SINET: Ethiop. J. Sci., 45(1): 115–124, 2022 ISSN: 0379–2897 (PRINT)
 eISSN: 2520–7997

Date received: August 14, 2021; Date revised: March 28, 2022; Date accepted: April 05, 22
DOI: *https://dx.doi.org/10.4314/sinet.v45i1.10*

Determining regions of higher extinction risk occurrences in South African cycads

Bamigboye Samuel O.

Department of Plant Sciences, Olabisi Onabanjo University, 2002, Ago-Iwoye, Nigeria
Corresponding author: reachtoba@gmail.com

ABSTRACT: Extinction crisis in South African cycads has been very high in recent times. This study used comprehensive distribution records of cycads that occurred in South Africa. The records obtained from the South African national herbarium named South African National Biodiversity Institute (SANBI) through the herbarium sheets were used to determine the regions of higher extinction crisis in South Africa. The threat status of the herbarium taxa was obtained from IUCN 2019 version and was analysed. Threats to these taxa were extracted from IUCN and the numbers of taxa facing each threat were determined to unravel the prominent threats. The herbarium records were used to construct a species distribution map for all the cycads in South Africa and another map for Critically Endangered and Extinct South African cycads. This study revealed that regions of high species richness for South African cycads are not the same as regions with highly threatened and extinct South African cycads. Prominent threats found in this plant group are also the major threats causing extinction crisis in the highly threatened and extinct cycads that occurs in few provinces in South Africa. This study therefore recommends that conservation efforts for South African cycads should be intensified in the hotspots of highly threatened and extinct South African cycads identified in this study to further mitigate extinction crisis of South African cycads.

Key words /phrases: Conservation, Extinction risk, Herbarium records, IUCN categories, Species richness, Threats

INTRODUCTION

Cycads are ancient plants with long evolutionary history dated back to about 300 million years ago (Stevenson, 1990; Klavins *et al.,* 2003; Makhegu, 2007; Crisp and Cook 2011; Davis and Schaefer 2011; Nagalingum *et al.,* 2011). They are members of two recognized plant families which are Cycadaceae, and Zamiaceae (Donaldson, 2003 Rousseau, 2012). The genera represented in Zamiaceae are *Bowenia* Hook ex. Hook f., *Ceratozamia* Brongn., *Dioon* Lindl., *Encephalartos* Lehm., *Lepidozamia* Lehm., *Macrozamia* Miq., *Microcycas* (Miquel) A. DC., *Stangeria* T.Moore, and *Zamia* L., while Cycadaceae has only one genus which is *Cycas* L. (Christenhusz *et al.,*2011). Cycadaceae geographical distribution is along the coast of Africa, Madagascar, and Australasia (Donaldson, 2003; Hill *et al.,* 2003). Zamiaceae is more diverse geographically compared to Cycadaceae with its distribution spanning between North and South America, Australia, and Africa (Donaldson, 2003; Hill *et al.,* 2003).

Although cycad species are found in 59 nations of the world, over 70% of them are represented from Australia, Mexico and South Africa (Stevenson et al. 2003). South Africa contains the third largest number of cycad taxa next to Australia and Mexico (Osborne *et al.,* 2012). There are two cycad genera in South Africa which are *Encephalartos* and *Stangeria* (Osborne *et al.,* 2012). *Encephalartos* contains 37 species represented in South Africa, while *Stangeria* contain only one species represented in South Africa (Osborne *et al.,* 2012).

Cycads are the most threatened plant taxa globally (International Union of Conservation of Nature 2010). Factors threatening their existence include illegal harvest to be traded for horticultural purpose (poaching), harvest for medicinal uses, habitat destruction, invasive species presence in areas of cycad populations (Donaldson, 2003: Hill *et al.,* 2003) and climate change (Yessoufou *et al.,* 2017). These ecological forces have contributed immensely to decline of these endangered species in the past years.

The International Union of Conservation of Nature (IUCN) Red List categories can be used to

evaluate extinction risk in species that their Red List status have been determined based on IUCN assessments (Hoffman *et al.,* 2008; IUCN, 2001; Mace *et al.,* 2008; Rodrigues et al., 2006). This evaluation of extinction risk can guide conservation planning in the area of determining factors contributing to the risk of extinction of threatened species and to what extent these factors are responsible for extinction crisis in certain taxonomic groups (e.g Tingley *et al.,* 2013, 2016). Bamigboye *et al.* (2016) used the IUCN to evaluate extinction risk in African cycads where they discovered an increase in number of African cycads that have gone extinct and also the ones that have become more threatened in between the space of one decade. Some studies have also integrated the IUCN data to evaluate extinction patterns in the Cycadales (e.g Marler and Marler 2015; Mankga andYessofou 2017; Yessoufou *et al.,* 2017).

Herbarium records provide relevant data for many biological research due to information they provide based on taxonomy and geographical locations of plant species (Pyke and Ehrlich 2010; Gairola *et al.,* 2013). These records are used for biodiversity conservation studies in areas of determining species distribution range and regions demanding conservation attention in relation to certain plant taxonomic groups (MacDougall *et al.,* 1998; Greve *et al.,* 2016). Modelling range expansion and contraction of threatened species are also important research that are based on herbarium records (Laidlaw and Forster 2012).

This study combined the herbarium records of all South African cycads from the South African National herbarium with the IUCN Red List to determine region of higher extinction occurrences in South African cycads.

Study Area and Study Species

South Africa is made up of nine provinces which are Eastern Cape, Free State, Gauteng, KwaZulu-Natal, Limpopo, Mpumalanga, Northern Cape, North West and Western Cape (Figure 1). It is a country of high level of floral diversity (Mkwevho, 2014) with many centre of floral endemism (Bamigboye, 2019). But flora extinction risk in South Africa is very high with many vascular plant taxa already at the brink of extinction (Mkwevho, 2014). There are 38 cycad taxa in South Africa which consist of 37 *Encephalartos* spp and 1 *Stangeria* sp. According to IUCN classification of these species, 3 are classified as Extinct in the wild (Ex), 12 are Critically Endangered (CR), 4 are Endangered (EN), 9 are Vulnerable (VU), while 7 are Near Threatened (NT) and 3 are Least Concern (LC) (International Union of Conservation of Nature 2019). All threatened cycads in South Africa are scattered among some provinces but extinct cycads on the geographic range of IUCN are more distinct with these species occurring in only two provinces which are Limpopo and Kwazulu-Natal (Figure 1).

Methodology

Comprehensive herbarium records of 38 South African cycads were obtained from the South African National Biodiversity Institute (SANBI) herbarium. The IUCN status of all the taxa was obtained from the IUCN red list 2019 version. Also the threats to each species were obtained from IUCN red list 2019 version. Percentages of South African cycads facing each threat found on IUCN were calculated. ArcGIS 10.1 was used to construct a species richness map for all the South African cycads using coordinates of all South African cycads obtained from the above-mentioned herbarium database. A map was also constructed using the SANBI records for South African cycads that are Extinct in the wild and Critically Endangered. The reason for focusing on these two categories of South African cycads was to determine the spatial distribution of highly threatened and extinct cycads in South Africa. Extinct in the wild species are taxa that can no longer be found in their natural habitat and also Critical Endangered taxa are the most threatened taxa at the brink of extinction based on IUCN categories. These two groups are good representation of taxa that are experiencing and have experienced higher extinction crisis. The percentages of South African cycads that are critically endangered and that are Extinct in the wild that are facing different categories of threats were calculated. This is to determine the cause of extinction crisis of these extinct and highly threatened (Critically Endangered) South African cycads.

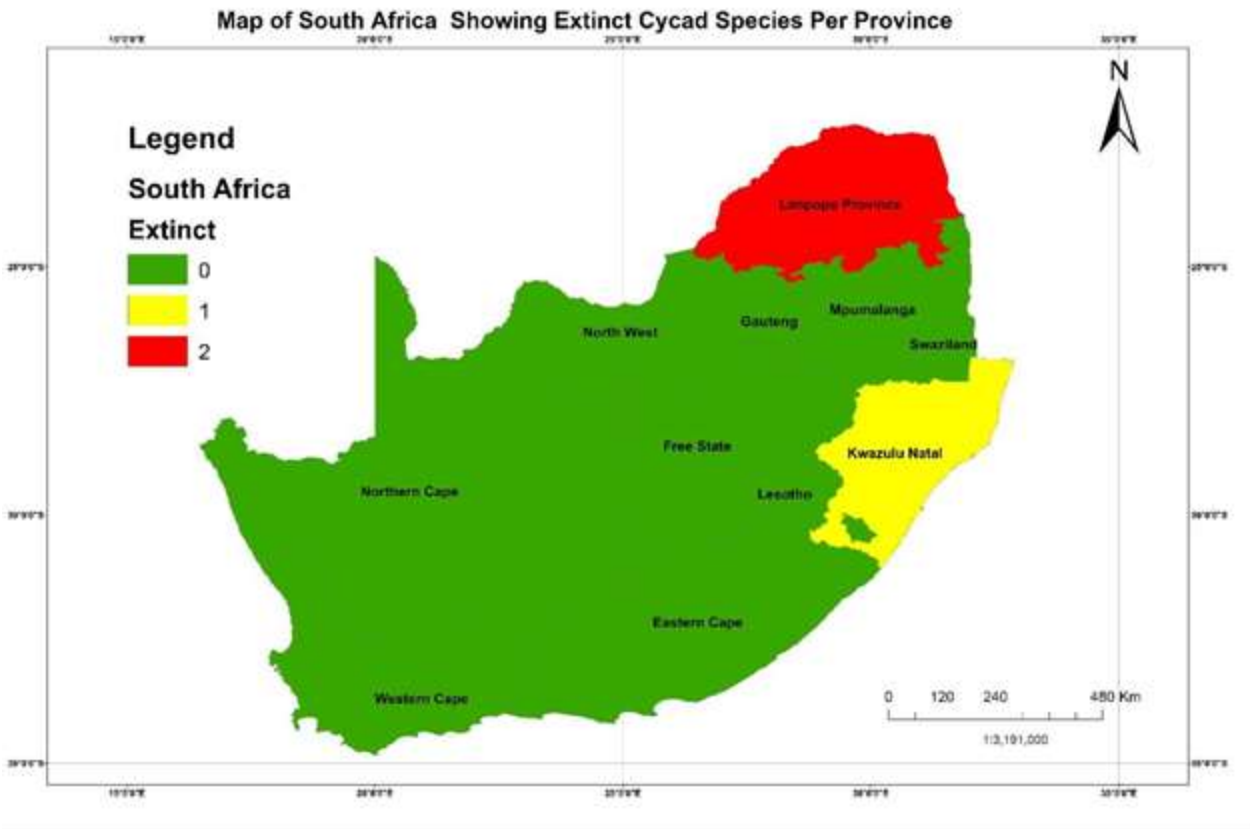
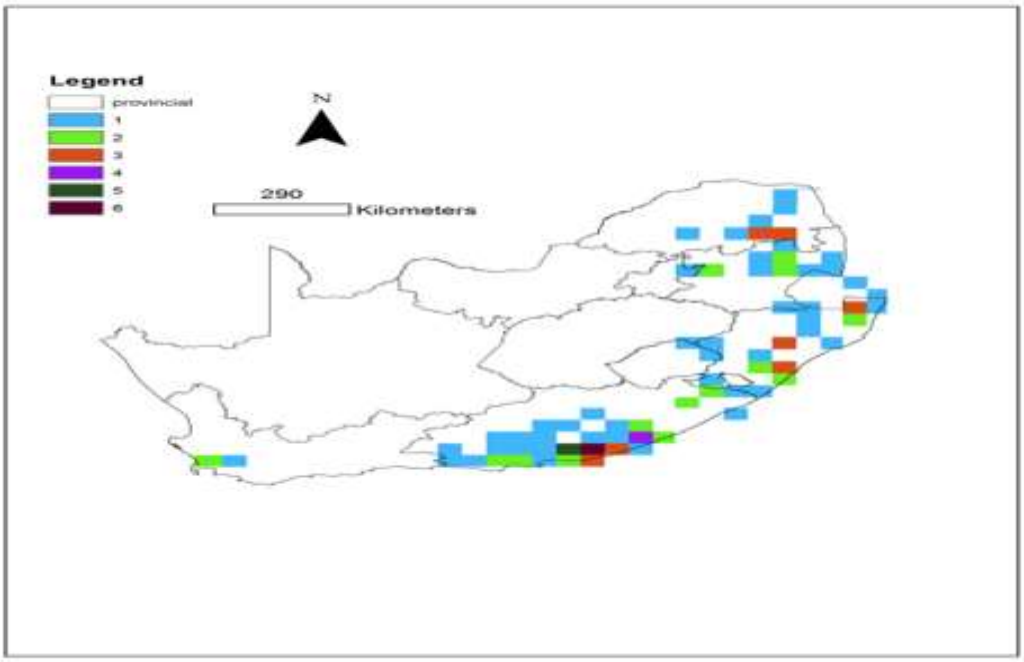


Figure 1. Map showing the number of Extinct in the wild cycad species in South Africa.

RESULTS

A total of 85 records were gotten from the SANBI herbarium for all South African cycads while only 17 records were found for Critically Endangered and Extinct in the wild cycads in South Africa. Species richness map based on herbarium records in South African cycads revealed there are more species record in Eastern Cape decreasing towards Kwazulu-Natal and north to Limpopo Province (Figure 2). But map of the herbarium records of the Critically Endangered and Extinct in the wild cycads showed that these categories of cycads in South Africa are more in Limpopo decreasing down southward direction to Mpumalanga, Gauteng and Kwazulu-Natal with only one record in Eastern-Cape (Figure 3). The two maps constructed showed trends that are in opposite direction in terms of the species records increase (Figure 2 and 3). There are 7 categories of threat to South African cycads obtained from IUCN 2019 version (Figure 4). These are individual's collection from the wild, ornamental uses, uses for medicinal purposes, habitat destruction, reproductive failure, drought and fire occurrences, and damages done to cones, leaves and stems of these plants by animals such as baboons and porcupines (Figure 4). But out of these seven categories, four that are more prominent are individual's collection, habitat destruction, ornamental purpose and reproductive failure (Figure 4). Also the four prominent threats among all South African cycads are also prominent among the extinct and critically endangered South African cycads (Figure 3 and 5). This showed a strong correlation between these prominent threats and extinction crisis in South Africa cycads which occurred at the upper regions in opposite direction to region of high species richness (Figure 3 and 5). It can therefore be inferred that these regions of Extinct and highly threatened (Critically Endangered) South African cycads are more prone to these prominent threats than regions with higher species richness. Vulnerability of these regions to these threats might have made them hotspots of Extinct and the most threatened (Critically Endangered) cycad taxa in South Africa hence becoming regions of cycads higher extinction crisis in South Africa



.

Figure 2: Map of species richness for 38 species of cycads in South Africa using herbarium records (coordinates) from South African National Biodiversity institute (SANBI). All species (colours in legend represent number of species per grid).

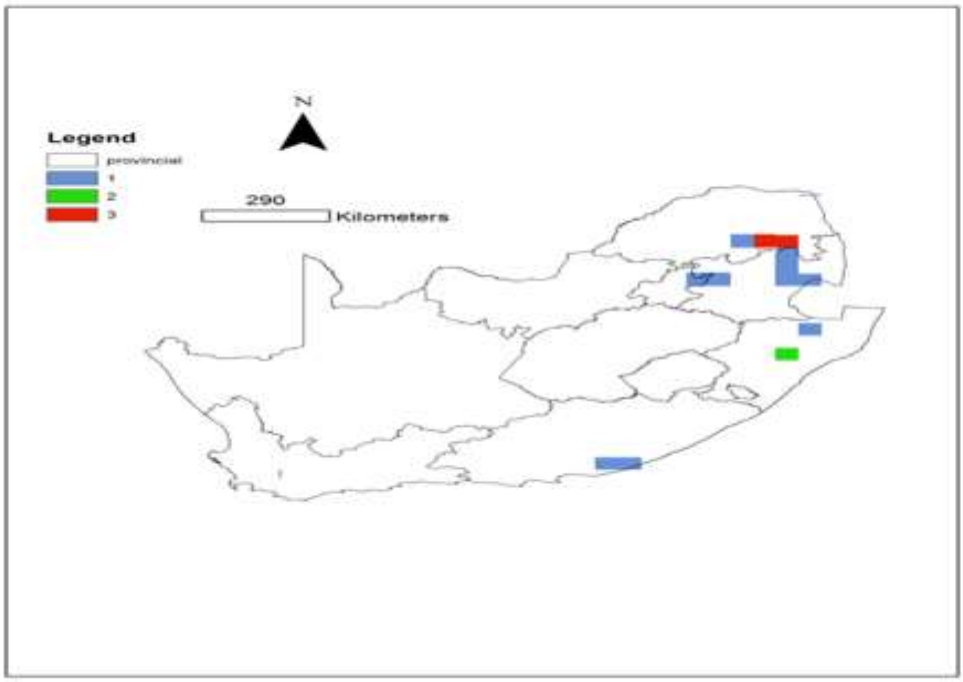


Figure 3: Map showing records for 15 Critically Endangered and Extinct South African cycads using herbarium record from South African National Biodiversity Institute.

DISCUSSION AND CONCLUSION

Cycads are experiencing decline in every regions they occur (Donaldson, 2003; Mankga and Yessoufou 2017: Yessoufou *et al.,* 2017) which makes all taxa in this plant order require conservation efforts to decrease their extinction risk. This same extinction crisis is also posing threats to cycads in South Africa (Bamigboye and Tshisikhawe 2020). Although cycads are threatened everywhere they occur in South Africa, it is important to look at geographic areas where extinction crisis are more concentrated so that this might give directional support to where much efforts is needed to be channelled to decrease extinction crisis in South African cycads in the face of limited conservation resources. Combination of Herbarium records and IUCN Red List for South African cycads revealed that out of nine provinces in South Africa, this study identified three provinces which are Limpopo, Mpumalanga and Kwazulu-Natal as provinces that are experiencing and have experienced higher extinction crisis in South Africa cycads than the rest of the provinces (Figure 2, 3). Limpopo province was detected as the province with the highest extinction crisis in South Africa based on the evidence provided in this study (Figure 3). This correlates with the study of Okubamicheal *et al.* (2016) which detected that the largest decline in South African cycads based on repeated photograph study of cycads population occurred in Limpopo province. It is therefore recommended that conservation of South African cycads be strengthened in Limpopo province than the rest of South African provinces. Minimizing prominent threats (individual's collection, habitat destruction, ornamental purpose and reproductive failure) (Figure 4, 5) identified in this study should be targeted in cycads conservation in Limpopo province than the rest of the provinces in South Africa.

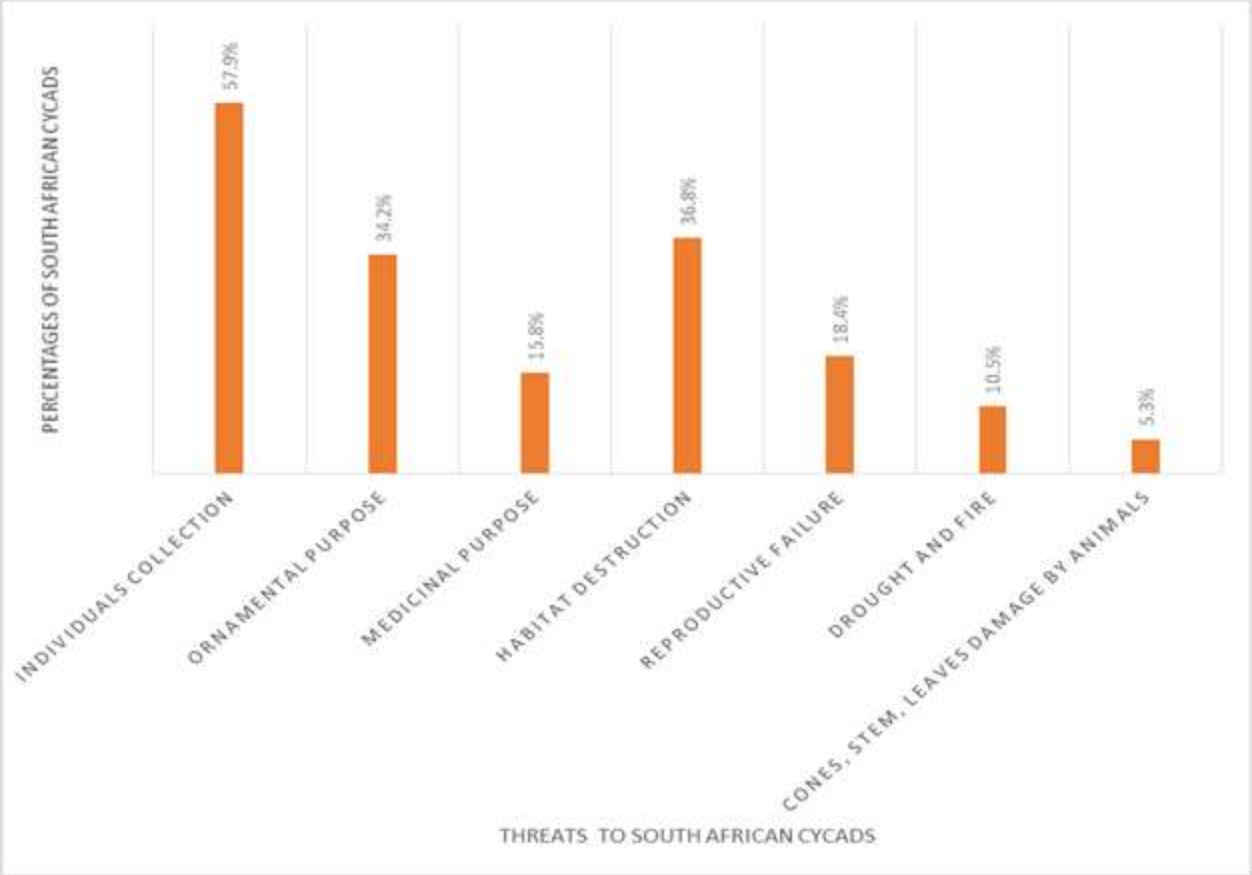


Figure 4: Figure showing percentages of South African cycads facing each threats based on data obtained from IUCN red list 2019 version.

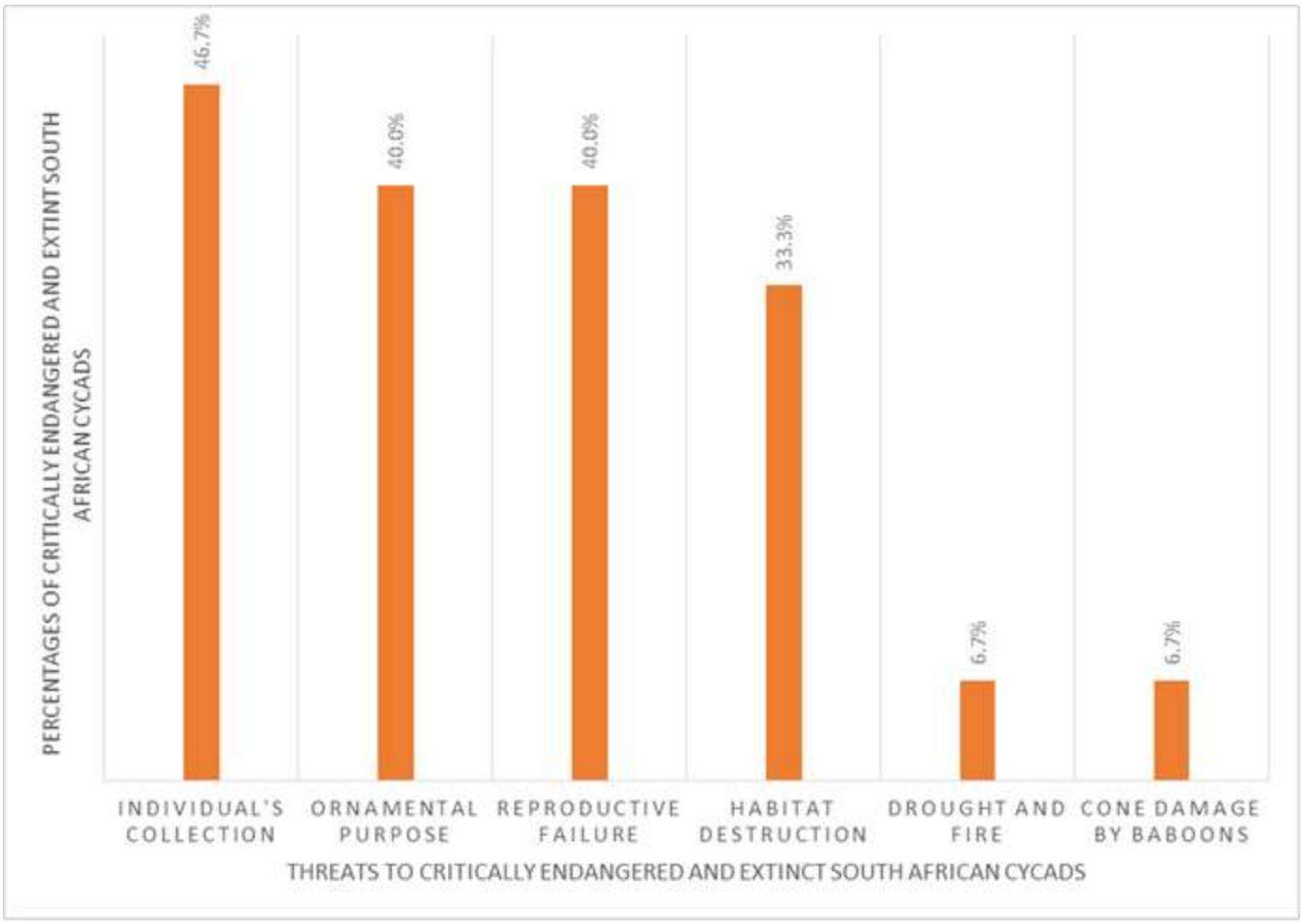


Figure 5. Figure showing percentages of Critically Endangered and Extinct South African cycads facing each threats based on data obtained from IUCN red list 2019 version.

ACKNOWLEDGEMENT

I acknowledge South African National Biodiversity Institute Kristenbosch Garden, Cape Town, South Africa for making the records of cycads distribution in South Africa available for this study through Professor John Donaldson. Also the full support of Professor John Donaldson in person for this project is duly acknowledged and well appreciated.

REFERENCES

1. Bamigboye, Samuel O. and Tshisikhawe, M. (2020).The impacts of bark harvesting on a population of *Encephalartos transvenosus* (Limpopo cycad) in Limpopo Province, South Africa. *Biodiversitas* **21**: 8-13
2. Bamigboye, S.O. (2019). Conservation status and threats to endemic plant species of Griqualand West of South Africa. *Journal of Plant Development.* **26**: 117-121. https://doi.org/ 10.33628 /jpd.2019.26.1.117.
3. Bamigboye, S.O., Tshisikhawe, M.P. and Taylor, P.J. (2016). Review of extinction risk in African cycads. *Phyton International Journal of Experimental Botany* **85**: 333-336.
4. Christenhusz, M.J.M., Reveal, J.L., Farjon A., Gardner, M.F., Mill, R.R. and Chase, M.W. (2011). A new classification and linear sequence of extant gymnosperms. *Phytotaxa* **19**: 55–70.
5. Crisp, M.D. and Cook, L.G. (2011). Cenozoic extinctions account for the low diversity of extant gymnosperms compared with angiosperms. *New Phytologist* **192**: 997-1009.
6. Davis, C.C. and Schaefer, H. (2011). Plant evolution: Pulses of extinction and speciation in Gymnosperm diversity. *Current Biology* **21**: 995-997.

7. Donaldson, J.S. (2003). Status Survey and Conservation Action Plan of Cycads' Edited by International Union of Conservation of Nature and Species Survival Commission Cycads Specialist Group. SSC Specialist group, IUCN. Gland, Switzerland.

8. Gairola, S., Mahmoud, T., Bhatt, A. and El-Keblawy, A.A. (2013). Importance of seed banking and herbarium collections in biodiversity conservation and research: a new initiative in the United Arab Emirates. *Current Science* **101**: 8.

9. Greve, M., Lykke, A.M., Fagg, C.W., Gereau, R.E., Lewis, G.P., Marchant, R., Marshall, A.R., Ndayishimiye, J., Bogaert, J and Svenning, J.C. (2016). Realising the potential of herbarium records for conservation biology. *South African Journal of Botany* **105**: 317-323.

10. Hill, K.D., Chase, M.W., Stevenson, D.W., Hills, H.G. and Schutzman, B. (2003). The families and genera of cycads: A molecular phylogenetic analysis of Cycadophyta based on nuclear and plastid DNA sequences. *Internal Journal of Plant Science* **164**: 933-948.

11. Hoffmann, M. T. M., Brooks, T.M., da Fonseca, G.A.B., Gascon, C., Hawkins, A.F.A.,

12. International Union of Conservation of Nature. (2010). The nature of progress: annual report. https://portals.iucn.org/library/sites/library/files/documents/2011-030.pdf.

13. International Union of Conservation of Nature red list of threatened species (2019) version. Red list categories of *Encephalartos* and *stangeria* species. https://www.iucn.org/

14. Klavins, S.D., Taylor, E.L., Krings, M. and Taylor, T.N. (2003). Gymnosperms from the Middle Triassic of Antarctica: The first structurally preserved cycad pollen cone. *International Journal of Plant Science* **164**: 1007-1020.

15. Laidlaw, M. J. and Forster, P. I., (2012). Climate Predictions Accelerate Decline for Threatened *Macrozamia* Cycads from Australia. *Biology* **1**: 880-894.

16. Mace, G.M., Collar, N.J., Gaston, K.J., Hilton-Taylor, C., Akaya H.R., Leader-Williams, N., Milner-Gulland, E.J. & Stuart S.N.(2008). Quantification of Extinction Risk: IUCN's System for Classifying Threatened Species. *Conservation Biology* **22**(6): 1424–1442.

17. MacDougall, A.S., Loo, J.A., Clayden, S.R., Goltz, J.G. and Hinds, H.R. (1998).Defining conservation priorities for plant taxa in south-eastern New Brunswick, Canada using herbarium records. *Biological Conservation 86*: 325-338.

18. Makhegu, A.M. (2007).Species-level phylogenetic reconstruction of the African cycad genus *Encephalartos* (Zamiaceae). MSc dissertation, University of the Western Cape, South Africa.

19. Mankga, L.T. and Yessoufou K. (2017). Factors driving the global decline of cycad diversity. AoB PLANTS 9: plx022;doi:10.1093/aobpla/plx022

20. Marler, P. N. and Marler, T. E. (2015).An Assessment of Red List Data for the Cycadales. *Tropical Conservation Science* **8(4):** 1114-1125.

21. Mkwevho, P. (2014). Investigating the correlates of extinction risk at regional scale: A case study of the Southern African flora. *Mini-dissertation submitted in fulfilment of the requirements for the degree Magister Scientiae at the Department of Botany and Plant Biotechnology, University of Johannesburg.*

22. Nagalingum, N.S., Marshall, C.R., Quental, T.B., Rai, H.S., Little, D.P. and Mathew, S. (2011).Recent Synchronous Radiation of a Living Fossil. *Science* **334**: 796-799.

23. Okubamichael, D.Y., Jack, S., De Wet B.J., Hoffman, M.T, and Donaldson, J.S. (2016). Repeat photography confirms alarming decline in South African cycads. *Biodiversity Conservation* 25: 2153-2170.

24. Osborne, R., Calonje, M.A., Hill, K.D., Stanberg, L. and Stevenson, D.W. (2012).The world list of Cycads. *Memorial New York Botanical Garden* **106**: 480-510.

25. Rodrigues, S.L., Pilgrim, J.D., Lamoreux, J.F., Hoffmann, M. and Brooks T.M. (2006). The value of IUCN red list for Conservation', *Trends in Ecology Evolution* **21** (2): 71-76.

26. Rousseau, P. 2012. A molecular systematic study of the African endemic cycads. [M.Sc. thesis], Univ. of Johannesburg, Johannesburg, South Africa, 176 p.

27. Pyke, G.H. and Ehrlich, P.R. (2010). Biological collections and ecological/environmental research: a review, some observations and a look to the future. *Biol. Rev.* **85**: 247-266.

28. Stevenson, D.W. (1990). Morphology and Systematics of the Cycadales. *Memorial New York Botanical Garden* **57**: 8-55.

29. Stevenson, D.W., Vovides, A. and Chemnick, J. (2003). Regional overview: New world. In: Donaldon J.S. (ed). Cycads status survey and conservation action plan. *SSC Specialist group, IUCN, Gland, Switzerland and Cambrodge, UK,* pp 31-38.

30. Tingley, R., Meiri S. and David G.C. (2016). Addressing knowledge gaps in reptile conservation. *Biological Conservation.* http://dx.doi.org/10.1016/j.biocon.2016.07.021

31. Tingley, R., Hitchmough, R.A. and Chapple, D.G., (2013). Life-history traits and extrinsic threats determine extinction risk in New Zealand lizards. *Biological Conservation* **165**: 62–68.

32. Yessoufou, K., Daru, B.H., Tafirei, R., Elansary, H.O. and Rampedi, I. (2017). Integrating biogeography, threat and evolutionary data to explore extinction crisis in the taxonomic group of cycads. *Ecology and Evolution 7:2735*–2746.

Table 1. Showing the list of total number of South African cycads obtained from SANBI records, their IUCN status and their threats on IUCN.

Species	IUCN Status 2019 version	Threats to South African cycads on IUCN for each species obtained from IUCN 2019 version
Encephalartos aemulans Vorster	Critically Endangered	Illegal collection of individuals.
Encephalartos altensteinii Lehm	Vulnerable	Habitat destruction, Illegal collection of individuals, harvest for medicinal purposes.
Encephalartos arenarius R.A.Dyer	Endangered	Illegal collection of individuals, habitat destruction.
Encephalartos brevifoliolatus Vorster	Extinct in the wild	Illegal collection of individuals.
Encephalartos caffer (Thunb.) Lehm.	Near Threatened	Habitat destruction, Ornamental use.
Encephalartos cerinus Lavranos & D.L.Goode	Critically Endangered	Ornamental use, reproductive failure.
Encephalartos cupidus R.A.Dyer	Critically Endangered	Ornamental use, drought and fire, reproductive failure.
Encephalartos cycadifolius (Jacq.) Lehm.	Least Concern	Cone and newly emerged leaves damage by baboons and porcupines, Fire occurrences.
Encephalartos dolomiticus Lavranos & D.L.Goode	Critically Endangered	Illegal collection of individuals.
Encephalartos dyerianus Lavranos & D.L.Goode	Critically Endangered	Reproductive failure.
Encephalartos eugene-maraisii Verd.	Endangered	Ornamental use, reproductive failure.
Encephalartos ferox G.Bertol.	Near Threatened	Ornamental use, habitat destruction.
Encephalartos friderici-guilielmi Lehm.	Near Threatened	Ornamental use, use for traditional medicine.
Encephalartos ghellinckii Lem.	Vulnerable	Ornamental use, fire occurrences.
Encephalartos heenanii R.A.Dyer	Critically Endangered	Ornamental use, habitat destruction, reproductive failure.
Encephalartos hirsutus P.J.H. Hurter	Critically Endangered	Ornamental use.
Encephalartos horridus (Jacq.) Lehm.	Endangered	Illegal collection of individuals, habitat destruction.
Encephalartos humilis Verd.	Vulnerable	Ornamental use.
Encephalartos inopinus R.A. Dyer	Critically Endangered	Illegal collections of individuals, cone damage due to presence of baboons.
Encephalartos laevifolius Stapf & Burtt Davy	Critically Endangered	Use for traditional medicine, Ornamental use, habitat destruction.
Encephalartos lanatus Stapf & Burtt Davy	Near Threatened	Habitat destruction.
Encephalartos latifron Lehm.	Critically Endangered	Illegal collection of individuals, habitat destruction.
Encephalartos lebomboensis Verd.	Endangered	Illegal collection of individuals, traditional medicine use, habitat destruction.
Encephalartos lehmannii Lehm.	Near Threatened	Drought, illegal collection of individuals, Stem leaves destruction by porcupines and goats.
Encephalartos longifolius (Jacq.) Lehm.	Near Threatened	Illegal collection of individuals.
Encephalartos Middleburgensis Vorster, Roobbertse & S.van der Westh	Critically Endangered	Illegal collection of individuals, habitat destruction, fire occurrences, reproductive failure.
Encephalartos msinganus Vorster	Critically Endangered	Ornamental use, habitat destruction, reproductive failure.

Encephalartos natalensis R.A.Dyer & Verdoorn	Near Threatened	Illegal collection of individuals, use for traditional medicine.
Encephalartos ngoyanus Verd.	Vulnerable	Illegal collection of individuals, fire occurrences.
Encephalartos nubimontanus P.J.H. Hurter	Extinct in the wild	Illegal collection of individuals.
Encephalartos paucidentatus Stapf & Burtt Davy	Vulnerable	Illegal collection of individuals, habitat destruction.
Encephalartos princeps R.A. Dyer	Vulnerable	Illegal collection of individuals, habitat destruction.
Encephalartos senticosus Vorster	Vulnerable	Illegal collection of individuals.
Encephalartos transvenosus Stapf & Burtt Davy	Least Concern	Illegal collection of individuals, habitat destruction.
Encephalartos trispinosus (Hook.) R.A.Dyer	Vulnerable	Illegal collection of individuals.
Encephalartos villosus Lem.	Least Concern	Ornamental use, habitat destruction.
Encephalartos woodii Sander	Extinct in the wild	Illegal collection of individuals.
Stangeria eriopus (Kunze) Baill.	Vulnerable	Illegal collection of individuals, habitat destruction, use for traditional medicine.