Extinct in the Wild omits seed banks from the IUCN Red List

Sarah Dalrymple[1] & Thomas Abeli[2]

[1]School of Natural Sciences & Psychology, Liverpool John Moores University, Byrom Street, Liverpool, L3 3AF, United Kingdom

[2] Department of Science, University of Roma Tre, Viale Guglielmo Marconi, 446, 00146 Roma, Italy

Extinct, or *just* Extinct in the Wild? Plants lost from *in situ* habitat but represented in seed banks are currently labelled as extinct despite the potential for restoration. A change in the IUCN Red List definition of Extinct in the Wild is needed to improve the status and prospects for some of our most threatened plant species.

The IUCN Red List is inconsistent in its treatment of seeds: *in situ,* seeds are recognised as "immature individuals" capable of maintaining a species in habitat and avoiding extinction even when all plants have died[1], and yet in *ex situ* facilities, seeds are not afforded the same status. Instead, plant taxa extirpated from the wild are classified as Extinct (EX)[2] even when the existence of good quality seed collections make future *in situ* restoration possible. A further discrepancy arises within *ex situ* conservation when plant taxa are formally recognised as absent from *in situ* habitat – if taxa are only represented by collections of plants in botanic gardens, Red List assessment results in a classification of Extinct in the Wild (EW), but if the taxa is reduced to seeds in *ex situ* seed banks, it will be declared EX. This situation can be attributed to the development of EX and EW categories preceding recent advances in *ex situ* seed and gene banking, but Red Listing guidelines must be updated to reflect the many advantages of seed banking over living collections. We recommend that the IUCN Red List category of EW is changed to reflect modern seed banking practice as described by the minimum requirements of the Millennium Seed Bank (MSB) Partnership[3] and explicitly acknowledge that properly stored viable seeds and spores (seeds hereafter) have the same status as cultivated plants (Box 1). This will necessitate the reclassification of EX plant species currently held as collections in the global seed bank network. The species that are reclassified as EW will benefit from improved eligibility for resources and higher profile than those consigned to EX and consequently delisted from frameworks directing conservation action. *Ex situ* plant conservation can then be better employed to avoid full extinctions and resources more effectively allocated.

Box 1: The IUCN categories of Extinct and Extinct in the Wild[2]

EXTINCT (EX)

A taxon is Extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

EXTINCT IN THE WILD (EW)

[Proposed additional wording is indicated by bold font.]

A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range. **For plants and fungi, this category can also be applied when the taxon is represented by viable seeds or spores in adequate storage facilities.** A taxon is presumed Extinct in the Wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.

Seed banks and their growing role in conservation

There is no technical reason why a species should go extinct[4]; in addition to *in situ* management options, a variety of facilities can deliver *ex situ* plant conservation according to the needs of the species - living collections are cultivated in botanic gardens (including nurseries and arboreta), whilst viable genetic material can be stored in gene and seed banks, and occasionally found in herbaria. Such facilities, collectively referred to as 'seed banks', are engaged in collecting and storing seeds from wild-growing individuals and are now in 74 countries with nearly 57000 taxa conserved as seed[5,6]. There are significant challenges in conserving seed for perpetuity but protocols exist to ensure minimum standards in collection, storage, distribution and data management are met[6]. Consequently, it is possible to judge whether a species is effectively stored in *ex situ* facilities as seeds and if these might support future restoration projects.

Adherence to these protocols elevates seed banking above living plant collections because secure seed stores can overcome some of the disadvantages of cultivation. These disadvantages include genetic diversity loss and relatively rapid adaptation to *ex situ* conditions, pathogen transfer, hybridisation and lack of conservation coherence[7]. In contrast, seed banking can store species with orthodox (desiccation-tolerant) seeds at high densities, reducing costs and facilitating better genetic representation from across a species' range, and importantly, most seed accessions can last longer than the lifespan of individual plants[4]. A further advantage is the ability to store species that are extremely difficult to be kept in cultivation such as parasitic species which must be grown with a host[8]. Whilst we acknowledge that seed banking is not a solution for all threatened plants (such as those with recalcitrant, or desiccation-sensitive, seeds[9]), the many benefits commend it as a valuable tool in modern plant conservation for an estimated 60% of threatened plants[10].

Change of IUCN extinction categories

These advances in seed banking have rendered the IUCN Red List categories of EX and EW as inaccurate with respect to the role of seeds in *ex situ* conservation. Viable seeds store genetic material, sometimes for extremely long time periods[11,12] (and to a lesser extent, spores do the same[13]), and autonomously initiate regeneration by germinating in response to favourable environmental cues. Consequently, these "immature individuals" feature in several sections of IUCN's Red Listing Guidance where seed dispersal through space, or persistence through time in a soil seed bank, are acknowledged as important roles in population survival, sometimes when all mature individuals have died[1]. If the IUCN's Red Listing guidance acknowledges the population-level role of seeds *in situ* (Fig. 1), then seeds in *ex situ* facilities should be treated similarly. In other words, the existence of viable seeds in *ex situ* seed banks is equivalent to keeping plants in botanic gardens, or animals in zoos and aquaria.

Seeds in *ex situ* facilities currently have no formal recognition in IUCN Red Listing; guidance for the application of Red List categories[2] makes no mention of 'seed' or 'seeds' at all. Our recommendation, that the IUCN Red List categories treat seeds consistently, regardless of their *in*- or *ex situ* status (Fig. 1), would necessitate a change in the IUCN definition of 'extinct in the wild' with consequences for species currently classified as extinct but held in seed banks.

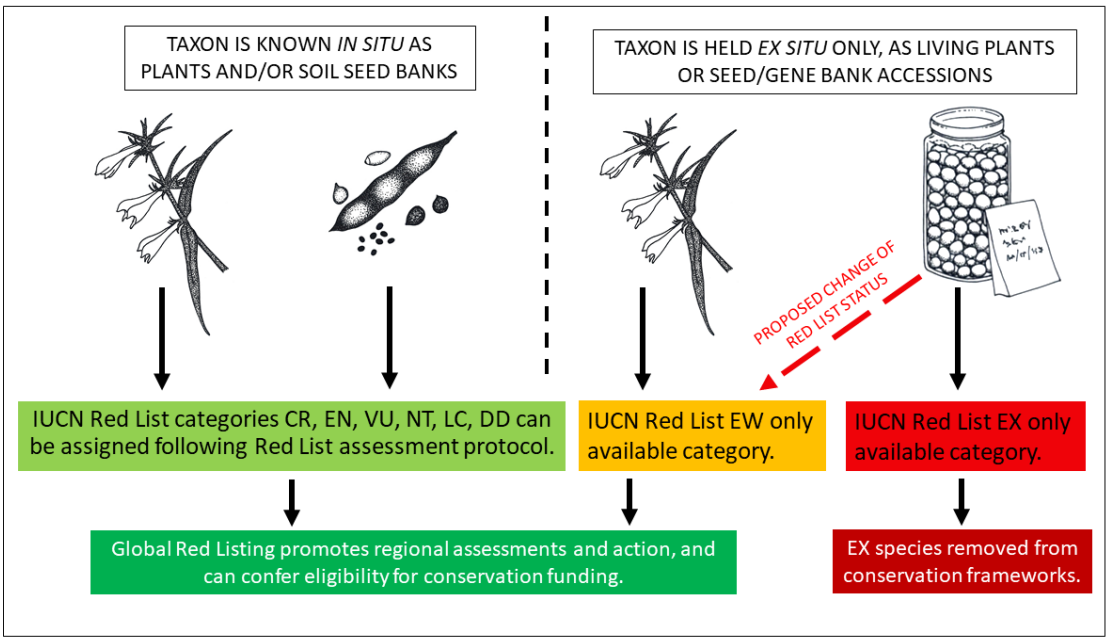

Figure 1. Inconsistent treatment of seeds in the application of the IUCN Extinct (EX) and Extinct in the Wild (EW) categories depending on *in situ* or *ex situ* status of taxon. Black arrows indicate the current implications for species conservation. Red arrow indicates implications of changing the IUCN Red List category of Extinct in the Wild to include seed accessions.

Guidelines for classification of extinct in the wild

If our recommendations are adopted by the IUCN, then species classed as EX, but with good stores of viable seeds in *ex situ* facilities, should be reclassified as EW. 'Good stores' might be defined using existing protocols of best practice such as those developed by the MSB Partnership[3]. In practice, EW should be applied when we: i) are certain there are no individuals *in situ*; ii) have confidence that seeds are stored in conditions that maintain viability over defined time periods and iii) that the

combined holdings of seed are deemed big enough to undertake species restoration either as direct conservation translocation of seed or by growing in cultivation before translocating whole plants to *in situ* habitat. Each of these requirements will be subject to species-specific metrics.

For the 500 species that are regionally or globally extinct but also kept in seed banks[5], a change in Red List status is likely to have beneficial impacts – instead of being consigned to extinction and forgotten, the status of EW makes them eligible for conservation action. By cross-referencing the BGCI PlantSearch[14] with the IUCN Red List[15] we have determined that there are eight species currently classified as globally EX but held *ex situ* that would be reclassified under our recommendations. There are also implications for plant taxa listed as critically endangered (CR; 2722 taxa in the current global Red List); in the case of complete loss from the wild, the existence of seed bank accessions would mean that EW is the next categorisation level rather than progressing directly to full extinction. Precedent exists for reclassification: *Diplotaxis siettiana* was declared extinct in 1998 after seeds were collected and stored at the Agronomists College of Madrid. These seeds formed the basis of a reintroduction and the species is now listed as critically endangered (CR)[16]. *Bromus bromoideus* was declared EX around 1930[17] and all but forgotten until the seeds were discovered by chance in *ex situ* facilities. They were grown successfully and there are now several populations in cultivation resulting in a revised Red List status of EW.

According to Akçakaya et al., "extinct is a well-defined state"[18], but we have demonstrated that the definition is not so clear-cut when referring to highly threatened plant taxa. For many species, *ex situ* seed banks might be the last resort but their classification as EX presents a bureaucratic barrier to any meaningful attempts at species restoration. Seed banks represent a significant conservation resource that are being overlooked and undervalued in current conservation frameworks, but when Red List categories are brought into line with current practice, we will not only reclassify current EX species and unlock the possibility of their restoration, but also avoid many more extinctions in the future.

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