–4 mm diam.; plants from southern and eastern South Africa:
- 10a. Filaments retrorsely scabrid-papillate:
- 11a. Bulb scales loose, subglobose; cataphylls not barred . . . . . 11.1. *D. globuligera*
- 11b. Bulb scales cohering, flattened; cataphyll transversely barred with thickened ribs . . . . 11.2. *D. zebrinella*
- 10b. Filaments smooth:
- 12a. Bulb scales loose and stalked; scape puberulous basally . . . . . 10. *D. edwardsii*
- 12b. Bulb scales usually tightly packed, rarely loose and subglobose but not stalked; scape glabrous throughout or minutely puberulous basally:
- 13a. Bulbs elongated and proliferous, forming clumps; leaves 2 or 3 per bulb . . . . . 11.3. *D. prolifera*
- 13b. Bulbs subglobose, not proliferating; leaf mostly solitary:
- 14a. Racemes 40- to 90-flowered; pedicels 17–25 mm long:
- 15a. Bulbs epigeal, keeled; leaves up to 500 mm long . . . . . 12. *D. flagellaris*
- 15b. Bulbs hypogaeal, smoothly rounded; leaves up to 200 mm long. . . . . 11.4. *D. longipedicellata*
- 14b. Racemes 3- to 30(40)-flowered; pedicels 2–10 mm long:
- 16a. Flowers white, tepals 4–6 mm long; filaments 2–4 mm long . . . . . 11. *D. calcarata*
- 16b. Flowers buff to brown, tepals 3.3–4.2 mm long; filaments 1.4–1.9 mm long. . . . 11.5. *D. brachyandra*

Sect. **Macrocentrae**

- 1a. Dwarf plants to 30 mm tall; leaves linear, 1.0–1.5 mm wide; pedicels 1.5–2.0 mm long . . . . . 5.1. *D. toxicaria*
- 1b. Larger plants more than 60 mm tall; leaves linear to lanceolate or cylindrical and 3–14 mm wide; pedicels 2–14 mm long:
- 2a. Bulbs dark red; inflorescence (60–)200–450(–600) mm tall, scape mostly shorter than rachis, often less than half as long; bracts 1–3 mm long, spur of lower bracts up to 1 mm long; leaves 3 to 8, linear to narrowly lanceolate, channelled; plants from western and northern interior South Africa. . . . . 4. *D. sanguinea*
- 2b. Bulbs white to greenish; inflorescence 300–800(–900) mm tall, scape longer than inflorescence rachis; bracts 4–6 mm long, spur of lower bracts 20–35 mm long, forming a skirt below raceme in bud; leaf solitary, cylindrical, resembling scape; plants from eastern Drakensberg . . . . . 5. *D. macrocentra*

Sect. **Physodia**

- 1a. Inflorescence globose-capitate, all pedicels  $\pm$  0.5 mm apart and rachis not elongating in fruit; scape glabrous; lower bracts 1.5–4.0 mm long with a spur 1–6 mm long; plants from mesic grasslands along eastern Escarpment. . . . . 39. *D. depressa*

- 1b. Inflorescence subcapitate-racemose or congested-racemose, lower pedicels often distant and rachis somewhat elongating in fruit; scape usually longitudinally puberulous; lower bracts 0.5–2.0 mm long with reduced spur up to 1.5 mm long; plants from drier habitats along western and southern coast and interior:
- 2a. Leaves subterete-filiform, 0.5–1.0 mm wide; pedicels arcuate-suberect in fruit . . . . . 42. *D. minor*
- 2b. Leaves linear to lanceolate, 1–25 mm wide; pedicels spreading-reflexed with tips abruptly erect in fruit:
- 3a. Pedicels (3.0–)5.0–6.5 mm long; ovary white with yellow shoulders edged with purple speckles; base of bulb and roots bulbiferous . . . . . 40. *D. montana*
- 3b. Pedicels (8–)15–20(–30) mm long; ovary uniformly white; plants not bulbiferous . . . . . 41. *D. physodes*

### Sect. **Thuranthos**

- 1a. Stamens 3 (inner whorl only), filaments  $\pm$  4 mm long; tepals 4.5–5.5 mm long . . . . . 21.1. *D. pellabergensis*
- 1b. Stamens 6, filaments  $>$ 5 mm long; tepals  $>$ 6 mm long:
- 2a. Inflorescence to 400 mm long; pedicels 8–12 mm long, abscising  $\pm$  midway if not pollinated; tepals 7–8 mm long; filaments 6–8 mm long; capsules 5–7 mm long; plants from southwestern Western Cape . . . . . 21. *D. hesperantha*
- 2b. Inflorescence 150–1 300 mm long; pedicels 15–80 mm long, abscising at base if not pollinated; tepals 8–33 mm long; filaments 7–20 mm long; capsules 7–40 mm long; plants from Eastern Cape northwards:
- 3a. Filaments fusiform, constricted basally,  $\pm$  7 mm long; anthers subglobose-sagittate,  $\pm$  1 mm long at anthesis; capsules on slender, horizontally spreading pedicels, subglobose-ovoid,  $\pm$  7 mm long; leaves terete-canaliculate, 0.5–1.0 mm diam. . . . . 22. *D. vespertina*
- 3b. Filaments filiform or lanceolate, sometimes abruptly narrowed midway but never constricted basally, 5–20 mm long; anthers oblong, 1.5–7.0 mm long; capsules on thickened, suberect pedicels, subglobose to ellipsoid, 3-lobed, 8–40 mm long; leaves linear-canaliculate, 4–18 mm wide:
- 4a. Leaf sheaths unmarked; tepals 22–33 mm long; filaments 15–20 mm long, basal 6–12 mm flattened and incurved around ovary forming a cage-like structure, sharply constricted and terete-fusiform above; style several times longer than ovary; stigma large and capitate . . . . . 25. *D. macrantha*
- 4b. Leaf sheaths barred or blotched with purple towards base; tepals 9–20 mm long; filaments 5–11 mm long, simple and lanceolate or fusiform; style as long as or slightly longer than ovary; stigma 3-angled:
- 5a. Inflorescence more than 500 mm tall; pedicels 35–80 mm long; tepals 14–20 mm long; filaments 7–11 mm long . . . . . 24. *D. pauciflora*
- 5b. Inflorescence mostly up to 500 mm tall; pedicels 10–30 mm long; tepals 6–12 mm long; filaments 5–6 mm long:
- 6a. Bulb scales loose and spatulate; leaves keeled beneath; pedicels 10–12 mm long at anthesis; filaments  $\pm$  6 mm long. . . . . 23. *D. zambesiaca*
- 6b. Bulb scales cohering; leaves rounded beneath; pedicels 20–30 mm long at anthesis; filaments  $\pm$  10 mm long . . . . . 23.1. *D. zebrina*

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# A new name for the illegitimate later homonym *Leonotis capensis* (Benth.) J.C.Manning & Goldblatt (Lamiaceae: Lamioideae)

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The new combination *Leonotis quinquedentata* J.C.Manning & Goldblatt is provided as a replacement for the illegitimate later homonym *L. capensis* (Benth.) J.C.Manning & Goldblatt (2010), non *L. capensis* Raf. (1837).

**Keywords:** Africa; *Leonotis* (Pers.) R.Br.; *Leucas* R.Br.; nomenclature; taxonomy.

## Introduction

Morphological and molecular studies in *Leucas* R.Br. and allied genera in the Lamiaceae (Ryding 1998; Scheen & Albert 2009) have confirmed earlier suggestions by Singh (2001) that the Asian and Arabian–African taxa comprise two distinct phylogenetic lineages. From these studies, the African species of *Leucas* are now understood to be more closely allied to the other African members of the group in the genera *Acrotome* Benth. ex Endl., *Isoleucas* O.Schwartz, *Leonotis* (Pers.) R.Br. and *Otostegia* Benth., and *Leucas* has consequently been more narrowly circumscribed to include only Asian taxa (Scheen & Albert 2007).

As part of circumscribing monophyletic genera among the African taxa, Scheen & Albert (2007) transferred a species of *Otostegia* to each of the two genera *Isoleucas* and *Moluccella* L., and segregated a further four species in the new genus *Rydingia* Sheen & V.A.Albert. They further recommended that the remaining African species in the group be treated as part of an enlarged *Leonotis*. This recommendation was partially implemented by Manning and Goldblatt (2012) in their transfer of the southern African species of *Leucas* to *Leonotis*. The traditional separation of *Leonotis* from *Leucas* was based on the size of the flowers and on the colour and proportions of the corolla, and these differences are now understood to reflect differences in pollination systems: the larger, orange flowers with reduced lower lip of *Leonotis* s.str. are consistent with bird pollination and the smaller, white, more equally bilabiate flowers of *Leucas* s.lat. with insect pollination (Iwarsson & Harvey 2003). The small genus *Acrotome* (8 spp.) has been provisionally retained pending further resolution of relationships in the group.

In its current circumscription, *Leonotis* is a genus of up to 60 or 70 species of annual or perennial herbs or subshrubs recognised by their strongly verticillate inflorescences with leaf-like bracts, and flowers with a 5- to 10-toothed calyx that is glabrous within, and a white or orange corolla with a bearded upper lip. *Acrotome* is morphologically distinctive in its beardless upper lip and included stamens held together by intermingling hairs (Codd 1985).

Unfortunately, one of the combinations in *Leonotis* published by Manning and Goldblatt (2012), *L. capensis* (Benth.) J.C.Manning & Goldblatt, is an

illegitimate later homonym for *L. capensis* Raf. (1837). The latter name was proposed by Rafinesque (1837) as a replacement name for *Phlomis leonitis* L. when he transferred that species to the genus *Leonotis* to avoid a possible tautonym (Turland et al. 2018: ICN Art. 23.4). The combination *L. leonitis* does not, however, exactly repeat the generic name' (Art 23.4) and is therefore not a tautonym. It is, therefore, an illegitimate superfluous name for *P. leonitis* (Turland et al. 2018: ICN Art. 52.1), which epithet should have been used. No additional names are available for this taxon and the new name

*L. quinquedentata* is provided here. The epithet refers to the five-lobed calyx that is distinctive for the species.



***Leonotis quinquedentata*** J.C.Manning & Goldblatt, nom. nov. pro *Lasiocorys capensis* Benth., *Labiatarum genera et species* 6: 600 (1848). *Leucas capensis* (Benth.) Engl.: 268 (1888). *Leonotis capensis* (Benth.) J.C.Manning & Goldblatt: 809 (2012), nom. illeg., non *L. capensis* Raf.: 88 (1837), nom. illeg. superfl. pro *Phlomis leonitis* L.: 398 (1767) [= *Leonotis ocymifolia* (Burm.f.) Iwarsson].

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# New combinations in *Crystallopollen* Steetz (Asteraceae: Vernonieae), the correct name for the illegitimate *Polydora* Fenzl ex H.Rob.

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*Polydora* Fenzl (1844) is recognised to be a nomen nudum that was only validly published by Robinson (1999). The inclusion by Robinson (1999) of the earlier validly published *Crystallopollen* Steetz ([in Peters] 1864) as a synonym however, rendered *Polydora* Fenzl ex H.Rob. (1999) superfluous and so illegitimate. *Crystallopollen* Steetz ([in Peters] 1864) is therefore the correct name for the genus as circumscribed by Robinson (1999) and later authors. Only one of the names currently accepted in *Polydora* has a combination in *Crystallopollen* and the necessary additional combinations are provided here for *C. bainesii* (Oliv. & Hiern) J.C.Manning, *C. chloropappum* (Baker) J.C.Manning, *C. jelliae* (S.Moore) J.C.Manning, *C. mbalense* (G.V.Pope) J.C.Manning, *C. rhodesiana* (S.Moore) J.C.Manning, *C. serratuloides* (DC.) J.C.Manning and *C. sylvicola* (G.V.Pope) J.C.Manning.

**Keywords:** Africa; classification; illegitimate superfluous name; nomenclature; nomen nudum; taxonomy.

## Introduction

The genus *Polydora* Fenzl (1844) (Asteraceae: Vernonieae) is one of twelve segregates of *Vernonia* Schreb. that were recognised by Robinson et al. (2016) in their synopsis of the southern African members of the tribe Vernonieae. It comprises mostly annual herbs with L-shaped or asymmetrically T-shaped hairs on the stems, a 6- or 7-seriate involucre of acute to awned bracts and lophate, pantoporate pollen (Robinson et al. 2016; Swelankomo et al. 2018). The generic circumscriptions adopted by Robinson et al. (2016) followed his earlier conclusion (Robinson 1999) that *Vernonia* in the narrow sense was restricted to the Western Hemisphere, and that the African and Asian taxa previously included in it had to be removed to other genera in order to render it monophyletic.

The revised classification proposed by Robinson (1999) was adopted for the southern African flora by Herman and Swelankomo (2011), who provided a nomenclator for the flora of the region. This was superseded by the more comprehensive synopsis provided by Robinson et al. (2016). None of these three accounts included critical taxonomic assessments of the species themselves. These have now been provided for some of the genera, viz. *Distephanus* Cass. (Swelankomo & Manning 2014), *Gymnanthemum* Cass. (Swelankomo et al. 2016a), *Hilliardiella* H.Rob. (Swelankomo et al. 2016b) and most recently *Polydora* Fenzl (Swelankomo et al. 2018).

It has since emerged that the generic name *Polydora* was not validly published by Fenzl (1844) and that the earliest available name for the genus is *Crystallopollen* Steetz ([in Peters] 1864). We examine this issue here and summarise the

nomenclature, as well as providing several new combinations in *Crystallopollen* for taxa currently recognised in *Polydora*.

## Materials and methods

Nomenclatural decisions follow the latest version of the International Code of Nomenclature for algae, fungi, and plants (Shenzhen Code) (Turland et al. 2018). The list of species accepted in *Polydora* follows that provided by Robinson (1999) and Swelankomo et al. (2018) with additions from Pope (1992).

## Results and nomenclature

The generic name *Polydora* was published by Fenzl (1844) in a checklist as the simple binomial *P. stoechadifolia*, and was thus not validly published here, as it lacked an accompanying description or reference to such a description (Turland et al. 2018: ICN, Art. 38.1). The binomial *P. stoechadifolia* Fenzl (1844) is likewise a *nomen nudum*. This name is currently regarded as a synonym of *P. serratuloides* (DC.) H.Rob. (1999).

Robinson (1999) overlooked the fact that *Polydora* was not validly published, and his description of the genus constitutes its valid publication, and it is thus to be attributed to him. In a further complication, his inclusion of the earlier validly published *Crystallopollen* Steetz ([in Peters] 1864) as a synonym, which should have been adopted as the earliest available name, renders *Polydora* Fenzl ex Robinson (1999) an illegitimate superfluous name (Turland et al. 2018: ICN, Art. 52.1).

*Crystallopollen* Steetz ([in Peters] 1864) was published for the two species *C. angustifolium* Steetz and *C. latifolium* Steetz, without the designation of a type. The citation by Robinson (1999) of *C. angustifolium* as the type of *Crystallopollen* is thus to be regarded as designation of that species as the type (Turland et al. 2018: ICN Art. 10.2). The combination of this name in *Polydora* was also provided by Robinson (1999). The second species, *C. latifolium*, is the type of *Vernoniastrum* H.Rob. (1999).

The generic name *Crystallopollen* Steetz is thus the earliest available name for the group of species treated as *Polydora* by Robinson (1999) and later authors. Unfortunately, only one of the several species that are currently included in the genus has a combination in *Crystallopollen* and we therefore provide the necessary combinations here. Typification of the names is provided in Pope (1986) and Swelankomo et al. (2018).

**Crystallopollen** Steetz in Peters, Naturw. Reise Mosambique 6(Bot., 2): 363 (1864). Type species:

*C. angustifolium* Steetz, designated by Robinson: 232 (1999).

*Polydora* Fenzl ex H.Rob. in Proc. Biol. Soc. Washington 112(1): 232 (1999), nom. illeg. superfl. pro *Crystallopollen* Steetz ([in Peters] 1864); Robinson et al.: 103 (2016); Swelankomo et al.: 336 (2018). Type: *P. stoechadifolia* Fenzl, nom. nud. = *P. serratuloides* (DC.) H.Rob. [*Polydora* Fenzl in Flora 27: 312 (1844), nom. nud., without description]

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- C. sylvicola** (G.V.Pope) J.C.Manning, comb. nov. *Vernonia sylvicola* G.V.Pope in Kew Bull. 41: 395 (1986).



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# New infrageneric taxa in *Leucospermum* (Proteaceae) and *Tetragonia* L. (Aizoaceae) and a new name in *Aizoon* subgenus *Galenia* (Aizoaceae) in southern Africa

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New infrageneric taxa are described in *Leucospermum* R.Br. (Proteaceae) and *Tetragonia* L. (Aizoaceae) to accommodate species that are currently unplaced in the respective generic classifications. *Leucospermum* section *Hamata* J.C.Manning is described to accommodate the relatively recently described *L. hamatum* Rourke and *L. harpogonatum* Rourke, and *L. section Secundifolia* J.C.Manning for *L. secundifolium* Rourke, which was unplaced following the transfer of the type of *L. section Xericola* Rourke to the genus *Vexatorella* Rourke. In *Tetragonia* L., *T. series Echinatae* J.C.Manning & Klak is described for three species that were left unplaced following their exclusion from subgenus *Tetragonoides* DC. In addition, the three series *T. series Chenopodinae*, series *Pedunculares* and series *Macranthae* are incorrectly attributed to Fenzl and are shown to be combinations by Adamson of unranked taxa published by Fenzl. In *Aizoon* L., we replace the illegitimate name, *A. procumbens* (L.f.) Klak, with the new name *A. flavescens* Klak.

**Keywords:** nomenclature; *Leucospermum* section *Hamata*; *Leucospermum* section *Secundifolia*; *Tetragonia* series *Echinatae*.

## Introduction

Advancements in our understanding of species relationships, either from increased phylogenetic insights or from additional discoveries, can result in modifications to existing generic taxonomies. These modifications may happen long after the original classifications were established, and their nomenclatural ramifications may not always be apparent at the time. Two such oversights in the South African flora were uncovered during the preparation of species lists for curatorial purposes. Both are the result of the transfer of the type species of a section or series to another taxon, whilst retaining the remainder of the species in the original section or series without making the necessary nomenclatural changes to accommodate these species. These 'orphan' species thus lack any position within the existing formal classifications. This poses problems for both the curation of these genera and for future testing of the classifications, and also for increasing the democratisation of biological knowledge, which demands the rapid assimilation of new data within existing frameworks.

Here we describe new sections in the genera *Leucospermum* R.Br. (Proteaceae) and *Tetragonia* L. (Aizoaceae) that are required to accommodate a handful of species that are currently unplaced in these genera, following the transfer of the type species of the relevant section or series to some other taxon. In addition, in *Aizoon* L. (Aizoaceae) we propose a new name for the illegitimate

*Aizoon procumbens* (L.f.) Klak, which was found to be an earlier homonym of *A. procumbens* Crantz.

## Taxonomy

### 1. *Leucospermum*

R.Br. (Proteaceae: Proteoideae)

*Leucospermum* R.Br. (Proteaceae: Proteoideae) is a genus of 48 species from temperate southern Africa, where it is concentrated in the Greater Cape Floristic region, extending along the Eastern Escarpment into eastern Zimbabwe (Rourke 1972, 1994). The genus was monographed by Rourke (1972), at which time the 47 accepted species were segregated among nine sections. Since then an additional three species have been described (Rourke 1979, 1983, 1994) and two have been transferred to the genus *Vexatorella* Rourke (Rourke 1984).

The genus *Vexatorella* Rourke (1984) was established following the discovery of an undescribed species of Proteoideae that could not be accommodated within any of the existing genera. It resembled *Leucospermum* in floral morphology but differed from that genus in its terminal (vs. lateral) inflorescences. The accrescent, woody floral bracts were also anomalous in *Leucospermum* but were common in the genus *Leucadendron* R.Br. Both characters were also identified in two of the three species of *Leucospermum* section *Xericola* Rourke, and they were accordingly transferred to *Vexatorella*. One of them, *L. alpinum* (Salisb. ex Knight) Rourke, was the type of the section, leaving just *L. secundifolium* Rourke still in *Leucospermum* but now unplaced to section. We describe the new section *Secundifolia* to accommodate this species.

Two of the three species of *Leucospermum* that were described after the publication of the generic monograph by Rourke (1972), *L. hamatum* Rourke (1983) and *L. harpagonatum* Rourke (1994), constitute a pair of morphologically similar taxa that are interpreted as closely allied geographical vicariads (Rourke 1994). They cannot be accommodated within the existing classification of the genus and Rourke (1994) was explicit in stating that ‘the two species should be placed within a distinct section of their own’. This section was not erected. Currently the two species are treated under the unpublished group name *Hamatum* in online resources (Identifying Pincushions, viewed on 28 October 2021, from <https://www.proteaatlas.org.za/pincushid.htm>). We describe the new section *Hamata* to accommodate these two species.

Finally, although the affinities of the third pincushion species to be described, *L. winteri* Rourke (1979), were

not immediately evident, Rourke (1979) suggested an affinity to certain members in section *Crinita* Rourke and it can be satisfactorily accommodated here.

**Leucospermum** R.Br. in Transactions of the Linnean Society, London 10: 95 (1810), nom. cons. Type: *L. hypophyllocarpodendron* (L.) Druce.

Section **Hamata** J.C.Manning, sect. nov. Type: *L. hamatum* Rourke

Prostrate, mat-forming shrublets. Leaves glabrescent, entire, obtuse or 3-toothed. Inflorescence turbinate, 15–30 mm diam. Perianth pink or off-white, tube inflated or utriculose. Style retrorsely barbed, recurved distally. Stigma conical.

Species: *L. hamatum* Rourke, *L. harpagonatum* Rourke

Section **Secundifolia** J.C.Manning, sect. nov. Type: *L. secundifolium* Rourke

Prostrate or decumbent, mat-forming shrublets. Leaves glabrous, thick and cartilaginous, entire, obtuse or rarely 3-toothed. Inflorescence small, globose, 10–15 mm diam.; bracteoles accrescent and woody. Perianth pink or whitish pink, tube subcylindric. Style glabrous, suberect. Stigma clavate.

Species: type only

### 2. *Tetragonia* L. (Aizoaceae: Aizooideae)

*Tetragonia* L. (Aizoaceae: Aizoideae) as recently re-circumscribed, is a genus of ± 50 species from temperate and subtropical regions, mainly in the southern Hemisphere (Klak et al. 2017). The southern African taxa were last revised by Adamson (1955), and this remains the current treatment for the species in the region. In his classification, Adamson (1955) segregated the species among the four subgenera *Tetragonia*, *Tetragonoides* DC., *Anisostigma* (Schinz) Engl. and *Tribulocarpus* (S.Moore) Adamson, defined by several characters of the fruits and flowers. The recent molecular phylogenetic analysis of the subfamily by Klak et al. (2017), however, uncovered some unexpected relationships among the species that necessitated realignments among several taxa in order to render them monophyletic. Among these was the removal of *Tetragonia* subgenus *Anisostigma* and subgenus *Tribulocarpus* to the new tribe Anisostigmateae Klak in subfamily Sesuvioideae as the genera *Anisostigma* Schinz and *Tribulocarpus* S.Moore respectively.

In addition to these changes, the circumscription of *Tetragonia* subgenus *Tetragonoides* was greatly altered by the removal from it of most of the southern African taxa previously included there by Adamson

(1955). *Tetragonia* subgenus *Tetragonoides* is now understood to be essentially Australasian in distribution, with the exception of the cosmopolitan littoral species *T. tetragonoides* (Pall.) Kuntze, the type of the subgenus. Two additional subgenera, subgenus *Tetragonella* (Miq.) Klak and subgenus *Americanae* Klak were established to accommodate respectively the other Australasian and the American species (Klak et al. 2017).

The remaining four southern African species that were included by Adamson (1955) in subgenus *Tetragonoides* were retrieved by Klak et al. (2017) as a clade sister to subgenus *Tetragonia* and were accordingly included in it, with the observation that the 'series erected by Adamson (1955) should be maintained'. This alludes to the seven sections recognised by Adamson (1955) in subgenus *Tetragonia*. Although they included these additional four former members of subgenus *Tetragonoides* in subgenus *Tetragonia*, Klak et al. (2017) did not accommodate them within the existing classification.

Significantly, the removal of *T. tetragonoides* from this group renders it morphologically more homogenous. The four species share a prostrate, ± annual habit and half-inferior ovary, and differ from all other members of subgenus *Tetragonia* in having the stamens less than twice as many as the perianth segments vs. more than twice as many as the perianth segments (Adamson 1955). The new series *Echinatae* J.C.Manning & Klak is accordingly proposed here to accommodate them.

There are two other nomenclatural corrections required in subgenus *Tetragonia*. The first concerns the authorities for the infrageneric names that were published by Fenzl (1862). Adamson (1955) treats these as series, with Fenzl (1862) as author. However, examination of Fenzl (1862) reveals that they were published as third tier names two ranks below sectional level but without a definite rank. Although they are to be accepted as validly published by Fenzl (1862) they are to be treated as unranked (Turland et al. 2018: 'Art. 37.3. A name published before 1 January 1953 without a clear indication of its rank is validly published provided that all other requirements for valid publication are fulfilled; it is, however, inoperative in questions of priority except for homonymy. If it is the name of a new taxon, it may serve as a basionym or replaced synonym for subsequent new combinations, names at new ranks, or replacement names at definite ranks.'). Their later publication by Adamson (1955) with a clear indication of the rank of series serves as the first publication at that rank and they are therefore to be treated as combinations by Adamson (1955).

The second correction concerns the status of the series that includes the type of the genus, *T. fruticosa* L. Although the genus *Tetragonia* was only lectotypified by Britton (1918) after the treatment by Fenzl (1862), the name *T.* [unranked] *Fruticulosae* Fenzl. (1862) is

to be treated as not validly published [Turland et al. 2018: 'Art. 22.2. A name of a subdivision of a genus that includes the type (i.e. the original type or all elements eligible as type or the previously designated type) of the adopted, legitimate name of the genus is not validly published unless its epithet repeats the generic name unaltered. For the purposes of this provision, explicit indication that the nomenclaturally typical element is included is considered as equivalent to inclusion of the type, whether or not it has been previously designated.']. Similarly, the publication of this taxon at series rank (spelled *Fruticosae*) by Adamson (1955) is to be treated as not validly published. The correct name for this taxon is series *Tetragonia* (Turland et al. 2018: 'Art. 22.1. The name of any subdivision of a genus that includes the type of the adopted, legitimate name of the genus to which it is assigned is to repeat that generic name unaltered as its epithet, not followed by an author citation.').

The species of *Tetragonia* subgenus *Tetragonia* are thus distributed among eight series as follows:

**Tetragonia** L., Species plantarum 1: 480 (1753). Type: *T. fruticosa* L., lecto., designated by Britton, Flora of Bermuda: 125 (1918).

#### Series **Tetragonia**

*Tetragonia* [unranked] *Fruticulosae* Fenzl in Flora capensis 2: 460 (1892), nom. inval.

*Tetragonia* series *Fruticulosae* Adamson in Journal of South African Botany 21: 112 (1955), nom. inval.

Species: *T. arbuscula* Fenzl, *T. arbusculoides* Engl., *T. calycina* Fenzl, *T. fruticosa* L., *T. glauca* Fenzl, *T. macroptera* Pax, *T. reduplicata* Welw. ex Oliv., *T. rangeana* Engl., *T. spicata* L.f., *T. virgata* Schltr.

Note: The Chilean species *T. macrocarpa* Phil. was erroneously included in this series by Klak et al. (2017) instead of the southern African *T. macroptera* Pax.

Series **Robustae** Adamson in Journal of South African Botany 21: 123 (1955). Type: *T. robusta* Fenzl.

Species: *T. distorta* Fenzl, *T. robusta* Fenzl, *T. sarcophylla* Fenzl

Series **Salignae** Adamson in Journal of South African Botany 21: 127 (1955). Type: *T. saligna* Fenzl.

Species: *T. erecta* Adamson, *T. haworthii* Fenzl, *T. lasiantha* Adamson, *T. saligna* Fenzl

Series **Decumbentes** Adamson in Journal of South African Botany 21: 130 (1955). Type: *T. decumbens* Mill.

Species: *T. decumbens* Mill., *T. namaquensis* Schltr., *T. verrucosa* Fenzl

Series **Macranthae** (Fenzl) Adamson in *Journal of South African Botany* 21: 133 (1955). *T.* [unranked] *Macranthae* Fenzl in *Flora capensis* 2: 461 (1892). Type: *T. hirsuta* L.f.

Species: *T. hirsuta* L.f., *T. rosea* Schltr.

Series **Pedunculares** (Fenzl) Adamson in *Journal of South African Botany* 21: 135 (1955). *T.* [unranked] *Pedunculares* Fenzl in *Flora capensis* 2: 460 (1892). Type: *T. herbacea* L., lecto., designated by Adamson: 135 (1955).

Species: *T. halimoides* Fenzl, *T. herbacea* L., *T. nigrescens* Eckl. & Zeyh., *T. portulacoides* Fenzl, *T. sphaerocarpa* Adamson

Series **Chenopodiinae** (Fenzl) Adamson in *Journal of South African Botany* 21: 141 (1955). *T.* [unranked] *Chenopodiinae* Fenzl in *Flora capensis* 2: 460 (1892). Type: *T. chenopodioides* Eckl. & Zeyh., lecto., designated by Adamson: 141 (1955).

Species: *T. chenopodioides* Eckl. & Zeyh., *T. galenioides* Fenzl, *T. pillansii* Adamson

Series **Echinatae** J.C.Manning & Klak, ser. nov.  
Type: *T. echinata* Aiton.

Prostrate ± annual herbs. Flowers sessile or subsessile, solitary or in small groups. Stamens as many as and alternating with perianth segments, sometimes in pairs, or sometimes fewer. Ovary half-inferior. Fruit not winged, often with ridges or projections at top or sides.

Species: *T. acanthocarpa* Adamson, *T. caesia* Adamson, *T. echinata* Aiton, *T. microptera* Fenzl

Note: The accession identified as '*T. microptera* (voucher Klak 2430, BOL)' in Klak et al. (2017)

was subsequently found to be misidentified, and true *T. microptera* was thus never included in the analysis. This species is therefore placed in series *Echinatae* based on the morphological characteristics that it shares with the other species in this series (Adamson 1955).

### 3. *Aizoon* L. (Aizoaceae: Aizooideae)

The generic circumscription of *Aizoon* L. (Aizooideae, Aizoaceae) was recently enlarged to include those species previously treated in the genus *Galenia* L. (Klak et al. 2017). In its new circumscription, *Aizoon* is recognized by capsules with reduced expanding tissue, and leaves and/or stems covered by silvery hairs or hair-like to rounded papillae. The species previously placed in *Galenia* subgenus *Galenia* were transferred to *Aizoon* subgenus *Galenia* (L.) Klak, which now includes six species. Among these, the new combination *A. procumbens* (L.f.) Klak proposed by Klak et al. (2017) for *G. procumbens* L.f. (1782) is, however, a later homonym of *A. procumbens* Crantz (1766: 135). Consequently, the proposed name is illegitimate (Turland et al. 2018: Art. 53.1 and 53.2), and a replacement name is required.

Although this species was originally described as 'procumbent', most forms are erect shrublets, some of which have been grouped under the manuscript name '*Galenia flavescens*', which alludes to the yellow to orange colour of the leaves (Adamson, 1956: 96). Since a new name is required, this unpublished epithet is taken up here.

***Aizoon flavescens* Klak**, nom. nov. pro *Galenia procumbens* L.f., *Supplementum plantarum*: 227 (1782). *Aizoon procumbens* (L.f.) Klak in *Taxon* 66: 1163 (2017), nom. illeg., non *A. procumbens* Crantz in *Institutiones Rei Herbariae* 1: 135 (1766).

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Authors of botanical names are abbreviated according to Authors of Plant Names (Brummitt & Powell 1992, Royal Botanic Gardens, Kew).

In names covered by the International Code of Zoological Nomenclature, the date of publication should be separated from the authority by a comma (e.g. *Anthomyza bellatrix* Roháček, 1984). When a species or subspecies is transferred to a genus other than that in which it was first classified, the original authority, including the date, is placed in parentheses.

Adjectives and nouns derived from genus names become Roman with a lower case initial (e.g. *Felis*→feline, *Libellula*→libellulids, *Streptococcus*→streptococcal infection). Those derived from higher taxonomic groups also begin with a lower case letter and are presented in Roman (e.g. Ostracoda→ostracods, Cactaceae→cacti).

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- Drawings in pencil will not be accepted.

- Provide original drawings electronically as bitmap TIF files, 1200 dpi.
- At the request of the author, the Graphic Design Section of SANBI will assist with the scanning of original material. Authors wishing to have the originals of figures returned must inform the editor in writing and mark each original 'To be returned to author'.

### Photographs:

- Provide photographs electronically as either TIF or JPG files, 600 dpi or higher.

### Graphs and histograms:

- The typeface for all graphs and histograms is Arial.
- Provide graphics originated in CorelDraw (version 16 or lower), as a .CDR file.
- Graphs and histograms generated in MS EXCEL or MS Word, should be provided as is. File conversion into the correct format will be accommodated by SANBI Graphics.
- Images generated in other programmes should be submitted as TIF or JPG files at a resolution of 600 dpi or as encapsulated postscript files (.EPS). If graphs and histograms are submitted in colour, please ensure that the shading used is easily discernible once the file is converted to grayscale.

### Maps:

- It is strongly recommended that taxonomic articles include dot maps as figures to show the distribution of taxa. If maps will be reduced to column width (80 mm), the symbols and numbers used must be large enough to accommodate the reduction. The maps should show: numbered grid lines of latitude and longitude; the provinces of South Africa; and a scale line. Maps of neighbouring countries should be treated in the same way, with bordering states clearly labelled. For orientation purposes, a small inset map should appear in a corner of the figure.
- Submit maps electronically as either TIF or JPG files, 600 dpi or higher.
- ArcView GIS maps are acceptable. The layout representing all the appropriate themes (including grid lines) should be submitted as an encapsulated postscript file (.EPS).
- If maps are submitted in colour, please ensure that the shading used is easily discernible once the file converted to grayscale.

### Tables:

- Tables should be drawn up in MS Word and not copied and pasted from other software such as MS Excel.
- Avoid copying and pasting text into the table as this often results in nested tables that are problematic to format and edit. Type in all text from scratch.

- Do not submit tables as text with separators such as tabs or commas, submit as MS Word standard tables.
- Do not include text boxes in table cells, type text directly in the primary table cell.
- Use Times New Roman 12pt if possible. However, should the width of the columns and the amount of text make this difficult, the size of the font may be reduced to no less than 9pt.
- If possible, present tables in portrait format. However, if tables must be presented in landscape format, use section breaks before and after the tables to separate it from the main text.
- Do not stretch the table to beyond the size of the paper on screen.
- Use the background fill function to shade cells if necessary. Do not use text highlights.

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## STRUCTURE OF YOUR ARTICLE

### Page 1:

The format of the compulsory cover letter forms part of your submission and is on the first page of your manuscript and should always be presented in English. You should provide all of the following elements:

- **Article title:** Provide a short title of 50 characters or less.
- **Full author details:** Provide title(s), full name(s), position(s), affiliation(s) and contact details (postal address, email, telephone and cellular number) of each author.
- **Corresponding author:** Identify to whom all correspondence should be addressed to.
- **Authors' contributions:** Briefly summarise the nature of the contribution made by each of the authors listed.
- **Summary:** Lastly, include a list containing the number of words, pages, tables, figures and/or other supplementary material with the submission.

### Page 2 and onwards:

**Title:** The article's full title should contain a maximum of 95 characters (including spaces).

**Abstract:** The abstract, written in English, should be no longer than 250 words and must be written in the past tense. The abstract should give a succinct account of the background, objectives, methods, results and significance of the findings/conclusion

Do not cite references in the abstract and do not use abbreviations excessively in the abstract.

The following points serve as a guide for presenting your manuscript in a well-structure format:

**Introduction:** The introduction contains two subsections, namely the background section and the literature review.

- **Background:** This section should be written from the point of view of the readers, including those without

specialist knowledge in that area and must clearly state and illustrate the introduction to the research and its aims in the context of previous work bearing directly on the subject. The Background section to the article normally contains the following five elements:

- **Key focus:** A thought-provoking introductory statement on the broad theme or topic of the research.
- **Context:** Provide the context to the study, which can include the conceptual framework or explain the role of other relevant key variables in this study.
- **Trends:** Cite the most important published studies previously conducted on this topic or that have any relevance to this study (provide a high-level synopsis of the research literature on this topic).
- **Objectives:** Indicate the most important controversies, gaps and inconsistencies in the literature that will be addressed by this study. In view of the above trends, state the core research problem and specific objectives that will be addressed in this study.
- **Contribution to field:** Explanation of the study's academic (theoretical and methodological) or practical merit and its importance (provide the value-add or rationale for the study).
- **Literature review:** The literature review is the second subsection under the Introduction and provides a brief and concise overview of the literature under a separate second-level heading, e.g. literature review. A synthesis and critical evaluation of the literature (not a compilation of citations and references) should at least include or address the following elements (ensure these are in the literature review):
  - Definitions of all key concepts.
  - A critical review and summary of previous research findings (theories, models, frameworks, etc.) on the topic.
  - A clear indication of the gap in the literature and for the need to address this void.
  - A clearly established link that exists between formulated objectives and theoretical support from the relevant literature.

### Research method and design (first-level heading):

The methods should include:

- **Materials (second-level heading):** Describe the type of organism/s or material/s involved in the study.
- **Study site (second-level heading):** Describe the site and setting where your study was conducted.
- **Design (second-level heading):** Describe your experimental design clearly. Note: Additional details can be placed in the online supplementary location.
- **Procedure or Methods (second-level heading):** Describe the protocol for your study in sufficient detail (with a clear description of all interventions and comparisons) so that other scientists could repeat your work to verify your findings.

- **Analysis (second-level heading):** Describe how the data were summarised and analysed. Additional details can be placed with the online supplementary information. Do not include lists here as they will be published as supplementary material.

#### Ethical considerations (first level heading):

- **Ethical clearance (second-level heading):** Articles based on the involvement of animals and/or humans must have been conducted in accordance with relevant national and international guidelines. Approval must have been obtained for all protocols from the author's institutional or other relevant ethics committee and the institution's name and any ethics certificate number/s should be provided at submission.
- **Risks or negative impacts associated with research and mitigation (second-level heading):** This section should consider any risks or negative impacts to the subjects caused by the project (the subject may be a human individual or a population of plants or animals). What precautions were taken to minimise any negative impacts of the research on the subject/s?
- **Permitting (second-level heading):** Projects that required permits for collection, transport or provision of material must provide all relevant permit details.
- **Recruitment and informed consent (second-level heading):** In the case where human subjects were involved, how were subjects recruited? Was there any sense in subjects being obliged to participate or were volunteers recruited. Authors must include how informed consent was handled in the study.
- **Data protection (second-level heading):** Authors must include, in detail, the way in which data protection was handled.

#### Results (first-level heading):

Results should be presented as follows:

- Present the results of your experiment(s) or research data in a sequence that will logically support (or provide evidence against) the hypothesis, or answer the questions / address the objectives, as stated in the introduction.
- Present the body of the results section in text with the key findings that include references to each of the tables and figures. Report statistical test summaries (test name, p-value) parenthetically (that is, inserted as a parenthesis in brackets) together with the biological results they support. Use the SI unit.
- All units should conform to the SI convention and be abbreviated accordingly. Metric units and their international symbols are used throughout, as is the decimal point (not the decimal comma).

#### Discussion (first-level heading):

This section normally contains the following four elements. It is suggested that subheadings are used in this section:

- **Outline of the results (second-level heading):** Restate the main objective of the study and reaffirm the importance of the study by restating its main contributions; summarise the results in relation to each stated research objective or research hypothesis; link the findings back to the literature and to the results reported by other researchers; provide explanations for unexpected results.
- **Practical implications (second-level heading):** Reaffirm the importance of the study by restating its main contributions and provide the implications for the practical implementation your research.
- **Limitations of the study (second-level heading):** Point out the possible limitations of the study and provide suggestions for future research.
- **Recommendations (second-level heading):** Provide the recommendations emerging out of the current research.

#### Conclusion (first-level heading):

This should state clearly the main conclusions of the research and give a clear explanation of their importance and relevance, with a recommendation for future research (implications for practice). Provide a brief conclusion that restates the objectives, the research design and the results with their meaning.

#### Acknowledgements (first-level heading):

If, through your study, you received any significant help in conceiving, designing or carrying out the work, or received materials from someone who did you a favour by supplying them, you must acknowledge their assistance and the service or material provided. *Authors should always acknowledge outside reviewers of their drafts and any sources of funding that supported the research.*

- **Competing interests (second-level heading):** A competing interest exists when your interpretation of data or presentation of information may be influenced by your personal or financial relationship with other people or organisations that can potentially prevent you from executing and publishing unbiased research. Authors should disclose any financial competing interests, but also any non-financial competing interests that may cause them embarrassment were they to become public after the publication of the manuscript.

*Where an author gives no competing interests, the listing will read:*

*'The authors declare that they have no financial or personal relationship(s) that may have inappropriately influenced them in writing this article.'*

- **Authors' contributions (second-level heading):** This section is necessary to give appropriate credit to each author, and to the authors' applicable

institution/s. The individual contributions of authors should be specified with their affiliation at the time of the study and completion of the work. An 'author' is generally considered to be someone who has made substantive intellectual contributions to a published study. Contributions made by each of the authors listed, can follow the example below (please note the use of author initials):

J.K. (University of Pretoria) was the project leader, L.M.N. (University of KwaZulu-Natal) and A.B. (Stellenbosch University) were responsible for experimental and project design. L.M.N. performed most of the experiments. P.R. (Cape Peninsula University of Technology) made conceptual contributions and S.T. (University of Cape Town), U.V. (University of Cape Town) and C.D. (University of Cape Town) performed some of the experiments. S.M. (Cape Peninsula University of Technology) and V.C. (Cape Peninsula University of Technology) prepared the samples and calculations were performed by C.S. (Cape Peninsula University of Technology).

#### References (first-level heading):

Begin the reference list on a separate page with no more than 60 references for full length articles and 30 references for short notes. The *Bothalia – African Biodiversity & Conservation* Journal uses the **Harvard referencing style**. Note: no other style will be permitted.

If you use any reference editor to add citations in the text, remove all data fields and replace with normal text before submission.

For journal articles, provide DOIs for as many as possible (usually all papers published in or after 2000). The DOI reference can be provided after a comma at the end of each reference.

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## TAXONOMIC PUBLICATIONS

*Bothalia – African Biodiversity & Conservation* publishes taxonomic findings where these align with the scope and focus of the journal (see Scope and Focus of *Bothalia – African Biodiversity & Conservation*). For such works the following headings should be used:

The Abstract and Introduction must follow the guidelines for full length articles, as described above.

#### Research method and materials (first-level heading):

- **Materials (second-level heading):** Briefly explain from which institutions material was studied, and whether any fresh material was collected as part of the study. If field collecting did take place explain

where this was carried out, over what time period and how samples were collected.

- **Procedure (second-level heading):** Explain how observations, measurements and illustrations were done, and what equipment was used.

#### Taxonomic treatments (first-level heading):

This section serves as a guide to understand and standardise the presentation of taxonomy in research articles and short communications.

More details of rules that must be adhered to can be obtained from:

- The International Plant Names Index at <http://www.ipni.org/>
- International Association for Plant Taxonomy at <http://www.iapt-taxon.org/>
- The International Commission for Zoological Nomenclature (<http://www.iczn.org>)

The following sequence and format must be followed for taxonomic treatments in *Bothalia – African Biodiversity & Conservation*:

#### Species treatments:

- Basionym (the first name validly published, which has priority over other names later given to the same species): **Name** (bold, not italicised), *author citation* (italicised), author/s of paper in which basionym stated (if different from original author, not italicised).
- Name of the journal/publication written out in full (not italicised), volume: page number/range (date of publication), fig/s.
- Type locality: COUNTRY (upper case), as provided in the original description. Type specimen/s: date of collection, *collector* (italicised), *collector number* (italicised) (where available), institution code (using global acronym), catalogue number (where available), status (holotype, isotype/syntype, lectotype). If specimen was examined, this is indicated by a '!' after the specimen status.
- Additional references, in chronological order, with author: page (year of publication), figure number/s reflected (e.g. Boris et al.: 14 (1966); Boris: 89 (1967), fig. 9.).
- List of synonyms in chronological order, arranged in groups of nomenclatural synonyms (i.e. homotypic synonyms (based on the same type), followed by heterotypic synonyms (based on a different type), arranged chronologically), with references cited as author, page (year of publication), and figure number/s listed in chronological order.
- Identification of illegitimate names in the nomenclatural component must be accompanied by an appropriate indication of the reason for their illegitimacy. The type details for each heterotypic synonym should be included (institution code followed by catalogue number where available and type status), and those specimens examined by the author/s

must be indicated by an exclamation mark. The full reference for citations must be included in the Reference List.

Examples:

1. **Eremiolirion amboense** (*Schinz*)  
*J.C.Manning & C.A.Mannheimer*  
in *Bothalia* 35: 117 (2005), fig. 4.  
Type: South West Africa [NAMIBIA],  
Amboland [**Ovamboland**], Ongangua  
[Ondongwa], without date, *Ruatanen*  
344 (Z.holo!).

2. **Walleria gracilis** (*Salisb.*) *S.Carter* in  
*Kew Bulletin* 16: 189 (1962). *Androsyne*  
*gracilis* *Salsb.*: 61 (1866). Type:  
SOUTH AFRICA, **Western Cape**,  
*William Marsden* [BM, holo!; drawing  
in *Salisbury mss.*: 818 (BM)].

*W. armata* *Scltr. & K.Krause* in *Krause*:  
235 (1921). Type: SOUTH AFRICA,  
[**Western Cape**, near Klawer], [Farm]  
Windhoek, 8 July 1896, *R. Schlechter*  
8074 (B, holo [not seen]; BM!, BR!,  
COI!, GRA!, K, MO!, PRE!, Sl. iso).

3. **Plagiotaphrus improvisus** (*Attems*  
1934) *Hoffman* in *Revue de Zoologie*  
et de Botanique Africaines, 83 (3–4):  
209 (1971), fig. 2. *Megaskamma*  
*improvisa*: *Attems*: 16: 13 (1934), figs  
14–17. Type: **ANGOLA**, near Cuanza  
River, Bié District, Jan. 1932, *F. Haas*  
(SMF 1694, holo. [not seen] 1 male).

- Lectotypes or neotypes should be chosen for correct names without a holotype. It is not necessary to lectotypify synonyms. When a lectotype or neotype is newly chosen, this should be indicated by using the phrase “here designated”. If reference is made to a previously selected lectotype or neotype, the name of the designating author and the literature reference should be given. In cases where no type was cited, and none has subsequently been nominated, this may be stated as “not designated”.

#### Description of new taxa:

- All newly described taxa and newly proposed synonyms and new combinations should be explicitly designated as such, e.g. fam. nov., trib. nov., gen. nov., sp. nov., nom. nudem., syn. nov., comb. nov.

**Name** (bold, not italicised) sp. nov.  
authority (if different to the authors of  
the manuscript)

TYPE/S: (holotype followed by  
paratype/s) (COUNTRY (upper case),  
**province** (bold), locality as given  
by original collector (if in foreign  
language or using archaic or outdated  
place names then these must be

placed in inverted commas, with  
modern equivalent of collecting  
locality in square brackets (if rele-  
vant)), geographic co-ordinates (if  
the geographic co-ordinates were  
not provided on the specimen label  
or provided by the collector, and  
were identified by the author using a  
gazetteer or Google Earth, this must  
be indicated by including the co-  
ordinates in square brackets, altitude,  
habitat or other available, relevant  
collecting details, date of collection,  
*collector's name* (italicised), *collec-  
tor's number* (italicised) (if available),  
(institution where specimen is housed  
(using global acronyms for these),  
catalogue number (if available),  
number of specimens by male and  
female (where relevant)).

Examples

1. **Lasiosiphon rigidus** *J.C.Manning &*  
*Boatwr.*, sp. nov.

TYPES: SOUTH AFRICA, **Northern**  
**Cape**, Tankwa [Tangua] Karoo  
National Park, SW foot of Leeuberg,  
along drainage lines, [32°18,2'S /  
20°0.3'E, 414 masl], 20 Jun. 2012,  
*Manning* 3363 (NMG, holo., MO,  
PRE, iso).

2. **Doratogonus microsetus** sp. nov.

TYPES: SOUTH AFRICA, **Mpuma-**  
**langa**: Wakkerstroom, 27.36670°S  
/ 30.01670° E, 20 Dec, 2000, *D.*  
*Forbes* (NMSA 21786, 1 male holo.;  
NMSA 21787, 2 males, 1 females,  
para.).

#### Second-level headings for taxonomic treatments:

- Description (with third-level headings if required, and according to diagnostic characters for the particular taxon)
- Distribution and habitat
- Ecology
- Etymology
- Local name/s
- Uses / economic value
- Diagnosis and relationships
- Conservation status – comment on whether included in existing Red Lists, or whether the species would potentially qualify as threatened and describe current and potential threats.
- Other material examined (country (upper case), province (bold): locality as given by original collector, modern equivalent of collecting locality in square

brackets (if relevant), co-ordinates (degrees, minutes decimal) (in square brackets if gazetteer or Google Earth used by author), approximate altitude, date of collection, *collector's name (italics)*, *collector's number (italics)* (if available) (institution where specimen is housed (using international acronym or code for these), catalogue number (if available), number of specimens by male and female (where relevant)).

- List of specimens must be arranged alphabetically by country, and within countries, by province in alphabetical order, and within provinces, alphabetically by locality name, and as far as possible keeping those specimens from the same locality together, then in chronological order by collection date.
- Herbarium acronyms follow Index Herbariorum [Thiers, B. [continuously updated]. Index Herbariorum: A global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium. <http://sweetgum.nybg.org/ih/>]. The accepted acronyms for other institutions can be obtained from the Global Registry of Biorepositories (GRBio) (<http://grbio.org>).
- Original locality information in a foreign language or using archaic/outdated place names should be indicated using inverted commas, with any relevant corrections for modern usage, including conversions to metric units, added in square brackets.

The date of collection is to be presented as day, month of the year (abbreviated as Jan., Feb., Mar., Apr., May, Jun., Jul., Aug., Sept., Oct., Nov., Dec.), and year in full.

Geographic co-ordinates must be presented as taken from a GPS, or from an online gazetteer or georeferencer in degrees, decimal minutes (DDM). Records must also indicate the hemisphere (E or W and N or S, and the estimated/approximate altitude. If the geographic co-ordinates and approximate altitude were not provided on the specimen label or provided by the collector, and were identified by the author, this must be indicated by including the co-ordinates in square brackets.

For species that may be threatened by over-collecting, the co-ordinates can be degraded to reflect only the degrees and minutes. In the case of old specimens where the exact locality is unknown the degree and minutes or equivalent, or the degree or quarter degree grid square can be provided.

Examples:

1. SOUTH AFRICA. **Western Cape:**  
Near Eendekuil, western foot of Piekensklou Pass, [32°37.136'S / 18°57.525'E 476masl], 28 Aug. 2009, Magee, Boatwright, Manning and Goldblatt 161 (NBC, PRE, K, BOL); roadside near Gouda, [33°37.136'S / 19°2.044'E, 85masl],

09 Sept. 1951, Esterhuysen 18840 (BOL [3 sheets], K, PRE).Tullbagh, 33°17.126'S / 19°8.257'E, 162masl, Sept. 1919, Bolus 16734 (BOL);

2. SOUTH AFRICA: **KwaZulu-Natal:** Nkandhla Forest, in forest along dirt road, 28°43'38.592"S / 31°07'58.281"E, 1121 masl, 19 Nov, 2001, A. Armstrong & H. Murray (NMSA 21970 [1 male, 1 female]).

Language for these sections must be as concise as possible, using principles instead of verbs.

The remaining first-level headings (Discussion, Conclusions, Acknowledgements, Competing interests, Authors' contributions and References) must follow the same format as for full length articles, as detailed above.

Images – low resolution version in the text file; high resolution files – correctly labelled – as separate JPG, TIF or EPS files.

**Identification keys:** Dichotomous keys must use sequential numbering, with the two parts of the couplet numbered 1a, b; 2a, b etc. New species included in keys must be bolded and not italicised, and sp. nov. must be stated, while other species names must not be bolded, must be italicised, and must include the species authority in the correct format.

**Illustrations for taxonomic works:** Descriptions of new plant species should include a photograph of the holotype specimen, unless there is a good reason for not providing this. For all taxa, descriptions of new species and taxonomic revisions should include annotated illustrations that clearly show and indicate diagnostic characters.

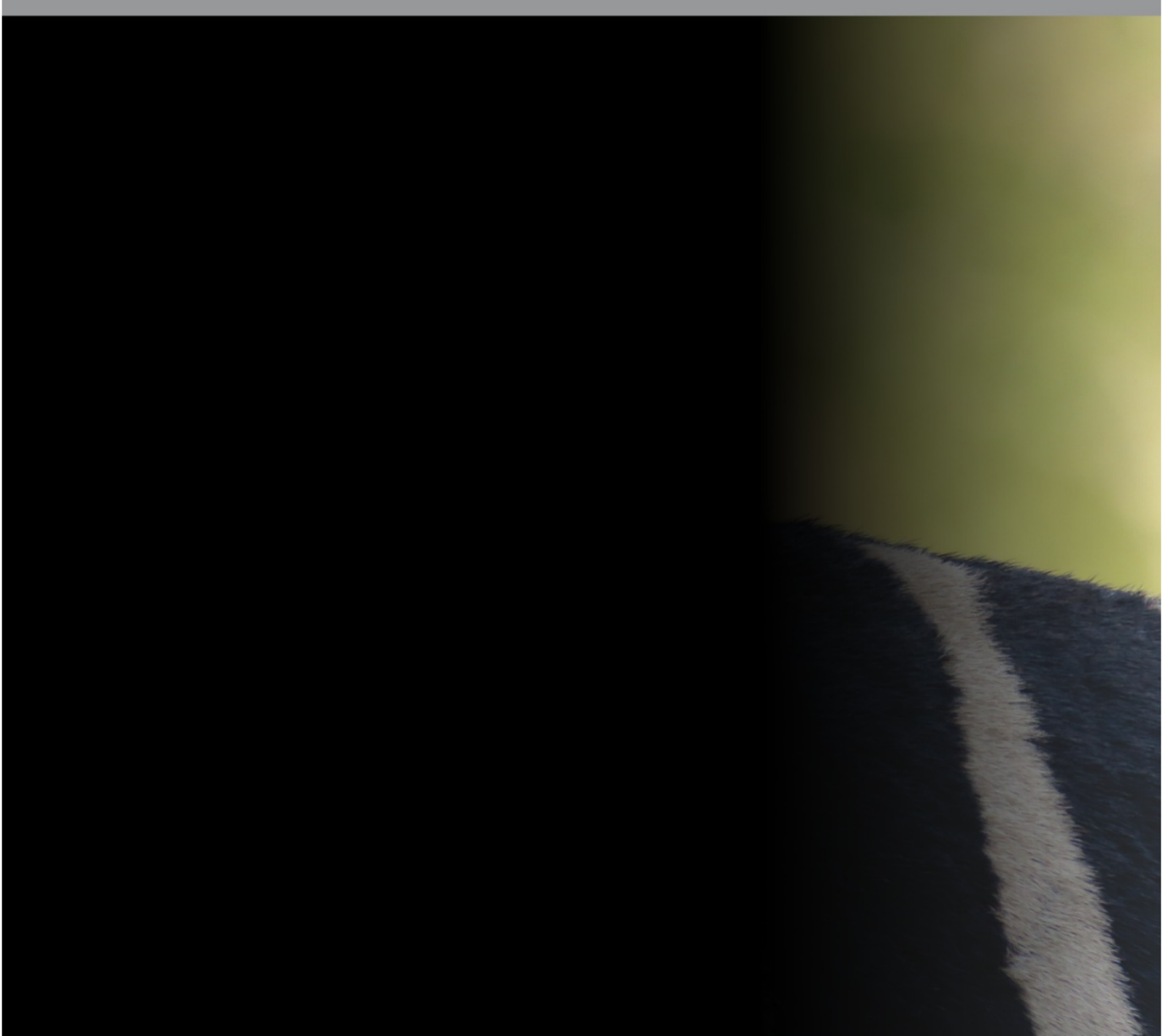
## Nomenclatural changes

*Bothalia – African Biodiversity & Conservation* will accept notes on nomenclatural changes. Authors are encouraged to include all name changes into a single manuscript and not to split these into separate manuscripts. Note that where a nomenclatural changes are a formality, and not based on research findings presented, the manuscript may not be subjected to a full review process. In such cases the publication will clearly state that the paper has not been peer reviewed.

## Range extensions / new distribution records

*Bothalia – African Biodiversity & Conservation* will accept new distribution records where these have an impact on the conservation status of a species, or they represent a new country record. Single new distribution records will only be considered for publication where these are of major significance, and authors are encouraged to compile all new distribution records into a single manuscript and not to split these into several papers.





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