

Rediscovery of the waterlily *Nymphaea thermarum* Eb. Fisch. in Rwanda

THOMAS ABELI^{*1,2,3} , SARAH MARIE MÜLLER⁴  and SIEGMAR SEIDEL⁴ 

Abstract *Nymphaea thermarum* Eb. Fisch. (family Nymphaeaceae) is a small waterlily endemic to Rwanda that has been categorized as Extinct in the Wild since 2010. We report the rediscovery of *N. thermarum* in July 2023, not far from its locus classicus, identify the current and potential threats to the wild population (mining and overharvesting by collectors, respectively) and recommend the urgent conservation measures and research required to save the species from extinction. The species occupies small muddy ditches fed by hot spring water used for avocado plantations and fish pools. The population comprises hundreds of individuals, including reproductive adult plants, and seedlings. In the short term, conservation actions should include land protection, negotiation to ensure that sufficient water is reaching the habitat of *N. thermarum* and the reassessment of the species on the IUCN Red List, probably as Critically Endangered. In the medium term, the creation of a nature reserve, the restoration of the areas already affected by mining, and the reintroduction of *N. thermarum* to its original site would support long-term in situ conservation of the species. Further research should clarify the total and effective population size, population structure, ecology and genetics of this species.

Keywords Conservation measures, East Africa, Extinct in the Wild, *Nymphaea thermarum*, rediscovery, threat assessment, waterlily, wetlands

According to the IUCN Red List Categories and Criteria (IUCN, 2012), species categorized as Extinct in the Wild are those that survive only under human care in ex situ facilities or naturalized outside their native range. Although ex situ facilities such as botanic gardens and seed banks limit plant species extinctions (Abeli et al., 2020), there are several problems associated with long-term ex situ cultivation that make the reintroduction of Extinct in the Wild species difficult (i.e. low genetic diversity, inbreeding and adaptation to ex situ conditions; Ensslin & Godefroid,

2020; Tremblay et al., 2022). As a result of these problems, and combined with the probable destruction or degradation of their original habitats, the rediscovery of species that are Extinct in the Wild has a significant impact on their conservation because it facilitates the coupling of ex situ and in situ conservation, including site protection, wild population reinforcement and revitalization of ex situ collections with new genetic material from the wild (Smith et al., 2023).

Nymphaea thermarum Eb. Fisch. (family Nymphaeaceae) is a small, iconic waterlily endemic to southern Rwanda that has become a model for the study of the evolution of early angiosperms (Povilus et al., 2020). The species was discovered and described in 1987 by Eberhard Fischer (Fischer, 1988; Fischer & Magdalena, 2011) near the Mashyuza hot spring in the area of Nyakabuye, Rusizi District. *Nymphaea thermarum* was last seen in its original site in 2008, and attempts to find it in the wild since then have been unsuccessful, leading to its categorization as Extinct in the Wild on the IUCN Red List in 2010 and 2019 (Juffe, 2010; Fischer et al., 2019). The species was initially cultivated and propagated at the Botanic Gardens of the University of Bonn, Germany, from several plants collected at the time of discovery, and it is currently cultivated in at least 13 botanical gardens (BGCI, 2023).

On 29 July 2023, authors TA and SMM, and Jean Marie Habiyaakare, visited the area of the Mashyuza hot spring and found *N. thermarum* in a new site west of its original location, on private land (Plate 1). Given the interest of collectors and waterlily enthusiasts for this species (which is sold on the horticultural market for c. EUR 500/plant) the exact location of the discovered population is not provided here, and will not be disclosed until protection measures are established. On 29 August 2023, author SS visited the site and completed preliminary observations on the population status of *N. thermarum*.

We found *N. thermarum* in small ditches and ponds in an area currently occupied by small plantations of banana, mango and avocado, and fishponds. We assessed the population to be healthy and to comprise hundreds of individuals, including reproductive adult plants, and seedlings (Plate 1). The area occupied by the species is c. 4,600 m².

There are serious and imminent threats to this wild *N. thermarum* population. Mining by a local cement factory (the property of which is c. 10 m from a group of *N. thermarum*) is the most significant threat, and the mining has already affected the population directly through excavations and road development and indirectly through impacts on the springs feeding the ditches and ponds where the species

*Corresponding author, thomas.abeli@uniroma3.it

¹Department of Science, Roma Tre University, Rome, Italy

²IUCN Species Survival Commission Conservation Translocation Specialist Group

³IUCN Species Survival Commission Freshwater Plant Specialist Group

⁴Rwanda Centre and Office for Africa Cooperation, University of Koblenz, Koblenz, Germany

Received 12 September 2023. Revision requested 15 November 2023.

Accepted 30 November 2023. First published online 21 February 2024.

This is an Open Access article, distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike licence (<http://creativecommons.org/licenses/by-nc-sa/4.0/>), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the same Creative Commons licence is used to distribute the re-used or adapted article and the original article is properly cited. The written permission of Cambridge University Press must be obtained prior to any commercial use.



PLATE 1 The rediscovery of *Nymphaea thermarum* in Rwanda: (a) a wild flowering individual, (b) *N. thermarum* along ditches, (c) adults and seedlings in a muddy fishpond, and (d) part of the team that rediscovered the species. Photos: Thomas Abeli, 29 July 2023.

grows. Potentially, local or foreign collectors might over-harvest the species given its high market value.

Although *N. thermarum* has not yet been reassessed for the IUCN Red List, it is likely to be categorized as Critically Endangered (IUCN, 2012) under Criterion B, considering its area of occupancy of $< 4 \text{ km}^2$, extent of occurrence of $< 100 \text{ km}^2$, the single location and the observed and projected continuing declines in extent of occurrence, area of occupancy, quality of habitat and number of mature individuals (IUCN, 2012).

Urgent conservation measures are required to ensure this population of *N. thermarum* is not extirpated. In the short term it will be important to: (1) protect and/or purchase land, especially in relation to the expansion of the mining site (investigations to identify the owners of the land where *N. thermarum* grows are in progress); (2) negotiate with the cement factory to ensure that sufficient water reaches the habitat of *N. thermarum*; and (3) reassess the species with the IUCN Red List Categories and Criteria to update its status from Extinct in the Wild to Critically Endangered, to prevent out-of-date information hampering prioritization of conservation measures for the species (Abeli et al., 2022). This reassessment is underway.

In the medium term it will be important to: (1) create a plant micro-reserve (sensu Laguna et al., 2013) or include the site of *N. thermarum* in the Mashyuza Natural Forest; (2) restore the areas already affected by mining in collaboration with the local cement factory and develop a ditch system for irrigation of the fishponds, providing benefits for both local farmers and the species; (3) reintroduce *N. thermarum* to its original site near the main Mashyuza hot spring pool; (4) propose to the Government of Rwanda the inclusion of *N. thermarum* in CITES Appendix II, which would guarantee the protection of the species and potentially allow local farmers to cultivate and trade it

(this species is in demand as an ornamental plant because of its small overall size and large flowers, and it can be grown out of water, on wet soil); (5) genetically revitalize existing ex situ collections with seeds from the wild population; and (6) create a new ex situ collection of the species in Rwanda for conservation and awareness purposes.

In addition to these urgent conservation actions, research is needed, and is being planned, to clarify aspects of the biology and ecology of *N. thermarum* that could inform conservation decisions, including the total and effective population size, population structure, abiotic factors influencing occurrence, natural vegetation dynamics of the wild site, pollination biology and population genetics of the wild and ex situ populations. All stakeholders (i.e. Rwandan governmental authorities, local community members, landowners, private companies working in the area and conservation biologists) now need to collaborate to conserve the rediscovered wild population of this iconic species.

Author contributions Study design, fieldwork: all authors; writing: TA, SS.

Acknowledgements We thank Jean Marie Habiakare (Cyamudongo Project of the University of Koblenz) for facilitating communication with local community members, and the local community (including The King of Water) for the information and assistance that led to the rediscovery of *N. thermarum*.

Conflicts of interest None.

Ethical standards This research abided by the Oryx guidelines on ethical standards. The rediscovery of *N. thermarum* was the result of a visit to the destroyed, original habitat of the species, which is known from the literature. The incidental discovery was neither planned nor was it the intention of the field visit. No plant material was removed, and private plots were entered with the permission of the local community, who also helped find the species. As of 4 September 2023, the Ministry of Environment of Rwanda has been

informed of the rediscovery, the local authority has been involved and information was shared prior to the writing and publication of this article. The site lies within a research area that is the subject of a bilateral agreement between the University of Koblenz and several Rwandan governmental institutions.

Data availability All disclosable data are reported here. The exact location of the wild population of *N. thermarum* is not disclosed, to protect the species from collectors.

References

- ABELI, T., DALRYMPLE, S., GODEFROID, S., MONDONI, A., MÜLLER, J.V., ROSSI, G. & ORSENIGO, S. (2020) Ex situ collections and their potential for the restoration of extinct plants. *Conservation Biology*, 34, 303–313.
- ABELI, T., SHARROCK, S. & ALBANI ROCCHETTI, G. (2022) Out-of-date datasets hamper conservation of species close to extinction. *Nature Plants*, 8, 1370–1373.
- BGCI (2023) *PlantSearch*. Botanical Gardens Conservation International, Richmond, UK. plantsearch.bgci.org [accessed 4 September 2023].
- ENSSLIN, A. & GODEFROID, S. (2020) Ex situ cultivation impacts on plant traits and drought stress response in a multi-species experiment. *Biological Conservation*, 248, 108630.
- FISCHER, E. (1988) Beiträge zur Flora Zentralafrikas I. Eine neue *Nymphaea* sowie ein neuer *Streptocarpus* aus Rwanda. *Feddes Repertorium*, 99, 385–390.
- FISCHER, E. & MAGDALENA RODRIGUEZ, C. (2011) 690. *Nymphaea thermarum* Nymphaeaceae. Plant in peril. *Curtis's Botanical Magazine*, 27, 318–327.
- FISCHER, E., NTORE, S., NSHUTIYAYESU, S., LUKE, W.R.Q., KAYOMBO, C., KALEMA, J. et al. (2019) *Nymphaea thermarum*. In *The IUCN Red List of Threatened Species* 2019. dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T185459A103564869.en.
- IUCN (2012) *IUCN Red List Categories and Criteria: version 3.1, second edition*. IUCN Species Survival Commission, Gland, Switzerland. portals.iucn.org/library/node/10315 [accessed January 2024].
- JUFFE, D. (2010) *Nymphaea thermarum*. In *The IUCN Red List of Threatened Species* 2010.
- LAGUNA, E., BALLESTER, G. & DELTORO, V. (2013) Plant micro-reserves (PMRs): origin and technical concept. In *Plant Micro-Reserves: From Theory to Practice: Experiences Gained from EU LIFE and Other Related Projects* (eds C. Kadis, C.A. Thanos & E.L. Laguna), pp. 3–12. Utopia Publishing, Athens, Greece.
- POVILUS, R.A., DACOSTA, J.M., GRASSA, C., SATYAKI, P.R., MOEGLEIN, M., JAENISCH, J. et al. (2020) Water lily (*Nymphaea thermarum*) genome reveals variable genomic signatures of ancient vascular cambium losses. *Proceedings of the National Academy of Sciences of the United States of America*, 117, 8649–8656.
- SMITH, D., ABELI, T., BRUNS, E.B., DALRYMPLE, S.E., FOSTER, J., GILBERT, T.C. et al. (2023) Extinct in the wild: the precarious state of Earth's most threatened group of species. *Science*, 379, eadd2889.
- TREMBLAY, R.L., ALICEA-ROMAN, P.A., ANAYA-REYES, A., DUCLERC-RODAS, S. & MEDINA-TIRADO, I. (2022) Evidence of artificial selection: are orchids in cultivation an effective ex situ conservation strategy? *Lankesteriana*, 22, 263–284.