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Chapter 7

Conservation Status and Threat Assessments for North American Crop Wild Relatives

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Abstract Conservation status and threat assessments evaluate species' relative risks of extinction globally, regionally, nationally, or locally, and estimate the degree to which populations of species are already safeguarded in existing conservation systems, with the aim of exposing the critical gaps in current conservation. Results of the assessments can therefore aid in directing limited conservation resources to the species and populations that are most at-risk. This chapter introduces the roles of conservation status and threat assessments in informing conservation priorities for crop wild relatives in North America, and provides an overview of the current results for U.S. taxa. Methods to assess the conservation status and to perform threat assessments for North American crop wild relatives are well developed via NatureServe and the International Union for Conservation of Nature (IUCN) Red List, and the essential infrastructure to perform these analyses is present, at least in Canada and the U.S. Current conservation assessments for North American wild relatives need updating, but already reveal a landscape of multiple complex threats, and major gaps in the *ex situ* and *in situ* conservation of prioritized species. Further resources and concerted efforts are needed to update conservation assessments and then to use the results to inform efforts to fill the critical gaps in conservation.

Keywords
Global Rank, Red List, *Ex Situ*, *In Situ*, Threat Assessment, Gap Analysis, Conservation Status

List of abbreviations
IUCN (International Union for Conservation of Nature), Global (G), National (N), Subnational (S), U.S. (United States), CWR (Crop Wild Relatives)

7.1 Introduction

The need to conserve crop wild relatives has long been recognized (Harlan 1976; Meilleur and Hodgkin 2004). Historically, most conservation actions have focused on *ex situ*, or off-site, collections, with emphasis on availability to researchers for crop breeding and other uses. In the last few decades, there has been an increased interest in *in situ*, or on-site conservation of crop wild relatives (Convention on Biological Diversity 2011; Dempewolf et al. 2014). Complementary conservation, also called integrated plant conservation, includes both *ex situ* and *in situ* measures (Kramer et al. 2011). An integrated approach is generally seen as more effective than either individual method in conserving crop wild relatives because it enables naturally occurring populations to be subjected to continued natural selection, while also securely safeguarding genetic resource diversity and making it available to the research community (USDA Forest Service and Agricultural Research Service 2014; Moray et al. 2014; Fielder et al. 2015).

Integrated conservation applied to the full spectrum of crop wild relatives thus represents the ideal, but insufficient resources for conservation, competing priorities for the use of wildlands, and, perhaps most importantly, lack of awareness by decision makers of the importance of crop wild relatives make actualization of this goal challenging. The current reality is that conservationists must choose their priorities, focusing their efforts on species and populations that are particularly threatened or have special cultural or genetic resource value. Robust information on the identities, distributions, threats, and realized or potential value of crop wild relatives provides the knowledge base needed to prioritize among these species.

This chapter introduces the roles of conservation status and threat assessments in informing conservation priorities for crop wild relatives in North America, and provides an overview of the current results for U.S. taxa. These assessments evaluate species' relative risks of extinction globally, regionally, nationally, or locally, and estimate the degree to which populations of species are already safeguarded in existing conservation systems, with the aim of exposing the critical gaps in current conservation (Master 1991; Collen et al. 2016). Results of the assessments can therefore aid in directing limited conservation resources to the species and populations that are most at-risk.

7.2 Assessing the Conservation Status of Species

Most conservation efforts rely on information from status assessments to prioritize their work. Due to the recognized importance of these assessments, they are included in several international policy initiatives and strategies. For example, Target 2 of the Conventional on Biological Diversity's Global Strategy for Plant Conservation calls for "an assessment of the conservation status of all known plant species, as far as possible, to guide conservation action" by 2020 (Convention on Biological Diversity 2012). Similarly, the North American Botanic Garden Strategy for Plant Conservation calls on botanic gardens to review and contribute to conservation status assessments of plants using criteria and standards developed by NatureServe and the International Union for Conservation of Nature (IUCN) (BGCI 2016). Finally, Target 12 of the Aichi Biodiversity Targets of the Convention on Biological Diversity's Strategic Plan recommend using the IUCN Red List of Threatened Species to identify imperiled species, prevent their extinction, and improve their conservation status, by 2020 (Convention on Biological Diversity 2011).

The two most widely used platforms for assessing the conservation status of species in North America are NatureServe's Conservation Status Assessments and the IUCN Red List. The next sections provide an overview of each platform and a comparison between them.

7.2.1 NatureServe Conservation Status Assessments

The NatureServe Network in North America comprises over 65 independent programs representing subnational jurisdictions in Canada, the United States, and Mexico, which collaborate in performing conservation status assessments and providing the results (called ranks) on a shared platform. The network gathers, analyzes, and distributes biodiversity data on species and ecosystems via an independent methodology from those used by the IUCN Red List and other pertinent conservation status assessments.

NatureServe ranks evaluate the potential extinction or extirpation risk of taxa by systematically analyzing rarity, threats, and trends (Faber-Langendoen et al. 2012; Master et al. 2012). Ranks have been produced at least once for over 70,000 North American plant and animal taxa, including nearly every vascular plant occurring in Canada and the U.S. These results have been used extensively by U.S. and Canadian state and federal agencies, including state natural heritage programs.

Ranks are completed at three nested, geographic scales: Global (G), National (N), and Subnational (S) (i.e. state and provincial). Data from Subnational Ranks are used to inform National and Global Ranks. Specifically, State Natural Heritage Programs and Canadian Data Centres provide Subnational level data on species including mapped populations (Element Occurrences) and local threats and conditions. The use of common standards and methodology enable these data to be aggregated into national and global datasets that serve as the basis for National and Global Ranks. By indicating species imperilment at different jurisdictional scales, governments and decision makers are better able to allocate resources for the most imperiled taxa in their respective jurisdictions while at the same time considering species' overall risks of extinction throughout their ranges (Faber-Langendoen et al. 2012).

Within each geographic scale, species and infraspecific taxa (i.e., varieties and subspecies) are ranked from most to least imperiled on a scale of 1-5 (Table 7.1). NatureServe ranks also include GX (Presumed Extinct) and GH (Possibly Extinct). Uncertainty in a global rank is expressed through range ranks, variant ranks, and rank qualifiers (Table 7.1). For example, taxa with questionable taxonomy that may affect the conservation assessment are assigned the rank qualifier of "Q".

Table 7.1 NatureServe Conservation Status Ranks adapted from Master et al. (2012)

Global (G) Rank	**Definition**
GX	Presumed Extinct — Species not located despite intensive searches and virtually no likelihood of rediscovery
GH	Possibly Extinct — Known from only historical occurrences but still some hope of rediscovery. There is evidence that the species may be extinct, but not enough to state this with certainty
G1	Critically Imperiled—At very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors
G2	Imperiled—At high risk of extinction or elimination due to very restricted range, very few populations, steep declines, or other factors
G3	Vulnerable—At moderate risk of extinction or elimination due to a restricted range, relatively few populations, recent and widespread declines, or other factors
G4	Apparently Secure—Uncommon but not rare; some cause for long-term concern due to declines or other factors
G5	Secure—Common; widespread and abundant
Variant Global Ranks	
G#G#	Range Rank — A numeric range rank (e.g., G2G3, G1G3) used to indicate uncertainty about the exact status of a taxon
GU	Unrankable — Currently unrankable due to lack of information or due to substantially conflicting information about status or trends

GNR	Unranked – Global rank not yet assessed
GNA	Not Applicable — A conservation status rank is not applicable because the species is not a suitable target for conservation activities
Rank Qualifiers	
?	Inexact Numeric Rank — Denotes inexact numeric rank; this should not be used with any of the Variant Global Conservation Status Ranks or GX or GH
Q	Questionable taxonomy that may reduce conservation priority—Distinctiveness of this entity as a taxon at the current level is questionable; resolution of this uncertainty may result in change from a species to a subspecies or hybrid, or inclusion of this taxon or type in another taxon or type, with the resulting taxon having a lower-priority (numerically higher) conservation
C	Captive or Cultivated Only —At present presumed or possibly extinct in the wild across entire native range but extant in cultivation, in captivity, as a naturalized populations outside their native range, or as a reintroduced population, not yet established. Possible ranks are GXC or GHC

Assessing the conservation status of a species requires detailed knowledge of its identity, distribution, population trends, and threats. NatureServe's ranking process uses eight core rank factors organized into three categories: rarity, threats, and trends (Master et al. 2012) (Table 7.2). Two additional factors are considered conditional and are used only when information on certain core factors is not available (Table 7.2; see Faber-Langendoen et al. 2012 for details). Using the Rank Calculator Tool, factors are scaled and weighted consistently to score the contribution of each factor to extinction risk. The combined scores result in a calculated rank, which is reviewed by an expert who then assigns the final conservation status rank.

The three factor categories—rarity, threats, and trends—require a minimum amount of information for each species to calculate a conservation status assessment. Rarity, which is weighed more heavily than threats and trends in NatureServe's ranks, includes five core factors and one conditional factor. Three of these factors (Range Extent/Extent of Occurrence, Area of Occupancy, and Population Size) are equivalent to Red List definitions. Threats are usually assessed by assigning an overall threat impact, although a species' intrinsic vulnerability may be used as a conditional factor when information on threats is not available. Threats are categorized using the hierarchy first published by Salafsky et al. (2008) while the threat impact score is calculated considering the scope, severity, and timing of present and future threats. The trends factors describe the degree of change in a species' range, distribution, abundance, or condition over the short-term (within 10 years or 3 generations) or long-term (ca. 200 years). Values for trends include estimates of increases, declines, and relative stability (Faber-Langendoen et al. 2012). Detailed guidance on the methodology, factors, and Rank Calculator is available on NatureServe's website (natureserve.org) and in Faber-Langendoen et al. (2012) and Master et al. (2012). Conservation status ranks of species and ecosystems are found on the NatureServe Explorer website (explorer.natureserve.org).

Table 7.2. Summary of NatureServe Conservation Status Rank Factors adapted from Master et al. (2012)

Factor Category	**Subcategory**	**Factor**	**Definition**
Rarity	Range/ Distribution	Range Extent	Minimum area that encompasses all present occurrences
		Area of Occupancy	Area within the range extent occupied by a species
	Abundance/ Condition	Population Size	Estimated total mature individuals occurring in wild populations within a species' natural range
		Number of Occurrences	Number of discrete areas occupied by a species (e.g., subpopulations, populations, metapopulations)
		Number of Occurrences with Good Viability	Number of occurrences with excellent-to-good viability, such that there is the likelihood of persistence under current conditions
		Environmental Specificity*	Degree to which the species depends on a relatively scarce set of habitats, substrates, food types, or other factors within the overall range
Threats		Overall Threat Impact	Degree to which a species' viability is affected by extrinsic factors (stressors), characterized by scope and severity
		Intrinsic Vulnerability*	Degree to which a species' inherent characteristics, such as life history, make it susceptible or resilient to stress
Trends		Long-term Trend	Degree of past directional change in population, range extent, area of occupancy, or number of occurrences over the long term (ca. 200 years)
		Short-term Trend	Degree of past directional change in population, range extent, area of occupancy, or number of occurrences in the short term, defined as within 10 years or 3 generations, whichever is longer

*Indicates conditional factors used only if information on certain core factors is not available.

7.2.2 The IUCN Red List of Threatened Species

The IUCN is a global network focused on environmental conservation with over 1,300 governmental and non-governmental member organizations and supported by over 10,000 experts. The IUCN network has been instrumental in producing global environmental protection agreements such as the Convention on Biological Diversity and the Convention on International Trade in Endangered Species (CITES).

The IUCN Red List of Threatened Species (Red List) was established in 1964 with the goal of providing a baseline from which to measure and monitor the state of the world's biodiversity (Westwood et al. 2017). Like NatureServe's Ranks, the Red List is designed to evaluate the relative risk of extinction among species with the purpose of highlighting species that are threatened or are facing a high risk of extinction.

Most Red List Assessments are completed by members of IUCN Species Survival Commission Specialist Groups and Red List Authorities, although anyone can request to assess or review a species. Specialist Groups and Red List Authorities are usually comprised of experts of taxonomic groups or geographic regions. For example, crop wild relatives in North America may be assessed by the Crop Wild Relative Specialist Group, the Red List Authority for North American Plants, or the Hawaiian Plant Specialist Group, to name a few (for a full list of plant specialist groups, see https://www.iucn.org/ssc-groups/plants-fungi.). The Red List includes global-level assessments, although regional or national assessments may also be included for species endemic to single countries.

The IUCN Red List uses five quantitative criteria in a rule-based approach to determine if a species is Threatened, Near Threatened, or Least Concern:

A. Declining population (past, present and/or projected)
B. Geographic range size, and fragmentation, decline or fluctuations
C. Small population size and fragmentation, decline, or fluctuations
D. Very small population or very restricted distribution
E. Quantitative analysis of extinction risk (e.g., Population Viability Analysis)

Threatened species include the categories of Critically Endangered, Endangered or Vulnerable (Table 7.3). Many of the criteria also require the use of sub-criteria to further justify listing species as Threatened or Near Threatened. The Red List Categories and Criteria (IUCN 2012) provides the methodology for assigning each of the criteria to a species, while detailed instructions and case studies are found in the guidelines (IUCN Standards and Petitions Subcommittee 2017). The IUCN provides a number of additional key documents, as well as all published Red List Assessments, on the Red List website (iucnredlist.org).

Table 7.3 IUCN Red List Global Status Categories

Red List Category	Definition
EX	Extinct--No reasonable doubt that the last individual has died
EW	Extinct in the Wild--Known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range
CR	Critically Endangered--Facing an extremely high risk of extinction in the wild based on meeting any of the criteria A to E for Critically Endangered using the best available evidence
EN	Endangered--Facing a very high risk of extinction in the wild based on meeting any of the criteria A to E for Endangered using the best available evidence
VU	Vulnerable--Facing a high risk of extinction in the wild based on meeting any of the criteria A to E for Vulnerable using the best available evidence
NT	Near Threatened--Close to qualifying for or is likely to qualify for a threatened category (Critically Endangered, Endangered or Vulnerable) based on an evaluation against the criteria
LC	Least Concern--Widespread and abundant taxa that have been evaluated against the criteria and do not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened
DD	Data Deficient--Inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status
NE	Not Evaluated--Not yet been evaluated against the criteria

7.2.3 Comparison between NatureServe and IUCN Red List Conservation Assessments

NatureServe and the IUCN Red List use many of the same concepts (such as the Area of Occupancy, Extent of Occurrence, and Population Size), underlying information, and methods for classifying and coding to inform status assessments (Salafsky et al. 2008). Moreover, many of the thresholds between the different categories are set at the same approximate level, so in the majority of cases the NatureServe rankings and the Red List categories largely align (Table 7.4). Both systems are dynamic and are updated, ideally based on new threats or changing population trends.

This said, the processes of evaluating the data and assigning Ranks and Categories by the systems differ. NatureServe ranks follow a weight-of-evidence approach with minimum criteria, whereas the IUCN Red List is based on applying a set of rules to the given criteria (Westwood et al. 2017). Red List Assessments place a higher emphasis on trends while NatureServe Ranks prioritize rarity in assessing extinction risk. Both platforms utilize methods and establish guidelines for addressing and expressing uncertainty in the underlying data; however, these methods differ substantially. For example, NatureServe uses multiple Range Ranks (e.g., G2G3, G1G3) to indicate uncertainty about the exact status of a species, while Red List Assessments include a category of Near Threatened to indicate a species close to qualifying for a Threatened category. Although many of the same concepts are utilized by both platforms, NatureServe rankings cannot automatically be transferred over to IUCN Red List categories and vice versa.

For reviews (albeit now outdated) of the NatureServe platform compared to the IUCN Red List as well as the Endangered Species Act (Endangered Species Act of 1973, 16 U.S.C. Sec 1531), see Master et al. (2012) and Regan et al. (2005).

In the case of the U.S. and Canada, nearly all plant species and infraspecific taxa have been ranked by NatureServe at least once (ca. 25,000 taxa). In contrast, there are only approximately 3,100 completed Red List Assessments for plant taxa in the two countries. Although NatureServe's Ranks provide a useful baseline for evaluating conservation status, many Global Ranks have not been reviewed in over ten years. Some taxa, especially those ranked G4 or G5, have not been reviewed in over twenty years. Both NatureServe and the Red List are aware of these data gaps and are working collaboratively to update conservation status information for North American plants. In particular, the Red List initiated the Plants for People (P4P) project to assess the conservation status of 6,000 species of crop wild relatives, medicinal plants, timber trees, and palms (IUCN 2017). Currently, Red List Assessments are underway for hundreds of crop wild relatives in Mesoamerica (IUCN 2017a).

Table 7.4: Comparable Categories between NatureServe Global Rank and IUCN Red List Category (adapted from Master et al. 2012).

NatureServe Global Rank	IUCN Red List Category
Presumed Extinct (GX)	Extinct (EX)
Presumed Extinct in the Wild[1] (GXC)	Extinct in the Wild (EW)
Possibly Extinct (GH)	Critically Endangered (CR) (possibly extinct)
Possibly Extinct in the Wild[1] (GHC)	Critically Endangered (CR) (possibly extinct)
Critically Imperiled (G1)	Critically Endangered (CR)
Critically Imperiled (G1)	Endangered (EN)
Imperiled (G2)	Vulnerable (VU)
Vulnerable (G3)	Near Threatened (NT)
Apparently Secure (G4)	Least Concern (LC)
Secure (G5)	Least Concern (LC)
Unrankable (GU)	Data Deficient (DD)

[1]Species ranked GXC and GHC are presumed or possibly extinct in the wild across their entire native range, but are extant in cultivation, in captivity, as a naturalized population (or populations) outside its historical native range, or as a reintroduced population not yet established. The C modifier is only used with status ranks at a global level, and not a national or subnational level. Similarly, IUCN's EW status is only used at a global level.

7.3 Indications of the Conservation Status and Threats to U.S. Crop Wild Relatives

Although the U.S. has for numerous decades been actively involved in various ways with the conservation of its crop wild relatives (see, e.g. USDA Forest Service 2016 and Seiler et al. 2017), a national inventory of these species was published only recently (Khoury et al. 2013). Such an inventory is a foundational step to conservation as it identifies species of interest and prioritizes them by their potential value for crop breeding and other research. Once species of interest are identified, their conservation status can be used as a further criterion to prioritize their conservation.

Conservation status assessments for 76% of taxa listed in the U.S. national inventory have been recorded in NatureServe (Khoury et al. 2013). Of these, eight (0.2%) taxa were assessed as known or presumed extinct in the wild, 115 (3.3%) as globally critically imperiled, 111 (3.2%) as imperiled, 337 (9.6%) vulnerable, 798 (22.7%) apparently secure, and 2143 (61%) globally secure.

Of the species in the inventory, the IUCN Red List assesses 16 taxa as extinct, endangered, or vulnerable (IUCN 2012). Sixty-two taxa are also listed as endangered under the U.S. Endangered Species Act (Endangered Species Act of 1973, 16 U.S.C. Sec 1531), 10 taxa as threatened, and 11 taxa as candidates for listing. Among the taxonomic groups with the largest absolute number of threatened taxa are members of the family Fabaceae, particularly within the genera *Astragalus*, *Lotus*, *Lupinus*, and *Trifolium*.

7.3.1 Threat Assessment for Critically Imperiled and Imperiled U.S. Crop Wild Relatives

Identifying the threats to rare and endangered species is critical for guiding conservation action (Murray et al. 2014). Both the NatureServe and IUCN Red List conservation status assessments identify threats using a hierarchical threats taxonomy, with the first level representing broad categories of threats and the second more specific threats (Table 7.5). The threats hierarchy used by NatureServe and the Red List are based on the threats taxonomy published by Salafsky et al. (2008) but differ slightly from one another due to modifications to the taxonomy over time. Currently NatureServe has conducted formal assessments using the hierarchical threats taxonomy for 963 plant taxa distributed in the U.S., though Hernández-Yáñez et al. (2016) employed a systematic textual analysis to extend coverage to all 2733 U.S. plant taxa that are Critically Imperiled (G1), Imperiled (G2), Possibly Extinct (GH), Possibly Extinct in the Wild (GHC), or listed or candidates for listing under the U.S. Endangered Species Act. Here threat assessments for 214 U.S. crop wild relatives are reported including 163 taxa analyzed by Hernández-Yáñez et al. (2016) plus an additional 51 taxa assessed for this chapter, using the same methods and standards.

Table 7.5. First and second level threats in the Threats Classification Scheme currently in use by the IUCN Red List and NatureServe. Third level threats are defined in some cases and can be found online (http://www.iucnredlist.org/technical-documents/classification-schemes/threats-classification-scheme). Threats are commonly specified using the hierarchical number plus full name.

First Level Threat	**Second Level Threat**
1 Residential & commercial development	1.1 Housing & urban areas; 1.2 Commercial & industrial areas; 1.3 Tourism & recreation areas
2 Agriculture & aquaculture	2.1 Annual & perennial non-timber crops; 2.2 Wood & pulp plantations; 2.3 Livestock farming & ranching; 2.4 Marine & freshwater aquaculture
3 Energy production & mining	3.1 Oil & gas drilling; 3.2 Mining & quarrying; 3.3 Renewable energy
4 Transportation & service corridors	4.1 Roads & railroads; 4.2 Utility & service lines; 4.3 Shipping lanes; 4.4 Flight paths
5 Biological resource use	5.1 Hunting & collecting terrestrial animals; 5.2 Gathering terrestrial plants; 5.3 Logging & wood harvesting; 5.4 Fishing & harvesting aquatic resources
6 Human intrusions & disturbance	61. Recreational activities; 6.2 War, civil unrest & military exercises; 6.3 Work & other activities
7 Natural system modifications	7.1 Fire & fire suppression; 7.2 Dams & water management/use; 7.3 Other ecosystem modifications
8 Invasive & other problematic species, genes & diseases	8.1 Invasive non-native/alien species/diseases; 8.2 Problematic native species/diseases; 8.3 Introduced genetic material; 8.4 Problematic species/diseases of unknown origin; 8.5 Viral/prion-induced diseases; 8.6 Diseases of unknown cause
9 Pollution	9.1 Domestic & urban waste water; 9.2 Industrial & military effluents; 9.3 Agricultural & forestry effluents; 9.4 Garbage & solid waste; 9.5 Air-borne pollutants; 9.6 Excess energy
10 Geological events	10.1 Volcanoes; 10.2 Earthquakes/tsunamis; 10.3 Avalanches/landslides
11 Climate change & severe weather	11.1 Habitat shifting & alteration; 11.2 Droughts; 11.3 Temperature extremes; 11.4 Storms & flooding; 11.5 Other impacts

Of the 214 taxa, 203 occur in the continental U.S. and 11 in Hawaii. Only 22.4% (48 taxa) are listed under the U.S. Endangered Species Act, with one additional species considered as a candidate. Seventy-nine percent of taxa (169) were documented as having at least one known threat, while 21 percent of taxa (45) had no documented threats. The distribution of threats was highly skewed, with most species having a few threats and a minority of species having either no threats or many threats.

First level threats affected crop wild relatives differently than rare U.S. plants as a whole. Across crop wild relatives, the most common threat was Natural System Modifications, affecting 44% of taxa, while across all U.S. species this threat was the fifth most common, affecting 29% of taxa (Hernández-Yáñez et al. 2016). Other common first-level threats to crop wild relatives included Residential & Commercial Development (41% versus 31% for all U.S. plant taxa), Agriculture & Aquaculture (32% versus 33%), Invasive & Other Problematic Species, Pathogens & Genes (30% versus 43%), Biological Resource Use (26% versus 15%), Human Intrusion and Disturbance (20% versus 33%), and Transportation & Service Corridors (19% versus 21%). Each of the other first level threats affected fewer than 10% of crop wild relatives.

Second level threats affecting >20% of U.S. crop wild relatives included:

- Housing and urban areas (33% of species),
- Fire and fire suppression (28%),
- Invasive non-native/alien plants and animals (23%), and
- Dams & water management/use (20%)

Threats from fire and fire suppression were largely due to the third level threat, Suppression in fire frequency/intensity (20%) and less to Increase in fire frequency/intensity (4%) or Unspecified changes in fire frequency/intensity (4%). The distribution of second level threats across crop wild relatives suggests that many taxa are affected by direct land usurpation (e.g., urbanization and inundation by dams) as well as factors that alter competitive and consumer-resource dynamics (e.g., invasive species and fire suppression). Several significant threats also pertained to use of wild or cultivated plants, including:

- Wood and pulp plantations (17%),
- Logging and wood harvesting (16%),
- Annual and perennial non-timber crops (13%),
- Gathering terrestrial plants (13%), and
- Livestock farming and ranching (10%).

Crop wild relatives were somewhat more likely to be affected by direct harvest (Gathering terrestrial plants) than U.S. taxa in general, though the overall rate of threat was low (13% of crop wild relatives versus 9% of all U.S. taxa).

The distribution of second level threats affecting wild relatives also differed substantially from those impacting all rare U.S. taxa (Fig. 7.1). Crop wild relatives were more noticeably likely to be threatened by Housing and urban areas, Fire and fire suppression, Dams & water management/use, and Forestry operations, including Wood & pulp plantations and Logging and wood harvesting. In contrast, U.S. taxa as a whole were more likely to be affected by Invasive non-native/alien plants and animals, Recreational activities, Livestock farming and ranching, and Mining and quarrying. Discrepancies between these two sets of taxa could arise due to differences in distribution across the U.S. (e.g., Estill and Cruzen 2001), life form (e.g., Prescott and Stewart 2014), or innate sensitivity to anthropogenic activities (Murray et al. 2014).

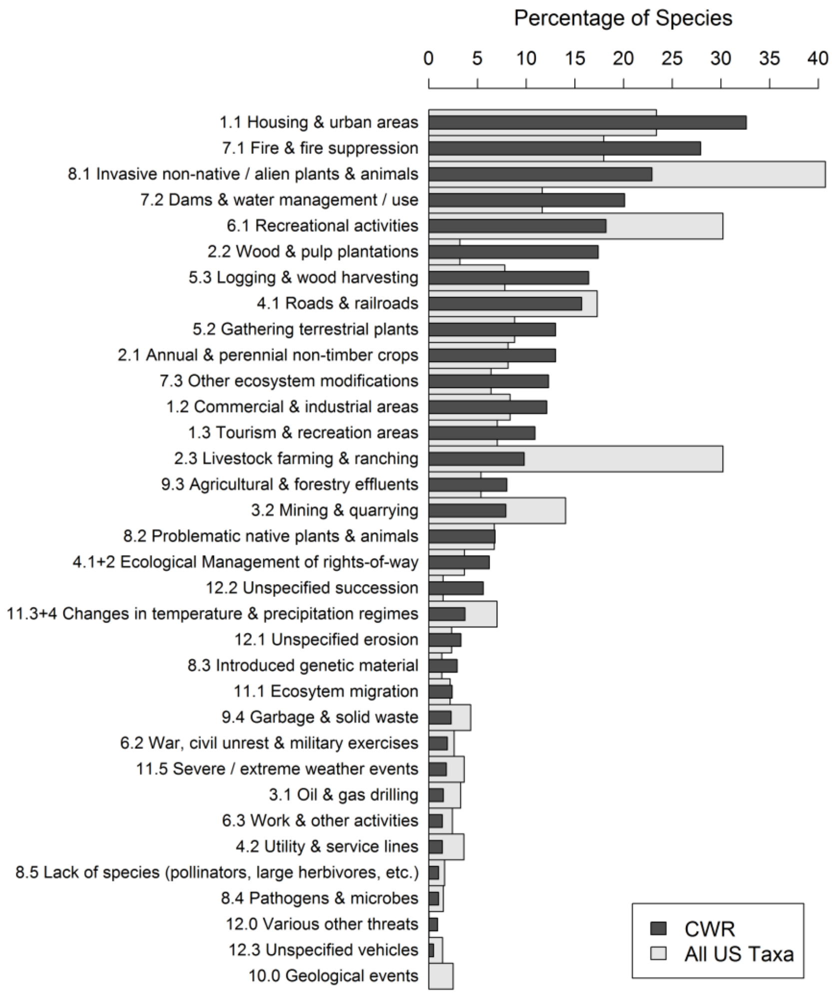

Fig 7.1. Frequency of second level threats affecting U.S. crop wild relatives (CWR) (n=214) and all rare U.S. plants (n=2733) (Hernández-Yáñez et al. 2016). Threats are listed in order from most common to least common among wild relatives. The frequency of most common threats affecting wild relatives is notably different from the frequency affecting rare plants in the U.S. as a whole.

Threats can co-occur to impart even more vulnerability than threats operating alone (Burgman et al. 2007; Budiharta et al. 2011; Jennings & Rohr 2011). Associations between threats can also offer opportunities for efficiencies in conservation efforts if they emanate from the same activity (e.g., agriculture is associated with land conversion, pollution from pesticides, introduction of invasive species, and dams and waterway diversions). Across wild crop relatives in the U.S. there were several positive associations between threats (Fig. 7.2). Of 861 possible pairwise associations between second level threats, 19% (165) were significant and positive (χ_2 test on Yule's φ measure of association), although the rate of positive associations was even higher (47%) across all continental U.S. rare taxa (Hernández-Yáñez et al. 2016). In contrast, <0.1% of associations between threats were significantly negative, a trend mirrored by continental U.S. taxa as a whole. The co-occurrence of threats suggests that conservation actions for crop wild relatives must mitigate multiple and sometimes interacting impacts (Burgman et al. 2007; Budiharta et al. 2011).

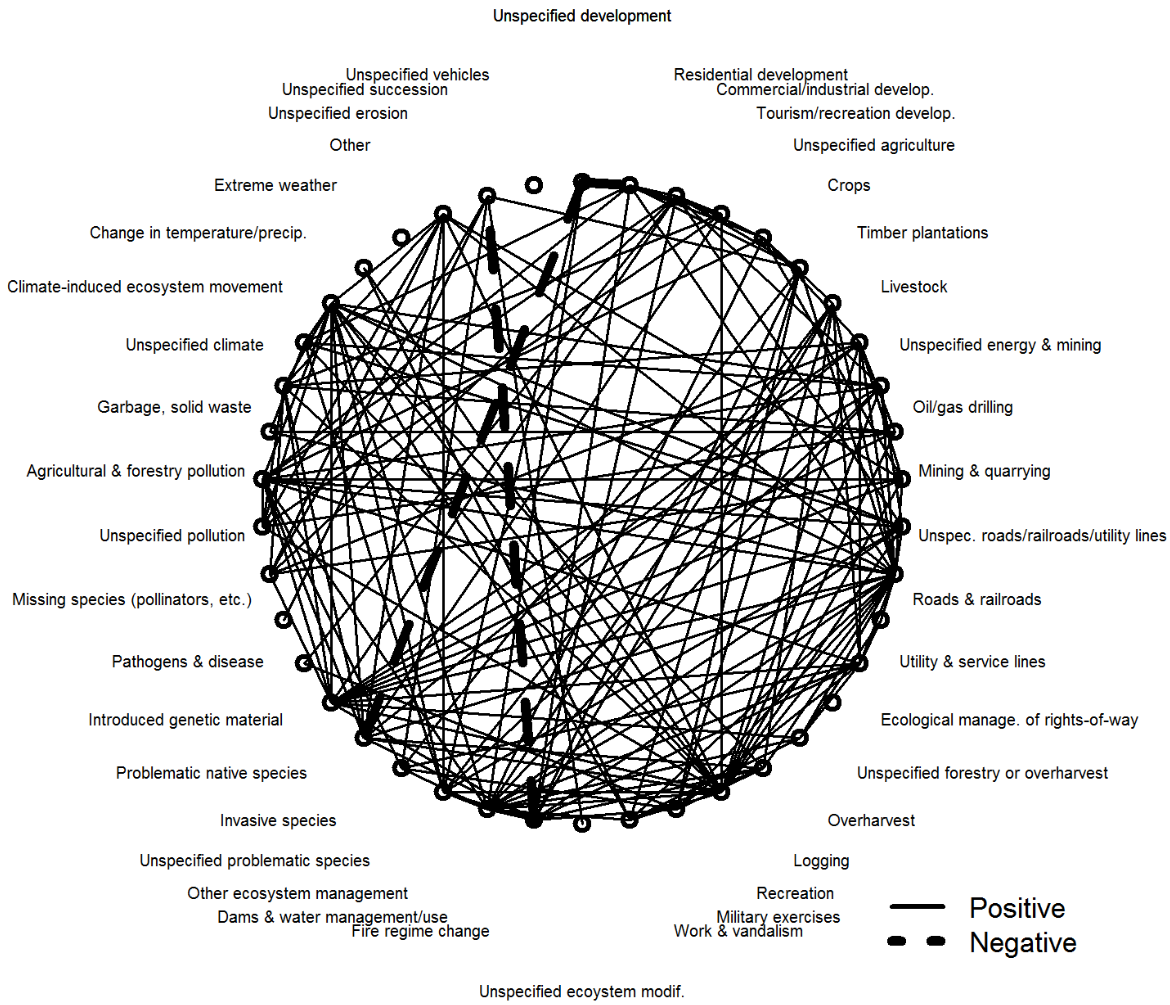

Fig 7.2 Positive and negative pairwise associations between second level threats affecting 214 rare U.S. crop wild relatives. Nineteen percent of possible associations are significantly positive and <0.1% negative, whereas by chance only 5% of associations should be significant, with an equal split between positive and negative. The high rate of positive associations suggests threats acting in concert often affect wild relatives.

7.3.2 Identifying Gaps in Conservation of U.S. Crop Wild Relatives

Identifying current gaps in *ex situ* and *in situ* conservation of crop wild relatives is integral to determining the next steps needed to improve integrated conservation. Gap analysis methodologies are aimed at effectively identifying the populations and species most in need of further conservation action (Ramírez-Villegas et al. 2010; Castañeda-Álvarez et al. 2016).

7.3.2.1 Gap Analysis of *Ex Situ* Collections of Crop Wild Relatives

Gap analysis methods enabling estimates of the degree of representation of crop wild relatives (and other important plant genetic resources) in genebanks have progressed considerably since geographic information systems technologies began to be applied to conservation planning, and as eco-geographic data has become more comprehensive (Hijmans et al. 2001; Hijmans and Spooner 2001; Olson et al. 2001; Jarvis et al. 2003; Hijmans et al. 2005; Phillips et al. 2006; Ramírez-Villegas et al. 2010; Parra-Quijano et al. 2012; Castañeda-Álvarez et al. 2016; Hengl et al. 2017; Fick and Hijmans 2017).

The basic steps in *ex situ* gap analysis for crop wild relatives include mapping or otherwise estimating the distributions of species, and then comparing the original collecting localities of existing genebank, botanic garden, and other collections against these distributions to both assess the representation of species *ex situ* as well as to expose the gaps in these collections. Gap analysis methods can also aid in locating which regions have the greatest richness in species, which can help to inform efficient collecting activities (Nabhan 1990).

Alongside basic assessments of taxonomic and geographic gaps in collections, such methods increasingly include environmental or ecological niche gaps (e.g., the degree of representation of the range of climates, soils, and habitats that species occupy) (Ramirez et al. 2010; Parra-Quijano et al. 2012; Castañeda-Álvarez et al. 2016). Recent studies have additionally analyzed the representation of populations harboring potentially valuable agronomic traits, particularly with regard to abiotic stresses (Tapia et al. 2014; Khoury et al. 2015; Khoury et al. 2015a). As the generation of molecular information becomes increasingly cost effective, such data are likely to be incorporated into gap analyses to more directly assess the current representation *ex situ* of useful genetic diversity (McCouch et al. 2013). More direct analyses of gaps in genetic diversity should help to mitigate some of the constraints inherent to methods relying on eco-geographic information as proxy for genetic diversity (e.g., Araújo and Guisan 2006; Hijmans and Graham 2006; Graham et al. 2008; Jimenez-Valverde et al. 2008; Loiselle et al. 2008; Costa et al. 2010; Lobo et al. 2010; Hijmans 2012; Gaiji et al. 2013), which may partly explain discrepancies in gap analysis prioritization results in comparison to expert opinion (Castañeda-Álvarez et al. 2016).

A comprehensive gap analysis for prioritized North American crop wild relatives has yet to be performed, although the process is underway in the U.S. A recent gap analysis of crop wild relatives in genebanks performed at the global level (Castañeda-Álvarez et al. 2016) produced worrying results. Of the 1100 wild species thought to be of greatest value worldwide to the improvement of food crops, almost 30% were completely missing from the world's genebanks, and over 70% were in urgent need of collecting. The U.S. and Mexico were recognized among the most important hotspots, with many important native species inadequately represented *ex situ*. Gap analyses performed at the crop genepool level and covering wild relatives native to North America have also revealed large gaps for most species (e.g., for apple [Volk et al. 2015], bean [Ramírez-Villegas et al. 2010], cotton [Wallace et al. 2009], potato [Castañeda-Álvarez et al. 2015], sweetpotato [Khoury et al. 2015a], and sunflower [Kantar et al. 2015]).

7.3.2.2 Gap Analysis of *In Situ* Conservation of Crop Wild Relatives

Similar to the state of production of *ex situ* gap analyses, comprehensive assessments of the level of protection of naturally occurring populations of North American crop wild relatives in designated protected areas have yet to be completed. What is clear is that while current federal, state, and other jurisdictional conservation policies in the region afford some protection for wild relatives, they clearly fall well short of providing adequate actively managed long-term *in situ* protection of the diversity of native wild genetic resource plants (see, e.g. Wilkes 2007). In only a handful of areas (i.e. the US Forest Service wild chile [*Capsicum annuum* var. *glabriusculum* (Dunal) Heiser & Pickersgill] preserve in Southern Arizona, U.S. [USDA Forest Service 2016], and the Sierra de Manantlan Biosphere Reserve in Jalisco/Colima, Mexico, which conserves a wild relative of maize [*Zea diploperennis* H.H. Iltis, Doebley and R. Guzmán], various wild beans, and other crop wild relatives), does such conservation include active management plans with regularly scheduled monitoring of populations.

Two important administrative and legislative formats by which *in situ* conservation can be improved in the U.S. are discussed below. Such federal and state, as well as other official threatened and endangered species prioritizations, provide critical justifications for conservation investment, and should be strengthened to better protect North American wild relative species.

The Endangered Species Act

The Endangered Species Act (ESA) is a federal law in the U.S. designed to protect imperiled species and the habitats upon which they depend. Endangered species under the ESA are in danger of extinction throughout all or a significant portion of their range and Threatened species are likely to become endangered within the foreseeable future. The U.S. Fish and Wildlife Service and the National Marine Fisheries Service determine which species are listed or are candidates for listing under the ESA. Threatened or endangered taxa under the ESA are eligible for federal protection, recovery planning, and funding for conservation actions.

While the ESA does confer protection to some threatened plants, neither the current number of listed plant species nor the funding allocated to their recovery is sufficient to ensure their protection. While 40 percent of vertebrates regarded by NatureServe as G1 (Critically Imperiled) or G2 (Imperiled) are also listed under the U.S. Endangered Species Act, only 20 percent of similarly ranked plants are federally listed (Evans et al. 2016). Federally listed plants receive less protection than federally listed animals. For example, even though nearly 60% of species on the U.S. Endangered Species List are plants, they consistently receive less than 5% of State and Federal funding (Negron-Ortiz 2014). In addition, while federal agencies must consider the protection of listed ESA species in land planning projects, private landowners are only required to consider the protection of listed ESA animals and not plants.

State Wildlife Action Plans

State Wildlife Action Plans are important state level processes in the U.S., which involve multi-year strategies to assess the health of wildlife and outline pathways to improved conservation.

The plans aim to protect species before they become endangered, and are custom-fitted to individual jurisdictional needs and priorities. State Wildlife Action Plans are consistently used to inform conservation actions at the state and national levels (Stein and Gravuer 2008).

Similar to the Endangered Species Act, plants are currently significantly underrepresented in State Wildlife Action Plans compared to animal species. States develop action plans to protect species designated of “Greatest Conservation Need”. To date, only 15 of 56 U.S. states and territories have included plants in their lists of Species of Greatest Conservation Need. One major challenge is that the national State Wildlife Grant Program continues to define wildlife as “fauna, and not flora,” due to historical funding sources, including excise taxes on hunting equipment (1937 Pittman-Robertson Act) and fishing gear (1950 Dingell-Johnson Act) (Stein and Gravuer 2008). Such a definition precludes the use of Program resources to work on plants, leaving jurisdictions to find alternative funding for flora.

7.4 Conclusion

Methods to assess the conservation status and to perform threat assessments for North American crop wild relatives are well developed via NatureServe and the IUCN Red List, and the essential infrastructure to perform these analyses is present, at least in Canada and the U.S. Current conservation assessments for North American wild relatives need updating, but already reveal a landscape of multiple complex threats, and major gaps in the *ex situ* and *in situ* conservation of prioritized species. Further resources and concerted efforts are needed to update conservation assessments and then to use the results to inform efforts to fill the critical gaps in conservation.

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