Bothalia - African Biodiversity & Conservation
ISSN: (Online) 2311-9284, (Print) 0006-8241

Fifty shades of red: Lost or threatened bryophytes in Africa

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Dates:
Received: 18 Jan. 2018
Accepted: 23 Aug. 2018
Published: 14 Jan. 2019

How to cite this article:
Van Rooy, J., Bergamini, A. & Bisang, I., 2019, 'Fifty shades of red: Lost or threatened bryophytes in Africa', *Bothalia* 49(1), a2341. https://doi.org/10.4102/abc.v49i1.2341

Background: A Red List of threatened bryophytes is lacking for Africa. The International Union for Conservation of Nature (IUCN) Species Survival Commission (SSC) Bryophyte Specialist Group has recently launched the 'Top 10 Initiative' to identify the 10 species on each continent that are at highest risk of extinction.

Objectives: The main aim of this paper was to highlight some of the lost or strongly threatened bryophyte species in sub-Saharan Africa and the East African islands and to draw up a Top 10 list for Africa.

Method: Lost or threatened species have been identified with the help of experts on the bryoflora of Africa, global and regional Red Lists and taxonomic literature. Each species on this candidate list is discussed at the hand of its taxonomy, distribution, habitat, threat and current global or regional Red List status as far as previously assessed.

Results: Fifty bryophyte species, representing 40 genera and 23 families, have been identified as Top 10 candidates. Of these, 29 are endemic to Africa and 21 are restricted to the East African islands. The majority of the candidate species occur in one of eight 'biodiversity hotspots' with most species (19) in the Madagascar and the Indian Ocean Islands hotspot.

Conclusion: This is the first list of lost or threatened bryophytes for Africa and the first Top 10 list of the IUCN Bryophyte Specialist Group. It represents an important step towards regional and global Red List assessment of bryophytes, thus meeting the targets of the Updated Global Strategy for Plant Conservation 2011–2020 and priorities of The Shenzhen Declaration on Plant Sciences.

Introduction

The bryoflora of sub-Saharan Africa and the East African islands is poorly known and recent taxonomic and floristic activity is minimal in comparison to other regions of the world (Diop et al. 2018; Hallingbäck & Hodgetts 2000; Magill 2010; O'Shea 2005; Wilding 2017). Recent, but still incomplete, floras and identification guides are available only for southern Africa (Magill 1981, 1987; Magill & Van Rooy 1998; Perold 1999), tropical Africa (De Sloover 2003), Kenya (Chuah-Petiot 2003; Wilding et al. 2016), West Africa (Wigginton 2004) and Rwanda (Fischer 2013). However, a series of regional checklists with accepted names, synonyms, literature references and geographical distribution by country, of which the moss checklist of O'Shea (2006) and the liverwort and hornwort checklist of Wigginton (2018) are the most recent, provide a sound basis for research on the taxonomy, ecology and conservation of African bryophytes.

The documentation of plant diversity and its urgent conservation are priority objectives of the Updated Global Strategy for Plant Conservation 2011–2020 (Convention on Biological Diversity [CBD] Secretariat 2017) and The Shenzhen Declaration on Plant Sciences (Crane et al. 2017). Several authors drew attention to the in general smaller and less spectacular, but to the same degree rare or threatened, bryophytes, especially in centres of bryophyte diversity, and emphasised the need for Red Lists (Hallingbäck & Tan 2010; Geffert et al. 2013; Longton & Hedderson 2000; Szabó & Pócs 2016).

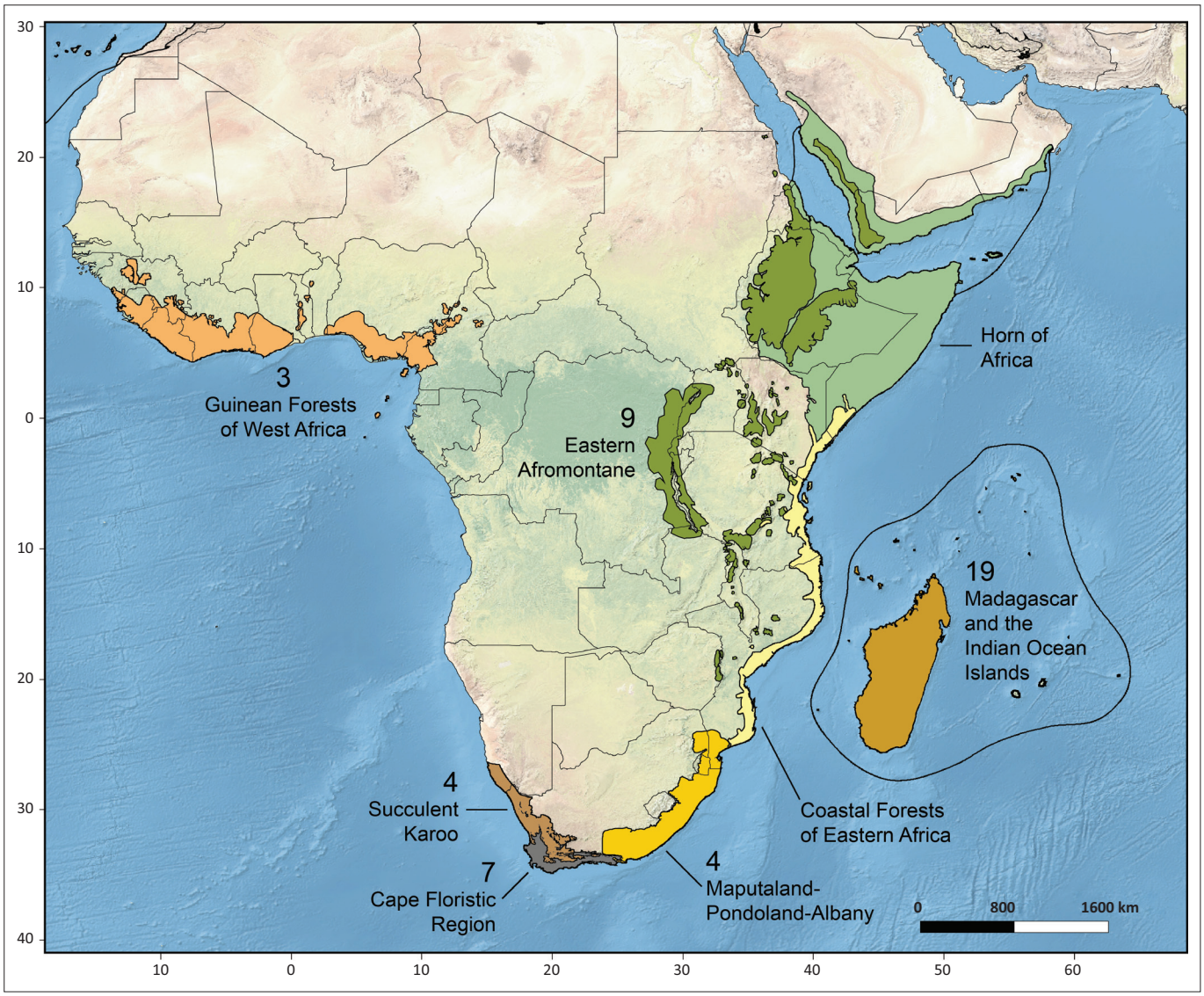
The International Union for Conservation of Nature (IUCN) Red List Categories and Criteria provide an explicit framework for classifying species according to their extinction risk (IUCN 2012a). The IUCN Species Survival Commission (SSC) lists the expansion of geographic and taxonomic coverage of the IUCN Red Lists as its top priority (IUCN 2017b). The IUCN Red List of Threatened Species for bryophytes (IUCN 2017e; Tan et al. 2000) currently contains 102 species, including several from Africa. However, most of these assessments are more than 10 years old and thus in need of careful revision. There is currently no Red List for African bryophytes and the only

regional Red List is the list of threatened liverwort and hornwort species compiled for the East African island of Réunion (Ah-Peng et al. 2012).

To rigorously assess the estimated 18 000 bryophyte species globally (Frey & Stech 2009), following IUCN methodology, which is now generally accepted and advocated by, for example, Vanderpoorten and Hallingbäck (2009:488), is an unsurmountable task given the current personnel and economic resources devoted to bryophyte conservation. Such an endeavour of IUCN red-listing is currently underway for the ca. 1800 European bryophyte species (IUCN 2017c). To reinitiate red-listing activities on a global scale, the IUCN SSC Bryophyte Specialist Group has launched the so-called 'Top 10 Initiative' (IUCN 2017d; IUCN SSC 2016) to identify a minimum of 10 species at high risk of extinction from each continent and properly assign them to an IUCN Red List category (IUCN 2012a; IUCN Standards and Petition Subcommittee 2017).

It is generally accepted that centres of diversity and endemism, or so-called 'biodiversity hotspots', are priority areas for conserving biodiversity (Geffert et al. 2013; Marchese 2015). Conservation International, through the Critical Ecosystem Partnership Fund (CEPF) (2016a), recognises 36 global biodiversity hotspots. A biodiversity hotspot is characterised by high levels of vascular plant endemism (>1500 endemic species) and 30% or less of its original natural vegetation remaining (Conservation International 2017). Many of these are heavily threatened by habitat loss and other human activities (CEPF 2016a; Mittermeier et al. 2004). The hotspot system is used to assess global conservation priorities and to provide grants to non-governmental and private sector organisations through the CEPF (2016b; Conservation International 2017).

Eight of the global biodiversity hotspots are found in sub-Saharan Africa and the East African islands (Figure 1):



Source: Based on the Biodiversity hotspots map downloaded from http://www.cepf.net/where_we_work/Pages/map.aspx, figure licensed under the Creative Commons Attribution-Share Alike 4.0 International license (Author: Conservation International)

km, kilometres.

FIGURE 1: The number of lost or threatened bryophytes in Africa and the East African islands (Top 10 candidates) in each of the eight Biodiversity hotspots recognised by Conservation International (CEPF 2016a). An additional four candidate species are only known from inland areas of southern Africa outside the Biodiversity hotspots (not shown on map).

Cape Floristic Region, Coastal Forests of Eastern Africa, Eastern Afromontane, Guinean Forests of West Africa, Horn of Africa, Madagascar and the Indian Ocean Islands, Maputaland–Pondoland–Albany and Succulent Karoo biodiversity hotspots.

Recent analyses of bryophyte distributions at a global, continental or regional scale (Geffert et al. 2013; Tan & Pòcs 2000; Vanderpoorten & Hallingbäck 2009; Van Rooy & Phephu 2016; Von Konrat et al. 2008) indicate that African centres of bryophyte diversity and endemism partly coincide with the biodiversity hotspots defined on the basis of vascular plants. The most species-rich areas are Madagascar, especially the lowland forests along the east coast, the mountains of eastern Africa, the Afromontane and Cape Floristic regions of South Africa, and West Africa.

The aim of this paper is to highlight lost and threatened bryophytes in sub-Saharan Africa and the East African islands and to draw up a Top 10 list of bryophytes in Africa that are at highest risk of extinction. The Top 10 species will be subjected to a careful IUCN Red List assessment to be included in The IUCN Red List of Threatened Species, and they will be further evaluated (IUCN 2012b) to identify and design the most urgent conservation actions. We also test the hypothesis that most lost and threatened bryophytes on our list fall within the global biodiversity hotspots recognised by Conservation International (CEPF 2016a).

Research method and design

The area covered in this publication comprises sub-Saharan Africa, together with the Atlantic and Indian Ocean islands in the tropics (Figure 1). This corresponds to the area covered by the checklists of O'Shea (2006) and Wigginton (2018), except for the islands of Cape Verde, Ascension and St. Helena, which are excluded here.

Experts on the taxonomy, ecology and conservation of African bryophytes were invited to contribute to two initiatives, namely the 'Top 10 Initiative' by the IUCN SSC Bryophyte Specialist Group (IUCN SSC 2016) and the 'Search for Lost Species' initiative (Global Wildlife Conservation 2014). Global Wildlife Conservation approached IUCN Specialist Groups in 2014 to suggest candidate species for a proposal to search in the field for species that have gone unrecorded for years or decades (funding pendent).

Inspired by these two initiatives, a list of lost and threatened species (Online Appendix 1) was compiled based on the experts' and the first author's (J.v.R.) contributions. The following criteria were applied in the selection of species:

- The species should be endemic to sub-Saharan Africa or the East African islands.
- Known from a single or few localities with a narrow geographical distribution range.
- The habitat should be threatened and declining or the known records date from previous centuries despite more recent collecting activity or searches in the area.

The list of 50 species includes all threatened African bryophytes listed in the global IUCN Red List of Threatened Species (IUCN 2017e; Tan et al. 2000), and the threatened African endemics identified as 'Critically Endangered' in the Red List of liverworts and hornworts for Réunion (Ah-Peng et al. 2012).

In the Online Appendix 1, each species is presented at the hand of its taxonomy, geographical distribution, habitat (including substrate) and most likely threats. The current Red List status is indicated for those species that were previously assessed, either at the global or at regional scales. However, not all of these Red List assignments follow IUCN methodology consequently, and some of the global Red List statuses are in need of revision. Family placement of the genera follows the classifications of Goffinet, Buck and Shaw (2009) and Frey and Stech (2009) for the mosses and Söderström et al. (2016) for the liverworts. Species author citations follow Söderström et al. (2016) for the liverworts and Missouri Botanical Gardens' TROPICOS database (Tropicos.org) for the mosses.

The 10 species that are at highest risk of extinction, and most likely to be categorised as 'critically endangered' when (re-) assessed using the latest IUCN Red List criteria (IUCN 2012a), were selected for the Top 10 list for Africa (Table 1). Monotypic genera and subgenera received priority and preference was given to species recognised and accepted in the latest world and African checklists of bryophytes

TABLE 1: The IUCN SSC Bryophyte Specialist Group Top 10 list of bryophytes in Africa that are at highest risk of extinction, compiled from the list of candidate species in the Online Appendix 1 where more details on the species' ecology and threats are provided.

Name	Family	Distribution	Biodiversity hotspot†
Bryopteris gaudichaudii Gottsche	Lejeuneaceae	Madagascar and Réunion	Madagascar and the Indian Ocean Islands
Cheilolejeunea ulugurica Malombe, Eb.Fisch. et Pócs	Lejeuneaceae	Endemic to Tanzania	Eastern Afromontane
Cololejeunea nosykombae A.Szabó & Pócs	Lejeuneaceae	Endemic to Madagascar	Madagascar and the Indian Ocean Islands
Ludorugbya springbokorum Hedd. & R.H.Zander	Pottiaceae	Endemic to South Africa	Cape Floristic Region
Neckeropsis pocsii Enroth & Magill	Neckeraceae	Endemic to the Comoros	Madagascar and the Indian Ocean Islands
Picobryum atomicum R.H.Zander & Hedd.	Pottiaceae	Endemic to South Africa	Cape Floristic Region
Pocsiella hydrogonioides Bizot	Dicranaceae	Endemic to Tanzania	Eastern Afromontane
Symbiezidium madagascariense Steph.	Lejeuneaceae	Madagascar and Seychelles	Madagascar and the Indian Ocean Islands
Xylolejeunea grolleana (Pócs) Xiao L.He et Grolle	Lejeuneaceae	Madagascar and Réunion	Madagascar and the Indian Ocean Islands
Xylolejeunea muricella Xiao L.He et Grolle	Lejeuneaceae	Endemic to the Seychelles	Madagascar and the Indian Ocean Islands

†, Biodiversity hotspots recognised by Conservation International through the CEPF (2016a).

(O'Shea 2006; Söderström et al. 2016; Tropicos.org) for which precise information on localities is available.

Results

We have identified a total of 50 species, representing 40 genera and 23 families of bryophytes, as lost and threatened in the area (Online Appendix 1). Of these, 29 are endemic to mainland Africa, 19 to the East African islands and two are restricted to West Africa as well as islands off the coast. Twenty-nine species (in 19 genera and nine families) are liverworts and 21 species (in 21 genera and 14 families) are mosses. The liverwort family Lejeuneaceae with 11 genera and 17 species is the largest family on the list whilst *Cololejeunea* (Spruce) Steph. and *Riccia* L. are the largest genera, represented by five species each.

Altogether, the species' known localities are found in 16 African countries (Online Appendix 1). Eighteen species occur in the Flora of Southern Africa area (Magill 1981), with 15 species being endemic to South Africa. Of these, seven species are restricted to the Fynbos Biome (Rebelo et al. 2006) of the southwestern Cape. The Indian Ocean islands of Réunion and Madagascar are well represented on the list with 12 (six endemic) and 11 (four endemic) species, respectively.

Six of the eight global biodiversity hotspots recognised in sub-Saharan Africa and the East African islands, based on vascular plant species and vegetation, contain candidates for the Top 10 list (Figure 1). The three hotspots with the most species are (1) Madagascar and the Indian Ocean Islands with 19 species, (2) Eastern Afromontane with nine species and (3) Cape Floristic Region with seven species. The remaining hotspots with threatened bryophytes are: Maputaland–Pondoland–Albany (four species), Succulent Karoo (four species) and Guinean Forests of West Africa (three species).

Only four species, all from inland areas of southern Africa, have not been reported from any of the global biodiversity hotspots. They are *Anacamptodon marginata* (Dixon) W.R.Buck from Mashonaland West Province of Zimbabwe, *Cryptomitrium oreades* Perold from the Highlands of Lesotho, *Fissidens capriviensis* Magill from the Caprivi Strip of Namibia and *Gymnostomum lingulatum* Rehmann ex Sim from the Woodbush–Haenertsburg area in the Limpopo Province of South Africa.

The majority of Top 10 species (six species) belong to the liverwort family Lejeuneaceae, and the Madagascar and the Indian Ocean Islands hotspot is the biodiversity hotspot with the highest number of species (six species) on the list (Table 1). *Xylolejeunea* Xiao L.He et Grolle (Lejeuneaceae) is the only genus with more than one (two) species on the Top 10 list for Africa.

Discussion

It is no coincidence that Lejeuneaceae is the liverwort family with the highest species number on the list of lost or threatened bryophytes in Africa as well as on the Top 10 list of bryophytes in Africa that are at highest risk of extinction. Not only is Lejeuneaceae the largest family of liverworts, but it contains more than 95% of all epiphyllous bryophytes (Gradstein 1994). The family displays high levels of diversity and endemism in moist tropical forests where they grow mainly on the bark of woody plants and on leaves at low and mid elevations (Gradstein 1992, 1994; Pócs 1996; Von Konrat et al. 2008). Von Konrat et al. (2008:431) calculated that in Madagascar and some countries of central and West Africa, between 50% and almost 90% of the liverwort flora consist of Lejeuneaceae.

Recent researches in tropical forests indicate that ancient uncut stands of forest, with original phorophyte diversity and intact forest canopies, are important drivers for high epiphytic and epiphyllous bryophyte diversity (Benítez, Prieto & Aragón 2015; Malombe et al. 2016; Pócs & Tóthmérész 1997; Zartman 2003). The ongoing destruction, degradation and fragmentation of forests in the biodiversity hotspots of Africa (Aynekulu et al. 2016; CEPF 2016a; Gradstein 1992; Green & Sussman 1990; IUCN 2017a; Malombe 2007) therefore pose serious threats to epiphytic and epiphyllous bryophytes in general and species of Lejeuneaceae in particular.

The fact that 46 (92%) candidate species for the Top 10 list fall within six of the eight biodiversity hotspots in the region suggests that the African biodiversity hotspots designated on the basis of information from vascular plants may also represent hotspots for bryophytes. However, the concentration of lost or threatened species in the biodiversity hotspots may also be a consequence of collecting bias. Only two of the global biodiversity hotspots in Africa, the Coastal Forests of Eastern Africa and the Horn of Africa, are not represented on our list (Figure 1). Whilst these areas are under-explored (Hylander, Nemomissa & Hedenäs 2017; Wilding et al. 2016), lower bryophyte diversity in arid areas such as in the Horn of Africa hotspot may further contribute to this outcome. Many African regions, for example in Western Africa (Diop et al. 2018), are much less researched and thus still poorly understood in terms of plant diversity and threats to it. Thus, the detailed picture of the distribution of African bryophyte diversity is likely to change along with increasing knowledge and exploration, but we are confident that some overall patterns are recognisable based on this compilation.

The biodiversity hotspot with the highest number of lost or threatened species, as well as Top 10 species which are at highest risk of extinction in Africa, is Madagascar and the Indian Ocean Islands (Table 1, Figure 1). This hotspot is dominated by Madagascar, the fourth largest island globally, and includes the Seychelles (including Aldabra), the Comoros, Mauritius (including Rodrigues) and the French overseas departments of Réunion, Mayotte (one of the Comoros) and the volcanic Iles Esparses around Madagascar (Figure 1). The island of Madagascar, especially

the eastern lowland rainforests, is known as a global centre of bryophyte diversity and endemism and the most species-rich area of bryophytes in Africa (Geffert et al. 2013; Tan & Pócs 2000; Vanderpoorten & Hallingbäck 2009). It has also been identified as one of two major Lost Spots in Africa, countries where 'lost species', including a few mosses, are concentrated (Global Wildlife Conservation 2014). Agricultural activities, urbanisation, invasive alien species and deforestation have devastated and fragmented habitats, especially in the lowlands, throughout this hotspot (CEPF 2016a). At least one of the endemic bryophyte species from the Seychelles island of Mahé, *Xylolejeunea muricella* Xiao L.He et Grolle, may already be extinct (Online Appendix 1). There is also concern about the recent marked increase in illegal logging in the remaining forests of Madagascar (Green & Sussman 1990; IUCN 2017a).

The second-highest number of lost or threatened species per biodiversity hotspot are found in the Eastern Afromontane hotspot (Figure 1). This hotspot is characterised by a series of montane islands and extensive plateaus along the eastern edge of Africa, from Ethiopia in the north to Zimbabwe in the south. It consists mainly of three ancient massifs: the Eastern Arc Mountains and Southern Rift, the Albertine Rift and the Ethiopian Highlands. Eastern Africa has also been suggested as one of the main centres of bryophyte diversity and endemism in Africa (Geffert et al. 2013; Von Konrat et al. 2008) and Tanzania is another major Lost Spot in the region for a variety of organisms (Global Wildlife Conservation 2014). Degradation and fragmentation of habitats and unsustainable exploitation of natural resources are the main threats in this hotspot (CEPF 2016a). This is caused by expanding agriculture, plantation forestry, logging, fires, invasive alien plants, mining, infrastructure development and gathering of firewood.

A substantial number amongst the lost or threatened bryophytes occur in the southwestern Cape, a region that contains the highest concentration of threatened vascular plants and plants of conservation concern in South Africa (Raimondo & Van Staden 2009). The Fynbos Biome of the Cape Floristic Region biodiversity hotspot is one of the most threatened biomes in southern Africa, classified as critically endangered (Driver et al. 2012). The southwestern Cape has been suggested as a global and regional centre of relatively high bryophyte species richness and endemism (Geffert et al. 2013; Tan & Pócs 2000). In an analysis of moss distributions in southern Africa, Van Rooy and Phephu (2016:29) recognised a Southwestern Cape Centre of Moss Diversity and found that the Cape Town-Table Mountain area is the most species-rich in the region. The Cape Floristic Region is under increasing population pressure and much of the Fynbos and Renosterveld vegetation types of the lowlands have been destroyed or transformed by agriculture and urbanisation (CEPF 2016a; Rebelo et al. 2006; Von Hase et al. 2003). The lowland Renosterveld areas have been identified as top conservation priorities by the Cape Action Plan for the Environment (Von Hase et al. 2003). The remaining Fynbos is threatened by invasive alien species, the disruption of fire regimes, plantation forestry and fragmentation.

Conclusions

This is the first compilation of bryophytes for sub-Saharan Africa and the East African islands that are most probably lost or threatened. Although it is not exhaustive, and many of the 'threat categories' reported herein are in need of revision and require to be scrutinised against the IUCN Red List criteria (IUCN 2012a), it represents a first approximation of the threats to bryophytes in Africa.

The species on the list of lost or threatened bryophytes served as candidates for the selection of the Top 10 species in Africa at high risk of extinction. Therefore, it is a crucial contribution towards the Top 10 Initiative of the IUCN Bryophyte Specialist Group (IUCN SSC 2015) and thus to the (global) IUCN Red List of Threatened Species (IUCN 2017e), as well as towards an assessment of the extinction risk of bryophytes on the African continent. Hence, it is a significant step towards meeting the targets of the Updated Global Strategy for Plant Conservation 2011–2020 (CBD Secretariat 2017) and priorities of The Shenzhen Declaration on Plant Sciences (Crane et al. 2017).

The vast majority of threatened species on our list, and all Top 10 species, are restricted to global biodiversity hotspots in Africa, areas of high endemism of vascular plants under severe threat of habitat loss (CEPF 2016a; Conservation International 2017). Investment in biodiversity conservation through the hotspots concept will therefore benefit threatened African bryophytes as well.

The Madagascar and Indian Ocean Islands biodiversity hotspot, which is also considered as a global centre of bryophyte diversity and endemism (Vanderpoorten & Hallingbäck 2009; Von Konrat et al. 2008), contains a particularly large number of threatened bryophytes. The recent increase in logging poses a serious threat to the remaining forest habitats on Madagascar and other Indian Ocean islands. The Eastern Afromontane and Cape Floristic Region biodiversity hotspots also stand out as hotspots of lost or threatened bryophytes in Africa.

The degradation and fragmentation of forests throughout sub-Saharan Africa and the East African islands have a visible impact on epiphytic bryophytes, epiphyllous liverworts of the family Lejeuneaceae in particular. Bryological exploration of Africa should be stepped up to increase our knowledge of species occurrences and threats and to facilitate the red-listing and the conservation of rare and threatened bryophytes.

Acknowledgements

We would like to thank Tamás Pócs, Frank Müller, Itambo Malombe and Claudine Ah-Peng for their contributions. We are grateful to Hester Steyn and Elizma Fouche for editing the map.

Competing interests

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

Authors' contributions

J.v.R. compiled the species accounts, analysed and interpreted the data and drafted the article. I.B. and A.B. conceptualised and initiated the project 'Top 10 Initiative' and commented on manuscript versions. All the authors contributed to the final version of the article.

References

Ah-Peng, C., Bardat, J., Pócs, T., Söderström, L., Staménoff, P. & Strasbergah, D., 2012, 'Red list of liverworts and hornworts for Réunion (Mascarene archipelago)', *Phytotaxa* 68, 1–23. https://doi.org/10.11646/phytotaxa.68.1.1

Aynekulu, E., Aerts, R., Denich, M., Negussie, A., Friis, I., Demissew, S. et al., 2016, 'Plant diversity and regeneration in a disturbed isolated dry Afromontane forest in northern Ethiopia', *Folia Geobotanica* 51(2), 115–127. https://doi.org/10.1007/s12224-016-9247-y

Benítez, L., Prieto, M. & Aragón, G., 2015, 'Large trees and dense canopies: Key factors for maintaining high epiphytic diversity on trunk bases (bryophytes and lichens) in Tropical Montane forests', *Forestry* 88(5), 521–527. https://doi.org/10.1093/forestry/cpv022

Convention on Biological Diversity Secretariat, 2017, *Updated global strategy for plant conservation 2011–2020*, viewed 16 August 2017, from https://www.cbd.int/gspc/strategy.shtml

Chuah-Petiot, M.S., 2003, *Mosses, liverworts and hornworts of Kenya*: *An illustrated guide with descriptions and figures of over 300 species and keys for identification*, Chuah- Petiot, Nairobi.

Conservation International, 2017, *Hotspots*, viewed 03 January 2017, from https://www.conservation.org/How/Pages/Hotspots.aspx.

Crane, P.R., Ge, S., Yuan, D.-Y., Huang, H.-W., Knapp, S., Mooney, H. et al., 2017, 'The Shenzhen declaration on plant sciences: Uniting plant sciences and society to build a green, sustainable Earth', *Journal of Systematics and Evolution* 55(5), 415–416. https://doi.org/10.1111/jse.12283

Critical Ecosystem Partnership Fund (CEPF), 2016a, *The biodiversity hotspots*, viewed 20 October 2017, from http://www.cepf.net/resources/hotspots/Pages/default.aspx

Critical Ecosystem Partnership Fund (CEPF), 2016b, *About CEPF*, viewed 07 September 2017, from http://www.cepf.net/about_cepf/Pages/default.aspx

De Sloover, J.L. (ed.), 2003, *Illustrations de mousses Africaines*, Scripta Botanica Belgica, National Botanic Garden of Belgium, Meise.

Diop, D., Diop, D., Bruggeman-Nannenga, M.A., Mbaye, M.S., Noba, K., Hedenäs, L. et al., 2018, 'Bryophytes of Kédougou (Eastern Senegal), with a key to the *Fissidens* of Senegal', *Journal of Bryology* 40(1), 62–67. https://doi.org/10.1080/03736687.2017.1415662

Driver, A., Sink, K.J., Nel, J.L., Holness, S.H., Van Niekerk, L., Daniels, F. et al., 2012, *National biodiversity assessment 2011: An assessment of South Africa's biodiversity and ecosystems*, Synthesis Report, South African National Biodiversity Institute & Dept. of Environmental Affairs, Pretoria.

Fischer, E., 2013, 'Liverworts and Hornworts of Rwanda', *Abc Taxa* 14, 552 pp.

Frey, W. & Stech, M., 2009, **'**Marchantiophyta, Bryophyta, Anthocerotophyta', in W. Frey, M. Stech & E. Fischer (eds.), *Syllabus of plant families* 3, 13th edn., pp. 9–259, Schweizerbart, Stuttgart.

Geffert, J.L., Frahm, J.-P., Barthlott, W. & Mutke, J., 2013, 'Global moss diversity: Spatial and taxonomic patterns of species richness', *Journal of Bryology* 35(1), 1–11. https://doi.org/10.1179/1743282012Y.0000000038

Global Wildlife Conservation, 2014, *The search for lost species*, viewed 20 October 2017, from https://www.globalwildlife.org/our-work/regions/global/the-search-for-lost-species/

Goffinet, B., Buck, W.R. & Shaw, A.J., 2009, 'Morphology and classification of the Bryophyta', in B. Goffinet & A.J. Shaw (eds.), *Bryophyte biology*, 2nd edn., pp. 55–138, Cambridge University Press, Cambridge.

Gradstein, S.R., 1992, 'The vanishing tropical rain forest as an environment for bryophytes and lichens', in J.W. Bates & A.M. Farmer (eds.), *Bryophytes and lichens in a changing environment*, pp. 234–258, Clarendon Press, Oxford.

Gradstein, S.R., 1994, *Lejeuneaceae: Ptychantheae, Brachiolejeuneae*, Flora Neotropica Monograph 62, New York Botanical Garden, New York.

Green, G.M. & Sussman, R.W., 1990, 'Deforestation history of the eastern rain forests of Madagascar', *Science* 248(4952), 212–215. https://doi.org/10.1126/science.248.4952.212

Hallingbäck, T. & Hodgetts, N., (compilers), 2000, *Mosses, liverworts, and hornworts. Status survey and conservation action plan for bryophytes*, IUCN/SSC Bryophyte Specialist Group, IUCN, Gland, Switzerland and Cambridge, UK.

Hallingbäck, T. & Tan, B.C., 2010, 'Past and present activities and future strategy of bryophyte conservation', *Phytotaxa* 9, 266–274. https://doi.org/10.11646/phytotaxa.9.1.15

Hylander, K., Nemomissa, S. & Hedenäs, L., 2017, 'Mosses of southwest Ethiopian montane forests – Notes on their occurrence pattern and many new country records', *Journal of Bryology* 39(4), 342–352. https://doi.org/10.1080/03736687.2017.1329793

International Union for Conservation of Nature (IUCN), 2012a, *IUCN red list categories and criteria: Version 3.1*, 2nd edn., IUCN, Gland, Switzerland and Cambridge, UK, viewed 05 December 2017, from http://www.iucnredlist.org/technical-documents/red-list-documents

International Union for Conservation of Nature (IUCN), 2012b, *Guidelines for application of IUCN red list criteria at regional and national levels: Version 4.0*, IUCN, Gland, Switzerland and Cambridge, UK, viewed 05 December 2017, from http://www.iucnredlist.org/technical-documents/red-list-documents

International Union for Conservation of Nature (IUCN), 2017a, *Illegal activities threaten natural World Heritage, pushing the vaquita to the brink and depleting forests*, viewed 10 July 2017, from https://www.iucn.org/news/iucn-41whc/201706/illegal-activities-threaten-natural-world-heritage-pushing-vaquita-brink-and-depleting-forests-%E2%80%93-iucn?dm_i=2GI3,13OT1,40ELQB,3C6Q3,1

International Union for Conservation of Nature (IUCN), 2017b, *IUCN species strategic plan 2013–2016*, viewed 11 October 2017, from https://cmsdata.iucn.org/downloads/2013_2016_species_strategic_plan_final.pdf

International Union for Conservation of Nature (IUCN), 2017c, *Europe: LIFE European red lists*, viewed 19 October 2017, from https://www.iucn.org/regions/europe/projects/life-european-red-lists

International Union for Conservation of Nature (IUCN), 2017d, *SSC Groups: Plants & fungi*, viewed 19 October 2017, from https://www.iucn.org/ssc-groups/plants-fungi

International Union for Conservation of Nature (IUCN), 2017e, *The IUCN red list of threatened species. Version 2017–2*, viewed 23 October 2017, from http://www.iucnredlist.org/

IUCN Species Survival Commission (SSC) (ed.), 2016, 'Annual report of the species survival commission and the global species programme', Bryophyte Specialist Group, *Species* 57, 70–71, viewed 08 November 2017, from https://portals.iucn.org/library/sites/library/files/documents/2017-008.pdf

IUCN Standards and Petition Subcommittee, 2017, *Guidelines for using the IUCN red list categories and criteria,* Version 13, Prepared by the Standards and Petitions Subcommittee, viewed 19 October 2017, from http://cmsdocs.s3.amazonaws.com/RedListGuidelines.pdf

Longton, R.E. & Hedderson, T.A., 2000, 'What are rare species and why conserve them?', *Lindbergia* 25, 53–61.

Magill, R.E., 1981, *Flora of Southern Africa: Bryophyta. Part 1 Mosses. Fascicle 1 Sphagnaceae–Grimmiaceae*, Botanical Research Institute, Pretoria, South Africa.

Magill, R.E., 1987, *Flora of Southern Africa: Bryophyta. Part 1 Mosses. Fascicle 2 Gigaspermaceae–Bartramiaceae*, Botanical Research Institute, Pretoria, South Africa.

Magill, R.E., 2010, 'Moss diversity: New look at old numbers' *Phytotaxa* 9, 167–174. https://doi.org/10.11646/phytotaxa.9.1.9

Magill, R.E. & Van Rooy, J., 1998, *Flora of Southern Africa: Bryophyta. Part 1 Musci. Fascicle 3 Erpodiaceae–Hookeriaceae*, National Botanical Institute, Pretoria.

Malombe, I., 2007, 'Systematics of *Cheilolejeunea* (Spruce) Schiffn. (Lejeuneaceae) in continental Africa and its ecological significance in conservation of Kakamega and Budongo rainforests', PhD thesis, University of Koblenz-Landau, Germany.

Malombe, I., Matheka, K.W., Pócs, T. & Patiño, J., 2016, 'Edge effect on epiphyllous bryophytes in Taita Hills fragmented afromontane forests', *Journal of Bryology* 38(1), 33–46. https://doi.org/10.1179/1743282015Y.0000000015

Marchese, C., 2015, 'Biodiversity hotspots: A shortcut for a more complicated concept', *Global Ecology and Conservation* 3, 297–309. https://doi.org/10.1016/j.gecco.2014.12.008

Mittermeier, R.A., Gil, P.R., Hoffmann, M., Pilgrim, J., Brooks, T., Mittermeier, C.G. et al., 2004, *Hotspots revisited: Earth's biologically richest and most endangered ecoregions*, CEMEX, Mexico City.

O'Shea, B.J., 2005, 'Building a bryological framework – Getting over the threshold', *Journal of the Hattori Botanical Laboratory* 97, 281–285.

O'Shea, B.J., 2006, 'Checklist of the mosses of sub-Saharan Africa', *Tropical Bryology Research Reports* 6, 1–255.

Perold, S.M., 1999, *Flora of Southern Africa: Hepatophyta. Part 1: Marchantiopsida. Fascicle 1: Marchantiidae*, National Botanical Institute, Pretoria.

Pócs, T., 1996, 'Epiphyllous liverwort diversity at worldwide level and its threat and conservation', *Anales del Instituto de Biología, Universidad Nacional Autónoma de México, Serie Botánica* 67(1), 109–127.

Pócs, T. & Tóthmérész, B., 1997, 'Foliicolous bryophyte diversity in tropical rainforest', *Abstracta Botanica* 21(1), 135–44.

Raimondo, D. & Von Staden, L., 2009, 'Patterns and trends in the Red List of South African plants', in D. Raimondo, L. von Staden, W. Foden, J.E. Victor, N.A. Helme, R.C. Turner, et al. (eds.), *Red List of South African plants*, pp. 19–25, *Strelitzia* 25, South African National Biodiversity Institute, Pretoria.

Rebelo, A.G., Boucher, C., Helme, N., Mucina, L. & Rutherford, M.C., 2006, 'Fynbos biome', in L. Mucina & M.C. Rutherford (eds.), *The vegetation of South Africa, Lesotho and Swaziland*, pp. 53–219, *Strelitzia* 19, South African National Biodiversity Institute, Pretoria, South Africa.

Söderström, L., Hagborg, A., Von Konrat, M., Bartholomew-Began, S., Bell, D., Briscoe, L. et al., 2016, 'World checklist of hornworts and liverworts', *PhytoKeys* 59, 1–828. https://doi.org/10.3897/phytokeys.59.6261

Szabó, A. & Pócs, T., 2016, 'New or little known epiphyllous liverworts, XX *Cololejeunea nosykombae* A.Szabó & Pócs sp.nov. from Madagascar', *Journal of Bryology* 38(4), 302–307. https://doi.org/10.1080/03736687.2016.1156357

Tan, B.C. & Pócs, T., 2000, 'Bryogeography and conservation of bryophytes', in A.J. Shaw & B. Goffinet (eds.), *Bryophyte Biology*, pp. 401–448, Cambridge University Press, Cambridge.

Tan, B., Geissler, P., Hallingbäck, T. & Söderström, L., 2000, 'The 2000 IUCN World Red List of Bryophytes', in T. Hallingbäck & N. Hodgetts (compilers), *Mosses, liverworts, and hornworts. Status survey and conservation action plan for bryophytes*, pp. 77–90, IUCN/SSC Bryophyte Specialist Group, IUCN, Gland, Switzerland and Cambridge, UK.

Tropicos.org, Missouri Botanical Garden, viewed 15 November 2017, from http://www.tropicos.org/

Van Rooy, J. & Phephu, N., 2016, 'Centres of moss diversity in southern Africa', *Bryophyte Diversity and Evolution* 38(1), 27–39. https://doi.org/10.11646/bde.38.1.3

Vanderpoorten, A. & Hallingbäck, T., 2009, 'Conservation biology of bryophytes', in B. Goffinet & A.J. Shaw (eds.), *Bryophyte Biology*, 2nd edn., pp. 487–533, Cambridge University Press, Cambridge.

Von Hase, A., Rouget, M., Maze, K. & Helme, N., 2003, *A fine-scale conservation plan for Cape Lowlands Renosterveld: Technical report*, Report CCU2/03, Botanical Society of South Africa, Kirstenbosch.

Von Konrat, M., Hagborg, A., Söderström, L., Mutke, J., Renner, M., Gradstein, S.R. et al., 2008, 'Early land plants today: Global patterns of liverwort diversity, distribution and floristic knowledge', in H.B.B. Mohamed, A. Baki, A. Nasrulhaq-Boyce & P.K.Y. Lee (eds.), *Bryology in the new Millennium*, pp. 425–38, University of Malaya, Kuala Lumpur.

Wigginton, M.J. (ed.), 2004, *E. W. Jones's Liverwort and Hornwort Flora of West Africa*, Scripta Botanica Belgica 30, National Botanic Garden (Belgium), Meise.

Wigginton, M., 2018, 'Checklist and distribution of the liverworts and hornworts of sub-Saharan Africa, including the East African Islands (edition 4, 25 June 2018)', *Tropical Bryology Research Reports* 9, 1–138.

Wilding, N., 2017, 'Three new species of *Entosthodon* Schwägr. (Bryopsida, Funariaceae) from sub-Saharan Africa' *Phytotaxa* 312(1), 103–110. https://doi.org/10.11646/phytotaxa.312.1.8

Wilding, N., Hedderson, T., Ah-Peng, C. & Malombe, T., 2016, *Bryophytes of Kenya's coastal forests: A guide to the common species*, Indian Ocean Commission, Biodiversity Project.

Zartman, C.E., 2003, 'Habitat fragmentation impacts on epiphyllous bryophyte communities in central Amazonia', *Ecology* 84(4), 948–954. https://doi.org/10.1890/0012-9658(2003)084[0948:HFIOEB]2.0.CO;2