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### Article

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

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7

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

12

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

Box 1: The IUCN categories of Extinct and Extinct in the Wild<sup>2</sup>

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.

32

33 **Seed banks and their growing role in conservation**

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

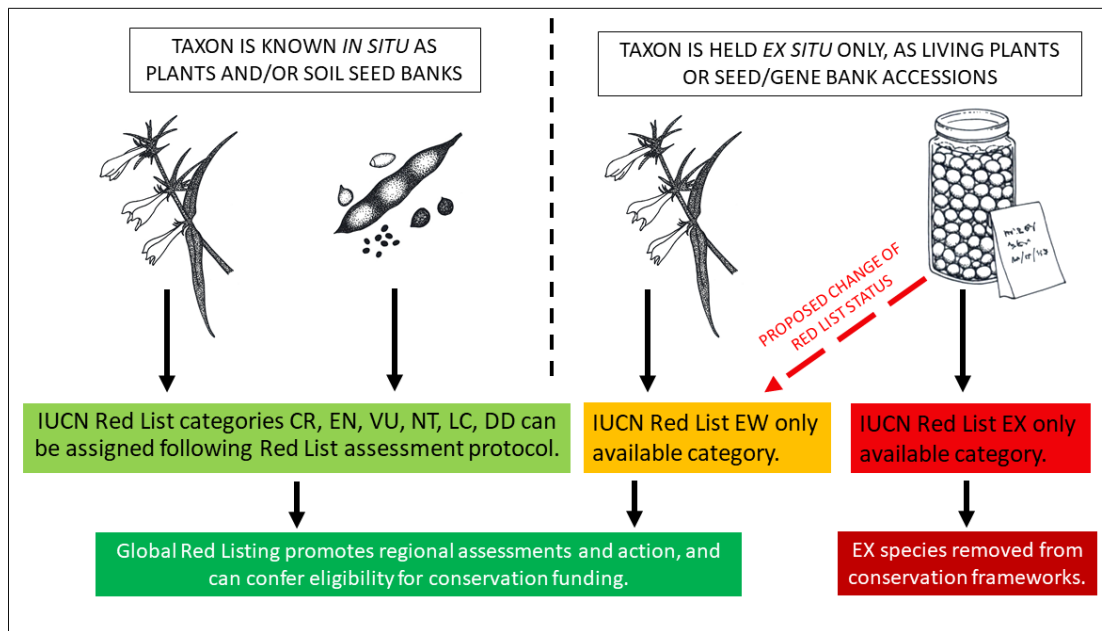
44 Adherence to these protocols elevates seed banking above living plant collections because secure  
45 seed stores can overcome some of the disadvantages of cultivation. These disadvantages include  
46 genetic diversity loss and relatively rapid adaptation to *ex situ* conditions, pathogen transfer,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

55

56 **Change of IUCN extinction categories**

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

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



73

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

78

79 **Guidelines for classification of extinct in the wild**

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

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

88 For the 500 species that are regionally or globally extinct but also kept in seed banks<sup>5</sup>, a change in  
89 Red List status is likely to have beneficial impacts – instead of being consigned to extinction and  
90 forgotten, the status of EW makes them eligible for conservation action. By cross-referencing the  
91 BGCI PlantSearch<sup>14</sup> with the IUCN Red List<sup>15</sup> we have determined that there are eight species  
92 currently classified as globally EX but held *ex situ* that would be reclassified under our  
93 recommendations. There are also implications for plant taxa listed as critically endangered (CR;  
94 2722 taxa in the current global Red List); in the case of complete loss from the wild, the existence of  
95 seed bank accessions would mean that EW is the next categorisation level rather than progressing  
96 directly to full extinction. Precedent exists for reclassification: *Diploaxis siettiana* was declared  
97 extinct in 1998 after seeds were collected and stored at the Agronomists College of Madrid. These  
98 seeds formed the basis of a reintroduction and the species is now listed as critically endangered  
99 (CR)<sup>16</sup>. *Bromus bromoideus* was declared EX around 1930<sup>17</sup> and all but forgotten until the seeds  
100 were discovered by chance in *ex situ* facilities. They were grown successfully and there are now  
101 several populations in cultivation resulting in a revised Red List status of EW.

102

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

111

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