Global Survey of *Ex situ* Conifer Collections

BGCI

Plants for the Planet

Global Survey of
Ex situ Conifer Collections

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THE USDA FOREST SERVICE is entrusted with 193 million acres of national forests and grasslands. The mission of the agency is to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations.

BOTANIC GARDENS CONSERVATION INTERNATIONAL (BGCI) is a membership organization linking botanic gardens in over 100 countries in a shared commitment to biodiversity conservation, sustainable use and environmental education. BGCI aims to mobilize botanic gardens and work with partners to secure plant diversity for the well-being of people and the planet. BGCI provides the Secretariat for the IUCN/SSC Global Tree Specialist Group.

FAUNA & FLORA INTERNATIONAL (FFI), founded in 1903 and the world's oldest international conservation organization, acts to conserve threatened species and ecosystems worldwide, choosing solutions that are sustainable, are based on sound science and take account of human needs.

THE GLOBAL TREES CAMPAIGN (GTC) is undertaken through a partnership between BGCI and FFI, working with a wide range of other organizations around the world, to save the world's most threatened trees and the habitats in which they grow through the provision of information, delivery of conservation action and support for sustainable use.

Acronyms

BGCI	Botanic Gardens Conservation International
BRAHMS	Botanical Research and Herbarium Management System
CBD	Convention on Biological Diversity
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
FFI	Fauna and Flora International
GSPC	Global Strategy for Plant Conservation
GTC	Global Trees Campaign
ICCP	International Conifer Conservation Programme
IPNI	International Plant Names Index
IPSN	International Plant Sentinel Network
IUCN	International Union for the Conservation of Nature
IUCN/SSC	International Union for the Conservation of Nature/Species Survival Commission
NTFP	Non Timber Forest Products
RBGE	Royal Botanic Garden Edinburgh
SFM	Sustainable Forest Management
USDA	United States Department of Agriculture

Contents

Sequoiadendron giganteum *in the living collections of the Arnold Arboretum of Harvard University, U.S.A. Endangered (EN), reported as held in 178* ex situ *collections worldwide. (Credit: Garth Holmann, University of Maine).*

Summary

This survey of *ex situ* threatened conifer collections has been undertaken by Botanic Gardens Conservation International (BGCI) as part of our ongoing contributions to the Global Trees Campaign (GTC), a joint initiative between BGCI and Fauna and Flora International (FFI) to safeguard threatened tree species and their benefits for humans and the environment. This report provides an overview of the current status of global *ex situ* collections of conifer taxa, with particular focus on threatened conifers.

Abies cilicica *seedlings at the Royal Botanic Gardens, Edinburgh. Near Threatened (NT), reported as held in 62* ex situ *collections worldwide. (Credit: Martin Gardner, RBGE).*

Target 8 of the Global Strategy for Plant Conservation (GSPC) calls for 'At least 75% of threatened plant species in *ex situ* collections, preferably within the country of origin, and at least 20% available for recovery and restoration programmes' by 2020.

A global reassessment of the conservation statuses of the world's conifers was undertaken and up-to-date assessments published to the IUCN Red List of Threatened Species in July 2013. This work was coordinated by Aljos Farjon, Chair of the IUCN/SSC Conifer Specialist Group, and jointly undertaken with staff at the Royal Botanic Garden Edinburgh. The global reassessment highlighted that 34% of conifers are globally threatened with extinction. This report uses data held in BGCI's PlantSearch database of *ex situ* collections, and the IUCN Red List assessments to analyse current *ex situ* conservation efforts for threatened taxa. Analysis of PlantSearch records shows that 81% of globally threatened conifer taxa are present in over 800[1] *ex situ* collections, thereby meeting the 75% *ex situ* goal of Target 8. However, further analysis shows that 46% (134 taxa) of threatened conifers are known in very few or no collections. These taxa are highlighted as priorities for establishing a more effective safety net against extinction of threatened conifers.

To further gauge the conservation value of known threatened conifer collections, additional information on provenance and number of individuals per collection was collected from 39 participating institutions and International Conifer Conservation Programme (ICCP) sites. These detailed data show that threatened conifer collections consist of 58% wild source material and 42% horticultural or unknown source. Additionally, the large majority (80%) of wild source collections of threatened conifers consist of only 1-5 individuals.

In addition to an *ex situ* collections gap analysis, this report highlights a number of case studies from gardens throughout the world, illustrating how *ex situ* conservation can go beyond collections that safeguard taxa outside their natural habitat, and move towards integrated conservation programmes that also reduce pressure on wild populations and supply a source of material to replenish wild populations. These and other successful cultivation and recovery and restoration programmes were identified for a few of the most threatened conifer taxa, however this is not the case for many threatened taxa. Much more work is needed to achieve the goal of 20% threatened species available for recovery and restoration programmes outlined by Target 8 of the GSPC.

To further meet the goals of GSPC Target 8, recommendations are provided in this report, aimed at increasing capacity for threatened conifer conservation, improving management of *ex situ* collections, and enabling supply of *ex situ* material for recovery and restoration programmes.

Araucaria angustifolia. *Critically Endangered (CR), reported as held in 89* ex situ *collections worldwide. (Credit: David Gill, FFI).*

[1] This represents conifer collection records from 635 institutions with plant lists held in BGCI's PlantSearch database and 230 institutions involved in the International Conifer Conservation Programme (ICCP), led by the Royal Botanic Garden Edinburgh. As some ICCP institutions maintain collection records in PlantSearch there is some overlap. The total number of *ex situ* collections represented in this study is 838.

Introduction

This survey has been undertaken by Botanic Gardens Conservation International (BGCI) as part of our ongoing contributions to the Global Trees Campaign (GTC), a joint initiative between BGCI and Fauna and Flora International (FFI) to safeguard threatened tree species and their benefits for humans and the environment.

Status of tree Red Listing

'The World List of Threatened Trees' (Oldfield *et al*., 1998) was the first comprehensive conservation assessment of the world's tree species. Using Version 2.3 of the IUCN Red List categories and criteria, over 7,400 of the tree taxa assessed qualified as globally threatened with extinction. The assessments provided in 'The World List of Threatened Trees' were subsequently added to the IUCN Red List of Threatened Species (www.iucnredlist.org).

The IUCN/Species Survival Commission (IUCN/SSC) Global Tree Specialist Group aims to fill the gaps in 'The World List of Threatened Trees' and to revise existing assessments using the most up-to-date IUCN Red List categories and criteria (Version 3.1) to produce a Global Conservation Assessment of the world's trees by 2020. Good progress is being made towards this ambitious target. Currently, more than 9,500 tree taxa have been assessed and published on the IUCN Red List, over 6,400 of which are assessed as globally threatened (Critically Endangered, Endangered or Vulnerable). Over 1,100 tree taxa are assessed as Critically Endangered and in urgent need of conservation action. A review of recent progress towards Red Listing the world's tree species (Newton and Oldfield, 2008) found that more than 2,500 tree taxa have been evaluated since 1998, but only a fraction of these have yet been published on the IUCN Red List. Overall, it is widely accepted that more than 8,000 (10%) tree taxa, are globally threatened with extinction.

Araucaria araucana*, the Monkey Puzzle tree. Endangered (EN), reported as held in 162* ex situ *collections worldwide.*

Contributions of BGCI and the Global Trees Campaign (GTC) to tree Red Listing

Working towards production of a Global Conservation Assessment of the world's tree species, the Global Trees Campaign (GTC) is leading Red Listing of trees in smaller taxonomic and geographic groups, depending on conservation priorities and practical opportunities. BGCI is the GTC partner that leads tree Red Listing. BGCI/GTC Red List publications completed to date include:

- The Red List of Magnoliaceae
- The Red List of Maples
- The Red List of Oaks
- The Red List of Rhododendrons
- The Red List of Trees of Central Asia
- The Red List of Endemic Trees and Shrubs of Ethiopia and Eritrea
- The Red List of Trees of Guatemala
- The Red List of Mexican Cloud Forest Trees

These publications are freely available for download from the BGCI and GTC websites (see the Useful Resources section for links). The assessments included in these publications are also being incorporated into the IUCN Red List and additional work is ongoing by BGCI and partners to produce updated Red List assessments of Betulaceae, Hydrangeaceae and important timber species.

The IUCN/SSC Conifer Specialist Group is responsible for undertaking conservation assessments of conifer species. The status of conifer Red Listing is detailed on p. 9.

Global *ex situ* surveys

Typically following publication of a taxonomically focused tree Red List, BGCI undertakes a global survey to assess *ex situ* collections of threatened taxa. Threatened taxa reported in a few or no *ex situ* collections are highlighted as priority taxa for conservation concern and recommendations are made for their conservation. BGCI/GTC global *ex situ* surveys completed to date for tree families and genera include (see the Useful Resources section, p. 30, for links):

- Global survey of *ex situ* Magnoliaceae collections
- Global survey of *ex situ* Maple collections
- Global survey of *ex situ* Oak collections
- Global survey of *ex situ* Rhododendron collections
- Global survey of *ex situ* Zelkova collections

The importance of *ex situ* collections

Ex situ plant conservation involves the maintenance and care of living plant material outside a species' natural habitat, in the form of whole plants, seeds, pollen, vegetative propagules, tissues or cell cultures. With 10% of the world's tree species threatened with extinction, and the multiple threats facing *in situ* populations of these species, *ex situ* conservation is of vital importance to safeguard these species. Botanic gardens and arboreta play a major role in the *ex situ* conservation of plants, including trees, along with other institutions such as academic institutions, forest services, private gardens, private nurseries and government agencies. For the greatest conservation value collections should, where possible, focus on threatened taxa, especially exceptional species (those that are unable to be seed banked (Pence, 2013)).

Maintaining *ex situ* collections not only provides a safe haven for taxa, securing their survival if wild populations are lost, they also have the potential to support *in situ* populations, and provide opportunities for research, such as propagation trials, and to support education programmes. *Ex situ* collections also allow for artificial propagation, which can create an available supply of material to reduce overharvesting of remaining natural populations of highly desirable plants. When produced from wild and genetically diverse material, *ex situ* plants can also supply material for reintroduction programmes, thereby reinforcing natural populations.

As detailed in Kramer *et al*. (2011) the value of *ex situ* collections for conservation depends on three main factors:

- **The type of plant material collected** – Seeds, explants and living plants. The type of material collected and how it is stored varies according to the characteristics of each taxon. Seed storage requires less space and staff effort to maintain, but is not suitable for taxa with recalcitrant or unavailable seed (exceptional species).

- **The protocols used for collecting** – Collections that are well documented, wild collected and capture broad genetic variation have the highest value to conservation. Only genetically diverse and representative collections are suitable for recovery and restoration programmes.

- **The subsequent maintenance of viable germplasm** – Proper curatorial management and appropriate care for material within collections is required to avoid unnecessary loss of plant material and any associated information.

Case Study 1:

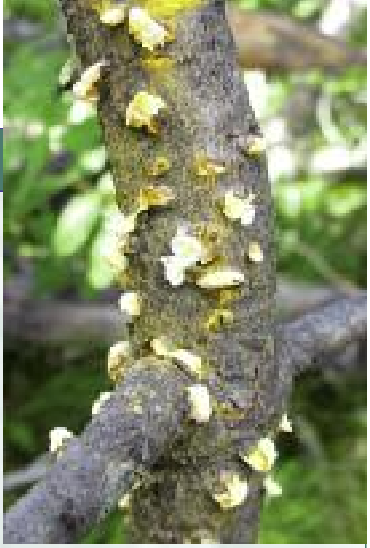
Dr. Mary Mahalovich, United States Department of Agriculture (USDA) Forest Service

Whitebark pine (*Pinus albicaulis*) is distributed from 37° to 55°N latitude and from 128° to 107°W longitude. Its distribution is split into two broad sections: the western section follows the British Columbia Coast Ranges, the Cascade Range, and the Sierra Nevada. The Rocky Mountain or eastern section extends along the high ranges in eastern British Columbia and western Alberta, and southward at high elevations to the Wind River and Salt River Ranges in west-central Wyoming. The species occurs as high as 3,050 to 3,660 m in the Sierra Nevada and northwestern Wyoming, 2,590 to 3,200 m in western Wyoming and as low as 900 m in the northern limits of its range in British Columbia. Outlying populations are found atop the Sweetgrass Hills in north-central Montana, in stands in the Blue and Wallowa Mountains of northeastern Oregon and in small, isolated ranges in northeastern California, south-central Oregon, and northern Nevada. Whitebark pine occurs on 5,770,013 ha in the western U.S.A. The total population in Canada is estimated to be around 200 million trees. In both the U.S. and Canada over 90% of the species occurs on public lands. Taxonomically whitebark pine is the only stone pine in North America, where genetic analyses place this five-needle pine in the new subsection *Strobus* within the new section *Quinquefoliae*.

The large, energy-rich wingless seeds of whitebark pine are a vital food source in the fall and spring diets of over 20 species of wildlife. During mast years, pine nuts provide 97% of the annual nourishment for Yellowstone grizzly bears. Female grizzly bears in the Greater Yellowstone Ecosystem derive 40-50% of their fall nutrition from pine nuts. Following mast years, fatter female bears produce more cubs that are born earlier and grow faster because the mothers produce more milk. During poor cone crops female bears produce smaller litters of twins or singletons.

Whitebark pine is also important as a keystone species in upper and subalpine ecosystems. As a foundation species it protects watersheds, tolerating harsh, wind-swept sites that other conifers cannot. The shade of its canopy regulates snowmelt runoff and soil erosion and its roots stabilize rocky and poorly developed soils. In upper subalpine sites whitebark pine is a major seral species that is often replaced by the shade-tolerant subalpine fir (*Abies lasiocarpa*), spruce (*Picea engelmannii*), or mountain hemlock (*Tsuga mertensiana*). The shade intolerant lodgepole pine (*Pinus contorta*) is also found with whitebark pine on seral sites.

Effect of Pests and Diseases on *Pinus albicaulis* in the U.S.A.



Below: Whitebark Pine Rust Screening CDA Nursery.

Right: Blister Rust Sporulating Canker on Whitebark Pine. (Credit: Dr. Mary Mahalovich, USDA Forest Service)

Other minor species sometimes found with whitebark pine are Douglas-fir (*Pseudotsuga menziesii*), limber pine (*Pinus flexilis*), alpine larch (Larix lyalli), and western white pine (*Pinus monticola*). Climax whitebark pine sites are found at high elevations, particularly harsh sites in the upper subalpine forests and at treeline on relatively dry, cold slopes, where trees often occur in elfin forests, clusters, groves or tree islands.

Most whitebark pine forests have low diversity in vascular plants with the majority of undergrowth plant cover being composed of grouse whortleberry (*Vaccinium scoparium*), blue huckleberry (*V. globulare*), black huckleberry (*V. membrenaceum*), false azalea (*Menziesia ferruginea*), woodrush (*Luzula hitchcockii*), and beargrass (*Xerophyllum tenax*). Other plants that may be occasionally dominant include Idaho fescue (*Festuca idahoensis*), Parry's rush (*Juncus parryi*), Wheeler bluegrass (*Poa nervosa*), buffaloberry (*Sheperdia* spp.), kinnikinnick (*Arctostaphylos uva-ursi*), and pipsissewa (*Chimaphila umbellata*). High elevation climax stands of whitebark pine can contain many unique alpine, subalpine, and montane undergrowth assemblages, some of which are only found in association with whitebark pine. Whitebark pine forests have unexpectedly high biomass but low productivity. The oldest known tree is about 1,280 years old and is found in central Idaho in the Sawtooth National Forest. This ancient tree has the only known rare allele and based on genetic markers it is homozygous at 13 loci.

The four threats facing whitebark pine are the exotic fungus white pine blister rust (*Cronartium ribicola*), the native mountain pine beetle (*Dendroctonus ponderosae*), altered fire regimes, and climate change. Blister rust was introduced in whitebark pine cover types around 1925. In stands throughout the U.S. and Canada, blister rust mortality averages 35% (range of 8-58%) and infection levels average 66% (range of 17-95%). The good news is whitebark pine does have proven rust resistance. Artificial inoculation trials of seedlings from phenotypically resistant 'plus' trees show 47% resistance in the Northern Rockies, and in the Cascade Range canker-free seedlings average 26%.

More recent mortality can be attributed to the native insect pest, mountain pine beetle. The likelihood of continued mortality is linked to future warmer weather at higher elevations. Since blister rust was introduced, there have been three beetle outbreaks: the first in the 1920-30s killed significant areas of whitebark pine and left many "Ghost Forests"; the second was in the 1970-80s; and the more recent outbreak began in 2001, killing 50-60% of the remaining whitebark pine. Aerial detection surveys and on-the-ground monitoring indicate the recent outbreak peaked around 2009. Tree protection against mountain pine beetle includes verbenone, an anti-aggregate pheromone in pouch or flake formulations and the insecticide carbaryl.

In addition to mortality due to wildfires, 60 years of fire suppression have resulted in seral replacement of whitebark pine to subalpine fir, Engelmann spruce, mountain hemlock, and lodgepole pine.

The impacts of warming temperatures and decreased precipitation will likely result in a decline in suitable habitat, increased mountain pine beetle activity, an increase in the number, intensity, and extent of wildfires, and an increase in blister rust particularly in wave years. Bioclimatic models predict whitebark pine is projected to diminish to an area equivalent to less than 3% of its current distribution, especially in forests at the lowest elevations. The future outlook however may not be as bleak. These models have not taken in to account plasticity and the generalist adaptive strategy of whitebark pine. Simply stated, plasticity is where an individual can buffer environmental changes by having many different phenotypes. Moreover, genetic studies indicate whitebark pine has moderate to high levels of genetic variation in key adaptive traits, an overall lack of inbreeding, and one of the highest levels of genetic diversity, shared by two other five-needle pines, Great Basin bristlecone pine (*Pinus longaeva*) and limber pine, and the aspen (*Populus tremuloides*).

Gene conservation efforts carried out by the USDA Forest Service, in collaboration with the United States National Park Service, the United States Bureau of Land Management, the United States Fish and Wildlife Service, Parks Canada and the Alberta Tree Seed Centre, include seed, pollen and clone banks, seed orchards, field tests, and the broad-scale network of plus trees in the genetics programs. Over 1,500 ha have been planted with rust resistant seedlings and research is ongoing in direct seeding to augment natural regeneration in the backcountry.

It is advisable to preserve lineages/accessions in more than one location via back up (duplicate) collections, both within a single collection (i.e. multiple individuals of one lineage/accession in a single location) and among collections (i.e. multiple locations for single lineages/accessions). This is an important security measure safeguarding against natural disasters, vandalism, invasive pests or diseases, natural death or human error.

Botanic garden and arboreta collections also provide a valuable monitoring network which can be used as an early warning system for the arrival of new invasive pests and diseases. The great potential of such a network has been recognised by BGCI. A survey was conducted in 2011, with support from the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (USDA-APHIS), to identify relevant expertise and policies at botanic gardens to detect, manage, and prevent invasive species. The survey found that 65% of responding institutions had invasive species policies or programs in place to help minimize the risks posed by insect pests, plant pathogens or potentially new invasive plants (Kramer and Hird, 2011). The study called for the development of a global network to coordinate the work currently being done, expand current efforts, connect collections, share information and increase collaboration at local, regional and global levels (Kramer and Hird, 2011). From October 2013, BGCI is hosting a new position to develop an International Plant Sentinel Network (IPSN) and examine how BGCI's PlantSearch database can be improved to capture information on pests and diseases within *ex situ* collections. Case Study 1 (p. 6) details the impact of pests and diseases on conifers in North America and the potential value of *ex situ* collections for detection and preventing the incursion of new pests and diseases.

Botanic garden collections are also being proposed as chaperones for threatened species to investigate and combat the effects of climate change. The subject of 'assisted migration' (intentionally relocating plants to new habitats) is a controversial one, but botanic gardens can assist by providing test sites for assisted migrations. Missouri Botanical Garden, U.S.A, in collaboration with BGCI, are developing a proposal to use botanic gardens as test sites for controlled introductions for species threatened with extinction due to changing climatic conditions (Gewin, 2013). Case Study 2 (p. 10) details the impact of climate change on conifers in North America.

Policy context - *ex situ* conservation

The Global Strategy for Plant Conservation (GSPC) was adopted in 2002, by parties to the Convention on Biological Diversity (CBD). The GSPC involves 16 targets for plant conservation. The targets were set with an initial deadline of 2010, after which they were revised and new targets were developed for the period 2011-2020. Target 8 is directly aimed at using *ex situ* collections to support conservation:

'At least 75% of threatened plant species in ex situ *collections, preferably within the country of origin, and at least 20% available for recovery and restoration programmes' by 2020.*

Measuring progress towards Target 8 of the Global Strategy for Plant Conservation (GSPC)

The ability to measure progress towards Target 8 is largely dependent on Target 2 of the GSPC:

'An assessment of the conservation status of all known plant species, as far as possible, to guide conservation action' by 2020.

BGCI's PlantSearch database is the only tool for measuring progress towards Target 8 at the global level. PlantSearch holds taxon-level information from *ex situ* collections around the world. Lists maintained in PlantSearch are cross-referenced with conservation assessments to determine progress towards Target 8 of the GSPC.

Based on the conifer conservation assessments on the IUCN Red List (IUCN, 2013a) and the data provided for this survey, this report investigates where *ex situ* conifer conservation stands in relation to Target 8.

GardenSearch
BGCI's GardenSearch database is the only global source of information on the world's botanical institutions. GardenSearch allows users to search over 3,000 profiles to locate botanic gardens, arboreta, zoos, and similar organization with specific resources and expertise. GardenSearch is a valuable tool for connecting researchers, collaborators, and the general public to botanical resources available in gardens worldwide. GardenSearch also provides a web presence for small institutions that do not have their own website, connecting them to the global conservation community. www.bgci.org/garden_search.php

PlantSearch
BGCI's PlantSearch database is the only global database of plants in cultivation, and is free to contribute to and access. PlantSearch connects around 2,000 researchers and horticulturists to collections every year. Locations and gardens are not publicly revealed, and requests can be made via blind email messages. PlantSearch is an easy way for *ex situ* collections to contribute to broader *ex situ* assessments such as this conifer survey. By uploading a taxa list to PlantSearch, collection holders can not only connect their collections to the global botanical community, but also find out the conservation value of their taxa including the number of locations each taxon is known globally and current global conservation status.

It is important for *ex situ* collections to share accurate data more broadly and keep it updated. PlantSearch relies on collection holders to upload up-to-date taxa lists on an annual basis to ensure accuracy and enhance usability of the data. www.bgci.org/plant_search.php

Conifers

Conifers grow on all continents except Antarctica. Some genera have broad distributions, spanning continents, with many taxa, while others are monotypic or contain taxa endemic to a very small area. Figure 1 shows a map of global conifer distributions in the wild.

There are 615 conifer species recognised globally[2]. Conifers are classified into eight families: Pinaceae (ca. 223 species), Cupressaceae (ca. 135 species), Podocarpaceae (ca. 174 species), Araucariaceae (ca. 36 species), Taxaceae (ca. 24 species), Cephalotaxaceae (ca. 8 species), Phyllocladaceae (ca. 4 species) and Sciadopityaceae (1 species) (IUCN, 2013a).

Uses

Conifers are one of the world's most important timber resources. Many species are fast growing, producing soft wood that is straight and has multiple uses. This means they have huge economic importance. Exploitation of conifer resources from forests is ongoing, but there is a trend towards using more sustainable sources, such as from plantations, especially in developed countries.

Not all conifer species are fast growing; some are slow growing and individuals can live for thousands of years and reach enormous sizes. *Sequoiadendron giganteum*, the Giant Redwood (assessed as Endangered (EN) on the IUCN Red List (IUCN, 2013a)) is the largest tree species in the world. Individuals can reach huge diameters, the largest individual tree, known as 'General Sherman' has a circumference near the ground of 31.1m and provides habitat to thousands of insect species (Global Trees, 2013).

Conifers also yield a variety of valuable Non Timber Forest Products (NTFPs) including food (nuts and seeds), resins and medicinal extracts. The most notable example of medicinal use is the anti-cancer agent Taxol produced from *Taxus* species (Yew trees). Since discovery of the medicinal uses of Taxol from *Taxus brevifolia* in the 1960s, species of this genus have become heavily exploited for treating various forms of cancer (Global Trees, 2013).

Conifers are also very popular for their ornamental value, leading to their high prevalence in private and public parks and gardens around the world. Many ornamental collections focus on conifer cultivars rather than true, botanical taxa.

Threats facing conifers

The threats facing the world's conifers are common to many of the world's tree species (see Table 1, p. 12).

Status of conifer Red Listing

The variety of threats facing wild conifer populations has led to a number of them being given threatened status. The IUCN/SSC Conifer Specialist Group is responsible for undertaking conservation assessments of the world's conifers.

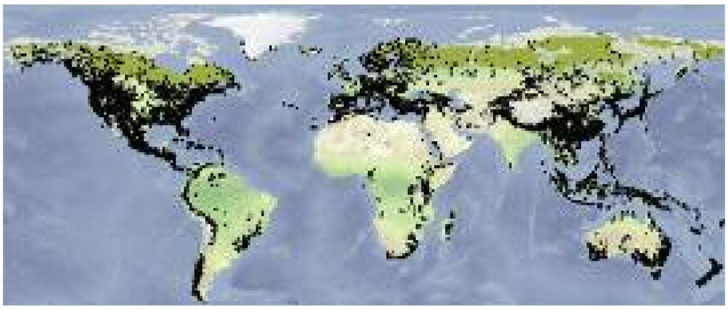


Figure 1: Global distribution of conifers in the wild (Source: Aljos Farjon and Denis Filer, An Atlas of the World's Conifers. Brill, Leiden & Boston, 2013).

All known conifer species were assessed and incorporated into 'The World List of Threatened Trees' (Oldfield, *et al*., 1998) and subsequently published to the IUCN Red List. Some taxa were reassessed periodically since the 1998 assessments.

A full global reassessment of conifer species was published to the IUCN Red List in July 2013[3]. This work was coordinated by Aljos Farjon, Chair of the IUCN/SSC Conifer Specialist Group, and jointly undertaken with staff at the Royal Botanic Garden Edinburgh. According to the global reassessment, of the 615 recognised species of conifer, 211 species (34%) are now listed on the IUCN Red List as threatened with extinction (IUCN, 2013a). This represents an increase of 4% since the last complete assessment in 1998.

Sequoiadendron giganteum *at Wakehurst Place, UK. Endangered (EN), reported as held in 181* ex situ *collections worldwide.*

[2] The exact figure varying with taxonomic revisions and disagreement among specialists.
[3] With the exception of *Microcachrys tetragona* which was published to the IUCN Red List in November 2013 and *Agathis australis* which has no assessment presently listed on the IUCN Red List as the conservation status of this taxon is under discussion.

Case Study 2: Climate Adaptation for the Conservation and Management of Yellow-cedar

Paul E. Hennon, United States Department of Agriculture (USDA) Forest Service

Expansive areas of pristine yellow-cedar (*Callitropsis nootkatensis* (D. Don) ex D.P. Little) forests have been dying for the past 100 years. This severe tree death (Figure A) extends 1,000 km along the North Pacific coast in Alaska and British Columbia. Once a mystery, research has revealed the paradoxical cause of this forest problem -- freezing injury to tree roots which are no longer protected by snow in a warming climate. We use this new knowledge as the foundation for a detailed climate adaptation strategy to sustain the culturally, economically, and ecologically valuable yellow-cedar.

Intense tree death in Alaska known as yellow-cedar decline. (Credit: Paul E. Hennon, USDA Forest Service)

Early research evaluated possible biotic causes of forest decline (e.g. fungi, insects, nematodes, and viruses) but found none to play significant roles in injury or death (Hennon *et al*., 1997). Spatial patterns of healthy and impacted forests on the landscape and a preliminary risk analysis of abiotic factors (D'Amore and Hennon, 2006) provided valuable clues that led to a working model to explain yellow-cedar tree death (Figure A). Individual studies were then used to test each step in the cascading complex of landscape and site factors and the one physiological vulnerability of yellow-cedar—late winter freezing injury to fine roots (Hennon *et al*., 2012).

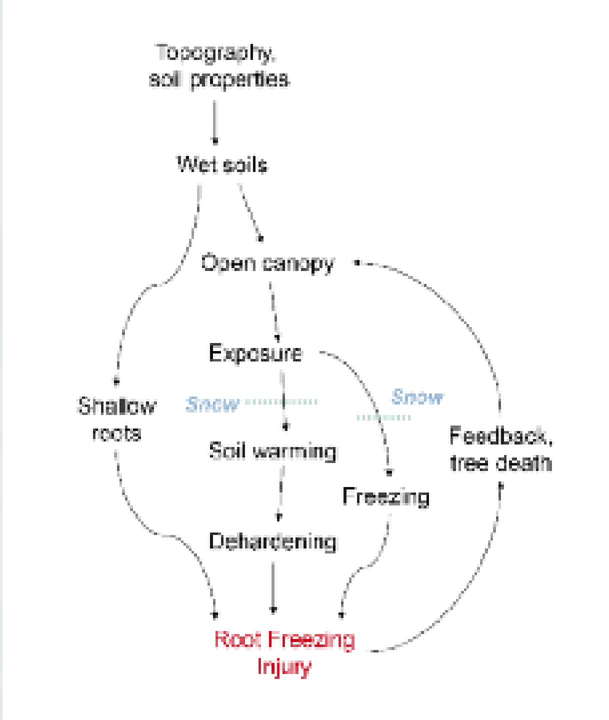


Figure A. Cascading site, climate, and physiological factors that lead to tree death for yellow-cedar. The mitigating role of snow is shown.

Longer-term climate or near-term weather events influence each of these steps. The cool, moist climate that developed in coastal Alaska several thousand years ago created the bog and forested wetland conditions that favoured the abundance of yellow-cedar but also forced shallow rooting (Beier, *et al*., 2008). A unique nitrogen acquisition adaptation helped yellow-cedar to be more competitive on these wet sites but further increased its vulnerability to fine roots freezing (D'Amore, *et al*., 2009). The open canopy condition of forests on boggy soils (Hennon *et al*., 2010) permitted a more extreme microclimate: greater warming to trigger cedar dehardening in late winter (Schaberg *et al*., 2005) and less thermal cover for cold temperature penetration into soils during cold weather (Hennon *et al*., 2010). Research on cold tolerance demonstrated the vulnerability of yellow-cedar roots to freezing in late winter and early spring: soil temperatures below -5 ˚C are lethal to yellow-cedar roots (Schaberg *et al*., 2008) but not other associated tree species (Schaberg *et al*., 2011). These seasonal conditions are frequent in coastal Alaska and British Columbia when cold high-pressure continental air masses move across the narrow interior-coastal boundary to injure yellow-cedar roots, which is the proximal cause of this forest decline (Hennon *et al*., 2012).

Reduced snow is the environmental change that triggered the widespread mortality, particularly as the climate emerged from the Little Ice Age in the late 1800s and further warmed in the late 1900s (Beier *et al*., 2008). The presence of snow buffers soil temperatures, disrupting the progression of events leading to tree injury (Figure A). Comparing snow models to the distribution of yellow-cedar decline at several spatial scales illustrates the controlling influence of snow in the health of yellow-cedar forests (Hennon *et al*., 2012). Yellow-cedar is healthy where snow persists past the last cold period in spring, or where yellow-cedar is deep-rooted on better-drained soils.

How do we use this knowledge to maintain and manage this valuable tree species? The initial step in the adaptive conservation strategy is to model and display current and future suitable habitat for yellow-cedar. The complex cause of tree death can be reduced to two risk factors for landscape species vulnerability modelling: soil drainage and snow accumulation. Forecasting future snow levels helps to identify yellow-cedar populations that are currently healthy but at risk for future mortality due to inadequate late winter snowpack.

This partitioning of the coastal landscape into suitable and unsuitable areas for yellow-cedar is essential for considering its viability in landscapes in protected conservation status and in those that are actively managed. Much of the widespread yellow-cedar mortality is in landscapes designated in conservation status that have no active forest management. Current research investigates how natural processes play out in unmanaged areas, especially the successional trajectories that favour other tree species as forests emerge from intensive yellow-cedar mortality. The loss of yellow-cedar populations may also signal changes in the chemistry of soils, stream water, and vegetation to create even broader ecosystem effects because of the manner in which yellow-cedar alters pH, calcium, phosphorus, and nitrogen concentrations (D'Amore, 2009). Yellow-cedar decline illustrates the challenge in establishing conservation landscapes to protect populations of species by minimizing human activities but yet nonetheless are significantly altered by climate change.

In areas where vegetation management occurs, yellow-cedar can be promoted through active management by assisting its regeneration and competitive status on sites considered to be favourable now and in the future. Planting or thinning is often needed to ensure the initial regeneration and early growth of yellow-cedar (Hennon *et al*., 2009), as the species has low reproductive capacity. These activities are directed at higher elevation or on well-drained soils where snow or deeper rooting, respectively, protects yellow-cedar roots from lethally cold temperatures. Nudging yellow-cedar's niche toward well-drained soils by planting and thinning offers an attractive option because these are the sites that have the greatest forest productivity and history of forest management.

The extreme economic value of yellow-cedar wood provides another opportunity for management in the conservation strategy. Recent studies demonstrate that dead yellow-cedar forests represent a surprisingly valuable potential wood resource from salvage recovery even for trees that have been dead for up to a century (Hennon *et al*., 2007; Hennon *et al*., 1990). The exceptional heartwood chemistry of dead trees (Kelsey, *et al*., 2005) greatly slows deterioration to retain wood properties long after death (Hennon *et al*., 2007). Salvage recovery of dead yellow-cedar where it is now maladapted (i.e. to inadequate snow on wet sites) can relieve pressures from timber harvesting in other areas more suitable for long-term conservation of yellow-cedar.

Yellow-cedar decline highlights the paradoxes and complexities that might be expected in other forest - climate change scenarios. The physiological mechanisms of species vulnerabilities to climate change need to be identified, tested experimentally, and linked to where tree species grow in forest ecosystems. Climate requirements can be viewed as one part of tree species' niches, which then need to be integrated with soils preferences, biotic interactions, as well as management experience to support the development of adaptive strategies.

Yellow-cedar tree succumbing to the root freezing injury and death. (Credit: Paul E. Hennon, USDA Forest Service).

Threat	Description
Habitat destruction and degradation	Conifers are common features in forests around the world. Areas of forest or woodland are increasingly being cleared for food production to support growing human populations, urban expansion, oil and mineral extraction operations and large scale developments such as hydro-electric infrastructure. This leads to loss of habitat and degraded forest areas.
Forest fires	Wildfires can destroy large areas of forests that provide habitat to the world's conifer species. The Food and Agriculture Organisation of the United Nations (FAO) reported that the area of forest affected by fire is hugely underreported; less than 10% of forest fires are prescribed burning while the rest are classified as wildfires (FAO, 2010).
Extraction for timber	Timber produced from conifer species provides an important source of income, but if not carefully managed, felling in natural forests can have negative effects on species populations and natural ecosystems. Establishment of timber plantations can reduce pressure on natural extraction. Sustainable forest management (SFM) has also been a major global goal over the past twenty years, but efforts have not always been successful, particularly in developing countries (FAO, 2010).
Extraction for ornamental/ landscaping purposes	The popularity of conifer species in private collections can threaten their survival in the wild. Full plants or seedlings can be extracted from the wild for sale as ornamentals. Over-harvesting can threaten wild populations. For such species wild collection needs to be controlled and nursery production can further subside collector demand. Over-exploitation can lead to taxa being listed as threatened on the IUCN Red List and included in Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES) Appendices, such as *Araucaria araucana* (IUCN status of Endangered (EN) and listed in CITES Appendix I).
Extraction of non-timber products	Non-timber products obtained from conifer species include resin, edible seeds, medicines and fire wood (particularly in developing countries). Sustainable harvesting is essential for these taxa, but such methods are often not employed. For example, the majority of Asian Yew species are now listed as threatened on the IUCN Red List (IUCN, 2013a) and are included in Appendix II of CITES (CITES, 2013) as a result of over-exploitation for the anti-cancer agent Taxol.
Pests, diseases and invasive species	Pests, diseases and invasive species pose great threats to the world's biodiversity and global economic health (Pimentel *et al*., 2005). Pests and diseases have had particularly detrimental effects on tree populations in recent years, including numerous wild conifer populations. Imports of timber and food products and ornamental plants have increased the risk of introducing new invasive plants, pests and diseases internationally. The effects of invasive species are particularly large for conifers and other tree species, as the growth and re-establishment rate of tree species is generally slow.
Climate change	Climate change can alter ecosystem integrity. Water availability and temperature increases can force species to shift to higher latitudes and altitudes. Climate change is a particular threat to montane tree species already occupying the highest elevations of their natural ranges. This is also of particular concern for species with poor regeneration mechanisms, which do not have the ability to shift and establish in new habitats fast enough to keep up with climate change.
Weak, outdated or fragmented legislation and insufficient or ineffective conservation measures	Proper legislation and enforcement is lacking to protect natural populations of some conifer species. Although many countries have signed the Convention on Biological Diversity (CBD) and Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), policy-related issues such as weak implementation at federal levels and conflicting policies can abate such measures (Brandon *et al*., 1998). This leads to insufficient or ineffective conservation. *In situ* conservation is an important mechanism for protecting species and most countries have established networks of protected areas such as national parks and nature reserves, but despite substantial efforts to ensure the effective management of some protected areas, many are not so well monitored; as a result, illegal logging, extraction, forest clearance and urban encroachment persist (Chape *et al*., 2005).
Slow or poor natural regeneration	Many conifer taxa have slow growth rates and slow or poor natural regeneration. This limits their ability to re-establish following habitat disturbance. All above-mentioned threats are compounded for taxa with regeneration difficulty.

Table 1: Threats facing conifers worldwide[4].

[4] Information included in Table 1 has been collated from a number of sources including Farjon and Page (1999) and Food and Agriculture Organisation of the United Nations (FAO, 2010). Additional references are provided within the text of Table 1. See individual taxon assessments on the IUCN Red List (IUCN, 2013a) or 'Threatened conifers of the world' (http://threatenedconifers.rbge.org.uk/), maintained by the Royal Botanic Garden Edinburgh (RBGE, 2013) for details of threats to specific taxa.

The conservation status of 33 conifer species has worsened since the 1998 assessments. The Monterey Pine (*Pinus radiata*) was previously assessed as Least Concern, but the most recent assessment categorises this species as Endangered. This species is the world's most widely planted pine species, highly valued for its rapid growth and pulp qualities. However, the continuing decline of natural populations of this species and the remaining small area of occupancy which has led to its Endangered status assignment is a result of past and ongoing threats including logging, feral goats, an introduced alien pathogen and competition from other trees in the absence of periodic fires (IUCN, 2013a).

Another conifer species previously assessed as Least Concern and now assessed as Endangered is the Atlas Cedar (*Cedrus atlantica*). This species is native to the Atlas Mountains of Algeria and Morocco and is now considered Endangered due to the species decline experienced over the last 50 years, mainly as a result of over-exploitation. Remaining populations are further threatened by various pests, overgrazing, drought and repeated burning (IUCN, 2013a).

Conservation action has led to an improved IUCN Red List status for the Lawson's Cypress (*Chamaecyparis lawsoniana*). This once heavily-logged species, the wild population of which also declined due to an introduced pathogen, was listed as Vulnerable in its last assessment in 2000. It is now classified as Near Threatened as a result of improved management practices in California and Oregon, including planting disease-resistant stock. If conservation actions continue for this species, it may be listed as Least Concern within 10 years (IUCN, 2013a).

The updated conservation assessments have been used to produce a Sampled Red List Index for Plants (IUCN, 2013b). The Red List Index aims to determine the status of biodiversity, how it changes over time, and the extinction risk of individual species. The Sampled Red List Index for Plants is based on a sample of 7,000 plant species, including all conifer species.

Table 2 summarises the number of conifer taxa recorded in 2013 under each IUCN Red List category.

	IUCN Red List Status	Number of taxa	% of total conifer taxa
	Extinct (EX)	0	0
	Extinct in the wild (EW)	0	0
Threatened	Critically Endangered (CR)	42	5.0
Threatened	Endangered (EN)	131	15.7
Threatened	Vulnerable (VU)	119	14.3
	Near Threatened (NT)	129	15.5
	Least Concern (LC)	389	46.7
	Data Deficient (DD)	23	2.8

Table 2: Conservation status of conifer taxa assessed on the IUCN Red List, according to IUCN Red List Categories and Criteria: Version 3.1 (IUCN, 2013a)[5].

Ex situ *conifer collections at Bedgebury National Pinetum, UK.*

Ex situ conservation of conifers

As described previously for all plant taxa, *ex situ* collections are an essential conservation measure to safeguard against extinction. Botanic gardens play valuable roles in conserving threatened conifers and are well-placed to carry out the essential work needed in the future. *Ex situ* conifer collections provide valuable means for researching and reducing the impacts of two major threats listed in Table 1; pests and diseases, and climate change. See Case Studies 1 (p. 6) and 2 (p. 10) for examples on how *ex situ* collections assist in the management of pests and diseases and climate change, respectively.

The maintenance of conifer taxa in *ex situ* collections, particularly in scientific institutions such as botanic gardens and arboreta, supports conservation, education and research of these taxa. Research in these institutions includes, for example, analysis of potential impacts caused by, and management techniques for, pests and diseases, and the development of propagation knowledge, including the cultivation of disease-resistant stock. *Ex situ* conifer collections also provide a valuable resource for reintroduction and restoration programmes (see Case Studies 4 (p. 23) and 5 (p. 25) for examples).

Conifers are popular in *ex situ* collections, historically and presently, due to their ornamental value. They are therefore commonly found in collections of botanic gardens, arboreta and private or public parks. This does not necessarily guarantee these collections are of high conservation value, however. Poor documentation, little genetic diversity, and unknown or non–wild source plant material are common issues for *ex situ* collections that limit their conservation value.

A number of studies have been undertaken prior to this one to determine the presence of threatened conifer taxa within *ex situ* collections. In September 1989 the Botanic Garden Conservation Secretariat (BGCS) undertook a survey to identify which of the 264 conifer taxa then considered to be threatened were held in *ex situ* collections. Information from 183 gardens was received for the 1989 survey and found that these gardens

[5] Table 2 shows information for infraspecific taxa assessed separately on the IUCN Red List. In some cases, where the infraspecific taxon assessment is the same as the species level assessment, a separate assessment has not been published. The total number of conifer taxa is therefore greater than the total number of taxa assessed separately. The percentage of threatened taxa represented in Table 2 is 35%, higher than the official figure of 34% which refers to the percentage of threatened species, rather than total taxa as presented here.

held 179 (or approximately 68%) of threatened conifers in cultivation. The majority of taxa held in collections (all except five species) included at least one accession of wild origin. *Picea omorika* was reported as the most commonly grown threatened species, followed by *Abies pinsapo* and *Araucaria heterophylla* (Leadlay, 1990).

The IUCN/SSC Conifer Specialist Group 'Status Survey and Conservation Action Plan' (Farjon and Page, 1999) listed priority taxa for *ex situ* conservation on a regional basis. The report also documented collections held by large institutions: Pinetum Blijdenstein (The Netherlands), Royal Botanic Garden Edinburgh (four gardens, UK), Royal Botanic Gardens Kew (UK) and Royal Botanic Gardens Sydney (Australia).

Aims and objectives of this survey

This assessment builds upon the 'Status Survey and Conservation Action Plan for Conifers' (Farjon and Page, 1999). The most up-to-date conservation status assessments available on the IUCN Red List (IUCN, 2013a) serve as the foundation for this conservation collections assessment.

The *ex situ* survey supporting this report reanalyses the current status of conifer collections, with particular focus on threatened taxa. The survey identifies which threatened taxa are currently maintained in and absent from *ex situ* collections. The survey also aims to determine the conservation value of collections of threatened taxa by analysing the number of individuals reported in collections and their known provenances.

This report provides a number of recommendations for *ex situ* conservation of threatened conifers based on collections data reported to BGCI in 2012 and 2013. The recommendations provide a basis for inclusion of additional threatened conifer taxa in collections as well as improving existing collections.

Chamaecyparis lawsoniana *at Bedgebury National Pinetum, UK. Near Threatened (NT), reported as held in 160* ex situ *collections worldwide.*

Guidance is also provided to go beyond *ex situ* collections and encourage integrated conservation of threatened conifers allowing for reintroduction and restoration programmes that support *in situ* conservation efforts.

Important references are presented in the Useful Resources section, p. 31. A key reference to be consulted alongside this report is 'Integrated conservation of tree species by botanic gardens: a reference manual' (Oldfield and Newton, 2012), which provides a step-by-step guide to undertaking integrated conservation of tree species.

A number of case studies are presented within this report to illustrate real-world examples of conifer conservation undertaken by various botanic gardens and arboreta throughout the world. These case studies illustrate the capacity and skills held in these institutions and demonstrate that they are well placed to carry out valuable conservation work.

The *ex situ* collections data, case studies, and recommendations within this report demonstrate how botanic gardens fulfil vital conservation roles, working in tandem with *in situ* efforts, to support threatened wild populations and reduce pressure on shrinking populations. While this report is focused on conifers, the information and recommendations presented are intended to be of value to the broader conservation community and *ex situ* collection holders.

Methodology

The methodology of this survey followed that employed for previous *ex situ* surveys undertaken by BGCI. The survey has been conducted at a global level, including all conifer taxa, and *ex situ* collection holders from around the world were invited to contribute data.

Data collection

In August 2012, the first announcement of the *ex situ* conifer survey was released, inviting collection holders to provide a list of the conifers held in *ex situ* collections to BGCI's PlantSearch database. Further information was also requested for each threatened conifer taxon, as follows:

- Provenance of material (wild, horticultural or unknown source)
- Number of individuals
- Whether the conifer is part of a restoration or reintroduction programme led by the institution

The invitation to participate in the survey was sent to members of the IUCN/SSC Global Tree Specialist Group and botanic gardens and arboreta identified as holding important collections of conifers, identified by searching for key words (including conifer, conifers, Abies, Araucaria, etc.) in BGCI's GardenSearch database. The survey was also promoted on the BGCI website and through BGCI's e-newsletter, *Cultivate*. Survey announcements were also sent to a number of networks, including the U.S. Conifer Societies and distributed

Sciadopitys verticillata at Bedgebury National Pinetum, UK. Near Threatened (NT), reported as held in 156 *ex situ* collections worldwide.

via a number of other relevant listserv and mailing lists. Additionally, all invitations and announcements requested that the invitation be forwarded on to other known important conifer collection holders in an aim to obtain data from as many conifer collections as possible.

Plant lists were either directly uploaded to PlantSearch by participating institutions, or sent to BGCI via email and subsequently uploaded to PlantSearch for analysis. Additional information on provenance and number of individuals was submitted in Microsoft Excel format and analysed in combination with PlantSearch data. Data submitted via the International Conifer Conservation Programme (ICCP) collections were carefully incorporated to avoid any duplicate data sets provided directly from institutions within the ICCP.

The data collection period was extended to align with the publishing of the updated conifer conservation assessments on the IUCN Red List in July 2013. This ensured the survey was based on the most recent conservation assessments available. Data was accepted until August 2013.

Information was not collected on the type of material held by institutions (i.e. seed, explants or living plant), although a majority of collections are assumed to be composed of living plants. It is recommended, p. 28, that this be incorporated into further study.

Taxonomy

The taxonomy used in this survey aligns with the Conifer Database, maintained by Aljos Farjon, the most up-to-date version is available in BRAHMS (Farjon, 2013). The Conifer Database recognises 615 conifer species (accepted names). The conifer assessments published on the IUCN Red List follow the taxonomy of the Conifer Database, therefore this taxonomy was selected to ensure the *ex situ* survey aligns with the conservation assessments. The Conifer Database also includes recognised synonyms. The following section explains how synonyms were incorporated into the analysis.

Analysis

Information held in PlantSearch was compared to a list of accepted names and synonyms held in the Conifer Database in BRAHMS (Farjon, 2013). Conifer records held in PlantSearch were downloaded from the database for further analysis. This included records that were an exact match to the accepted names and synonyms listed in the Conifer Database, as well as records that were a near match (for example *Abies fraserii* as well as *Abies fraseri* and *Abies cilicica* ssp. *cilicica* as well as *Abies cilicica* subsp. *cilicica*). Records that linked to more than one accepted name were left out of the analysis[6]. All records including a cultivar epithet were excluded from analysis.
The results of this initial analysis was the number of institutions known to maintain each taxon (see Annex I, p. 35). A separate analysis was undertaken including all known cultivar records, to analyse overall conifer collections composition. Additional accession-level information was collected and compiled for threatened taxa and analysed to determine further conservation value of collections. This included provenance information and number of individuals held in each collection (see Results and analysis section, p. 16).

Xanthocyparis vietnamensis at Bedgebury National Pinetum, UK. Endangered (EN), reported as held in 17 ex situ collections worldwide.

A number of limitations to the data provided and survey methodology are acknowledged in the Results and analysis section as well (p. 24). Overall findings were used to develop recommendations for further work and *ex situ* collections development (see Recommendations, p. 28).

[6] This accounted for ca. 50 plant records, representing ca. 30 synonyms matching more than one accepted name.

Results and analysis

Ex situ collections: Number of species in collections (per IUCN Red List status)

The survey of *ex situ* collections identified 27,173 conifer records[7] from over 800 institutions[8] matching accepted names or synonyms listed in the Conifer Database in BRAHMS (Farjon, 2013). This included data uploaded to PlantSearch and data provided directly to support this survey. Table 3 summarises the conifer collections identified in this survey.

Overall survey results show that **81.2% of threatened conifer taxa are reported in *ex situ* collections**; and that Target 8 of the GSPC to have at least 75% of threatened plants in *ex situ* collections is being met for threatened conifer taxa.

Despite meeting Target 8, there are no known *ex situ* collections reported for 7 Critically Endangered (CR) and 33 Endangered (EN) conifer taxa. If the threatened wild populations of these taxa are lost, there are no *ex situ* collections in place as an insurance policy against extinction. Presence and absence of taxa in *ex situ* collections according to IUCN Red List status is shown in Figure 2.

The following seven Critically Endangered (CR) taxa are currently not reported by any collections and should be brought into *ex situ* collections as a matter of urgency:

- *Juniperus gracilior* var. *ekmanii*
- *Pinus squamata*
- *Podocarpus costaricensis*
- *Podocarpus palawanensis*
- *Podocarpus perrieri*
- *Podocarpus sellowii* var. *angus*
- *Amentotaxus argotaenia* var. *brevifolia*

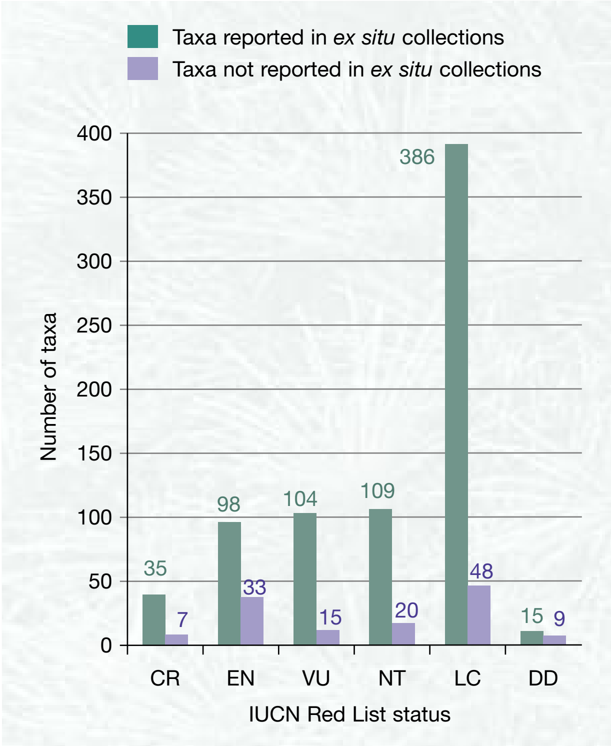


Figure 2: Presence and absence of threatened conifer taxa known in ex situ *collections per IUCN Red List status (Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD)).*

Annex I (p. 35) provides a full list of all threatened conifer taxa, with IUCN Red List status and the number of *ex situ* collections reporting each taxon. This list is available electronically upon request.

Further, this survey has shown that many threatened conifer taxa are only represented in a single or small number of collections. Figure 3 illustrates that 79 globally threatened taxa (Critically Endangered, Endangered or Vulnerable) have only been reported in 1-5 collections. This is not a sustainable

	No. of taxa reported in *ex situ* collections	No. of taxa not reported in *ex situ* collections	Total no. of taxa		
CR EN VU	35 98 104	7 33 15	42 131 119	Threatened taxa reported in *ex situ* collections: 81.2%	Threatened taxa not reported in *ex situ* collections: 18.8%
NT LC	109 386	20 48	129 434[9]	Non-threatened taxa reported in *ex situ* collections: 87.9 %	Non-threatened taxa not reported in *ex situ* collections: 12.1%
DD	15	9	248	Data Deficient taxa reported in *ex situ* collections: 62.5%	Data Deficient taxa not reported in *ex situ* collections: 37.5%
Total	747	132	879		

Table 3: Summary of ex situ *conifer collections survey.*

[7] Each record included in this survey represents the presence of a single living conifer taxon within an institution and may include multiple accessions and/or individual specimens.
[8] This represents conifer collection records from 635 institutions with plant lists held in BGCI's PlantSearch database and 230 institutions involved in the International Conifer Conservation Programme (ICCP), led by the Royal Botanic Garden Edinburgh. Overlap between ICCP institutions which maintain collection records in PlantSearch has been accounted for. The total number of *ex situ* collections represented in this study is 838.
[9] The total number of Least Concern (LC) and Data Deficient (DD) taxa presented in Table 3 differs to the total number in Table 2 as some infraspecific taxa were assessed within species level assessments on the IUCN Red List, reducing the total number of taxa reported in Table 2.

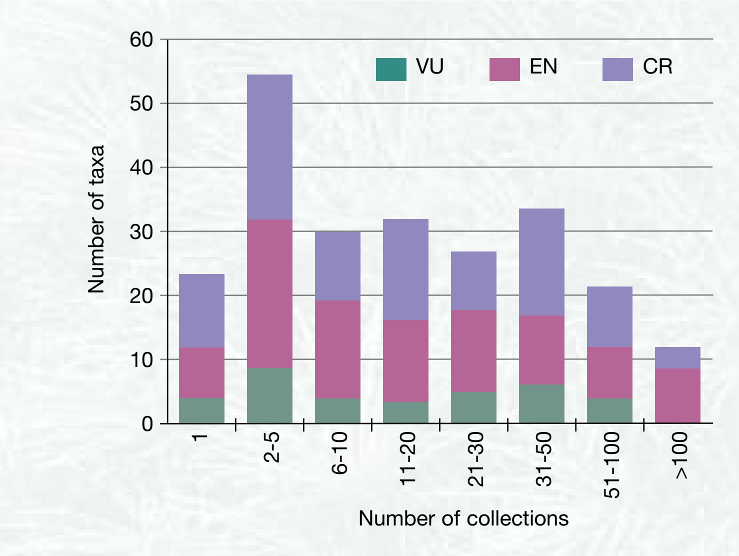


Figure 3: Number of collections of threatened conifer taxa reported to PlantSearch per IUCN Red List status (Critically Endangered (CR), Endangered (EN) and Vulnerable (VU)).

conservation approach due to the vulnerability of a small number of collections to, for example, a natural disaster or disease outbreak. Additionally, one or a few collections would likely not provide sufficient genetic diversity for *in situ* applications if remaining wild populations are lost. Four Critically Endangered (CR) conifer taxa are reported as held in only one collection and an additional nine Critically Endangered (CR) conifer taxa are reported as held in less than five collections, as listed in Table 4. Additionally, 32 Endangered (EN) conifer taxa and 34 Vulnerable (VU) conifer taxa are also reported as held in 1-5 collections.

Taxon name	Number of collections reported worldwide
Juniperus barbadensis var. *barbadensis*	1
Juniperus saxicola	1
Abies yuanbaoshanensis	1
Podocarpus decumbens	1
Cupressus chengiana var. *jiangensis*	2
Juniperus deppeana var. *sperryi*	2
Libocedrus chevalieri	2
Abies beshanzuensis	2
Abies delavayi ssp. *fansipanensis*	2
Pinus massoniana var. *hainanensis*	2
Podocarpus urbanii	3
Dacrydium guillauminii	3
Widdringtonia whytei	4

Table 4: Critically Endangered (CR) conifer taxa reported to PlantSearch as held in fewer than 5 collections.

Ex situ collections, particularly of threatened taxa, should ideally be represented at multiple *ex situ* sites. Measures should be taken to ensure these taxa are represented in an increased number of *ex situ* collections to increase the security and conservation value of such collections.

Conversely, four Critically Endangered (CR) taxa are reported as present in more than 50 collections worldwide and therefore presumably more secure. These are listed in Table 5. Sixteen Endangered (EN) taxa and fifteen Vulnerable (VU) taxa are also reported as present in more than 50 collections worldwide. There is great potential for these collections to collaborate to achieve maximum conservation potential by comparing data on genetics or provenance of material and increase the genetic diversity of collections by sharing existing material and strategically planning collections from missing populations. Case Study 3 (p. 20) provides details of the International Conifer Conservation Programme (ICCP), demonstrating how conservation value can be increased through the development of partnerships and ensuring material is shared across multiple institutions and sites.

Taxon name	Number of collections reported worldwide
Abies numidica	71
Glyptostrobus pensilis	77
Wollemia nobilis	96
Araucaria angustifolia	89

Table 5: Critically Endangered (CR) conifer taxa reported to PlantSearch as held in more than 50 collections worldwide.

Wollemia nobilis *at the Royal Botanic Gardens, Kew, UK. Critically Endangered (CR), reported as held in 96* ex situ *collections worldwide.*

The most common threatened taxon reported in *ex situ* collections is *Metasequoia glyptostroboides* (EN) with 316 collections. This taxon provides a good example of international collaborative conservation efforts. The Arnold Arboretum and several partner institutions helped to collect the species from the wild in 1947 after it was rediscovered in China The Arnold Arboretum then distributed seeds to over 600 locations worldwide[10].

Metasequoia glyptostroboides *in Queens Gardens, Nelson, New Zealand. Likely a result of the seed distribution effort by the Arnold Arboretum, U.S.A.*

Collection balance

Additional analysis was undertaken to gauge the number of conifer cultivars in collections due to their popularity as landscape and ornamental trees. Figure 4 illustrates the proportion of conifer collection records in PlantSearch that are cultivars, compared with the proportion of matching botanical taxa. Overall, 27,173 (45.7%) records are matching botanical taxa (i.e. matching accepted names or synonyms in the Conifer Database, Farjon, 2013), 3,695 (6.2%) are unplaced records (i.e. they could not be matched to accepted names or synonyms in the Conifer Database) and 28,592 (48.1%) are cultivar records.

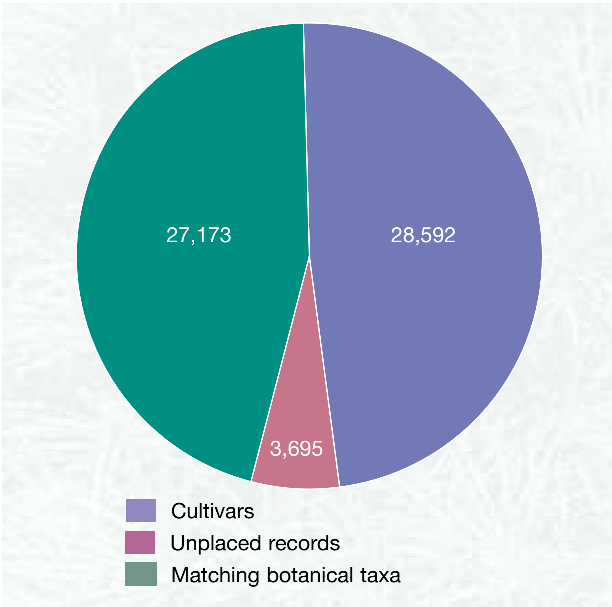


Figure 4: Collection balance showing number of conifer taxa records reported to PlantSearch (matching botanical taxa, unmatched names and cultivars) reported by ex situ *collections.*

As monitoring conservation of botanical taxa is the top priority for PlantSearch, cultivars are not the main focus. However, conservation of heritage and rare cultivars is an area that PlantSearch can easily support. Figure 4 illustrates a strong presence of cultivars in conifer collections reported to PlantSearch (48.1% of records). This is probably due to the availability of cultivars at nurseries, and their high display value.

Taxa that could not be matched to botanical taxa listed in the Conifer Database (Farjon, 2013) also account for a fairly large number of records held in PlantSearch (3,695 records, 6.2%). These records have been labelled as unplaced records. This includes records with ‘sp.’ or ‘sp./hybrid’ as the specific epithet as well as unmatched records (i.e. with full botanical names including matching genus but infraspecific epithets that did not match any names in the Conifer Database (Farjon, 2013)).
As far as possible, records held within PlantSearch with slight misspellings were incorporated within the analysis. The high number of unplaced records as a result of taxonomic issues (i.e. genus matches, but infraspecific epithet does not) indicates variations in taxonomy among institutions, as well as between different references (see Limitations section for further detail).

[10] There are likely more surviving collections from this effort than documented in this survey as many were distributed to parks and private collections that have not participated in this survey.

	Horticultural or unknown source		Wild source		Cultivated from material of known wild source	
	No. of collections	No. of taxa	No. of collections	No. of taxa	No. of collections	No. of taxa
CR	97	21	72	25	28	8
EN	410	63	518	63	40	21
VU	367	64	447	63	49	19
Total	874	148	1,037	151	156	48

Table 6: Provenance summary of threatened conifer ex situ *material reported by 39 collections and ICCP sites, per IUCN Red List category (Critically Endangered (CR), Endangered (EN) and Vulnerable (VU)).*

There is much potential to shift the focus of collections from cultivated to botanical taxa, and improve management of taxon identification, verification, and plant records management to increase the value of collections for conservation. Recommendations to achieve this are outlined in the Conclusions and Recommendations section (p. 27).

Further analysis

PlantSearch currently only collects taxon-level information from collections, and therefore cannot be used to determine progress towards the restoration and recovery component of Target 8 (i.e. whether collections can provide sufficient and appropriate material to support recovery and restoration programmes). PlantSearch is only a first step toward measuring collections diversity. For example, one record in PlantSearch may represent a single plant of horticultural source with little direct value to conservation efforts, or it may represent multiple individuals that are genetically representative of wild populations which would be appropriate for restoration work.

Further analysis was undertaken to determine the conservation value of *ex situ* collections of threatened conifers (CR, EN and VU) and their availability and suitability for recovery and restoration programmes. This analysis focused on the provenance of material held in collections and the number of individuals held for each taxon. Overall, 39 institutions contributed additional information about the threatened conifer taxa maintained in their collections, 28 provided both provenance and number of individuals, 5 provided information about provenance only, and 6 provided information about number of individuals only. In addition to this, provenance and number of individuals were successfully provided from all International Conifer Conservation Programme (ICCP) collections by the Royal Botanic Garden Edinburgh, UK, (ICCP involves 230 sites) which increases the confidence in this assessment[11]. See Case Study 3 (p. 20) for more information about ICCP collections.

Provenance

Provenance analysis results for threatened taxa are summarised in Table 6 and Figures 5 and 6. This information has been used to further determine the conservation value of *ex situ* collections of threatened taxa, with material of documented wild source being of highest conservation value.

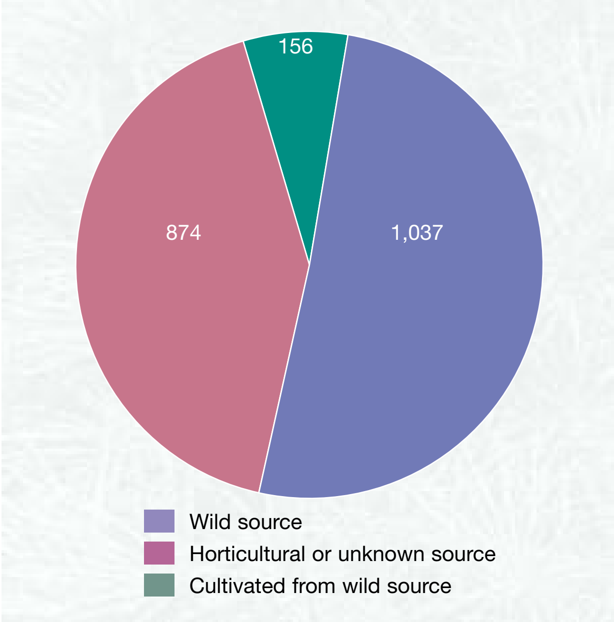


Figure 5: Number of threatened conifer accessions per provenance type (horticultural or unknown source, wild source, or cultivated from wild source) reported by 39 collections and ICCP sites.

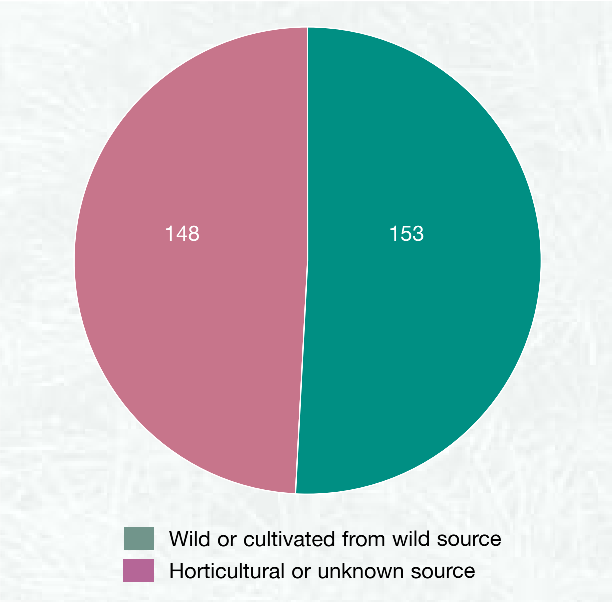


Figure 6: Number of threatened conifer taxa reported by 39 collections and ICCP sites per provenance type (horticultural or unknown source, or wild or cultivated from wild source)[12].

[11] Some ICCP collections provided additional information to the survey separately. These institutions were removed from ICCP records to avoid duplication.
[12] Wild and cultivated from wild source taxa are represented together in Figure 6 to eliminate duplicate records.

Case Study 3: The value of partnerships for conifer conservation

Martin Gardner, Royal Botanic Garden Edinburgh (RBGE)

The International Conifer Conservation Programme (ICCP) based at the Royal Botanic Garden Edinburgh (RBGE) was established in 1991. The main theme of the Programme is to integrate *ex situ* with *in situ* conservation in order to assist the conservation of conifers and associated species. This is being achieved through scientific research, education and cultivation. Much of the *in situ* work has involved capacity building in countries such as Chile, Vietnam, Laos PDR and Cambodia which has resulted in the publication of checklists, conifer conservation status reports and a book on the threatened plants of south-central Chile. The ICCP, working through the IUCN Conifer Specialist Group, plays a key role in the red listing of conifers and recently it has published the results of this work on a website (http://threatenedconifers.rbge.org.uk/).

Multiple accessions of Prumnopitys andina *being prepared for planting in a conservation hedge at an ICCP site. Vulnerable (VU). (Credit: Martin Gardner, RBGE)*

At an *ex situ* level the aim is to maintain a representative collection of known wild source threatened conifers containing a broad genetic base which can be used for research and aid the restoration of depleted wild populations. RBGE has one of the world's most comprehensive collections of conifers numbering 550 taxa but even with its four widely distributed gardens in Scotland covering a total area of 210 hectares it still does not have sufficient room to support a truly comprehensive conservation collection of space-demanding trees such as conifers. The ICCP has therefore developed a network of 'safe sites' outside of RBGE in order to accommodate a large number of conifers. Today the network of 230 sites contains 255 conifer taxa represented by 2,100 accessions and totally 15,800 individual plants. (ICCP collections are represented in the analysis undertaken in this report).

Networking has been fundamental to the relative success of the ICCP and has the advantage of spreading the risk against catastrophic losses through pathogen attack, regionally bad weather, etc. The network is mostly spread throughout Britain and Ireland but also includes some sites in Europe (Belgium, Malta and France) and for the more tropical conifer species there is a network of sites in southeast U.S.A. which is coordinated through Montgomery Botanical Center and Atlanta Botanical Garden. This is typical of the sorts of regional networks the ICCP has been able to stimulate and collaborate with.

Other examples include the iCONic Project (Internationally Threatened Conifers In Our Care http://iconictrees.org) which was set up in 2008 to establish a network of 'safe sites' in Perthshire, a county in Scotland well known for its historic conifer plantings. The project, which is a partnership between the Royal Botanic Garden Edinburgh, Forestry Commission Scotland and the Perth and Kinross Countryside Trust, is planting the next generation of conifers in Perthshire using material of known wild source and focusing on threatened species. To date 17 sites have been carefully chosen in which 665 conifers have been planted. All these conifers originate from the ICCP and are monitored on the RBGE database.

The Bedgebury National Pinetum has developed a similar initiative called the Bedgebury Conifer Conservation Project (http://www.forestry.gov.uk/forestry/infd-8rgek8) again in close collaboration with the ICCP.

ICCP has focused on species which are known to thrive in cultivation in the British Isles. For example, all five Chilean threatened species have been a priority (see Table A).

Molecular research carried out by ICCP on *Fitzroya cupressoides* indicated that historical plantings of this species were in fact a single male clone. Since this research in 1993 the ICCP has been able to broaden the genetic base of plants in cultivation by using material which has been sampled from across its nature range in Chile (see Table A). Such an example does show what progress can be made in a relatively short period of time and highlights the fact that just because a species is relatively common in cultivation it may not have the sort of genetic integrity that is of use for conservation programmes.

Species	No. sites	No. accessions	No. individuals
Araucaria araucana	43	155	1125
Fitzroya cupressoides	64	74	293
Pilgerodendron uviferum	43	59	325
Podocarpus salignus	59	52	529
Prumnopitys andina	55	59	325

Table A. Chilean threatened conifers in the ICCP network of sites (including RBGE sites).

Volunteer planting Abies fraseri *in an iCONic safe site. Endangered (EN), reported as held in 99* ex situ *collections worldwide. (Credit: Martin Gardner, RBGE)*

Ex situ material suitable for recovery or restoration programmes should be of documented wild source. This analysis shows that a larger number of records of threatened taxa for which additional information was provided do consist of material of wild or cultivated from wild source material: 1,193 (57.7%) records of threatened taxa in contributing collections, from wild or cultivated from wild source, compared to 874 (42.3%) records from horticultural or unknown source[13]. The proportion of reported records to taxa is similar for both horticultural or unknown source collections (874 records representing 148 taxa) and wild source collections (1,193 records representing 153 taxa) (Figure 6). This shows that the collections that supplied additional information have an equal focus on wild source and horticultural source material.

Taxon name	IUCN Red List Status	Number of wild source collections
Araucaria araucana	EN	40
Chamaecyparis formosensis	EN	25
Cunninghamia konishii	EN	25
Fitzroya cupressoides	EN	55
Sequoia sempervirens	EN	34
Abies *pinsapo* var. *pinsapo*	EN	38
Picea omorika	EN	42
Pinus armandii var. *mastersiana*	EN	23
Abies cilicica ssp. *isaurica*	VU	32
Picea likiangensis	VU	27
Pilgerodendron uviferum	VU	41
Podocarpus salignus	VU	34
Prumnopitys andina	VU	61

Table 7: Threatened taxa of wild or cultivated from wild source material reported as held in a large number (25+) of collections.

Further analysis (and reiterating the findings reported in Figure 3) shows that of the wild source taxa held in collections, many are represented only in a single collection, or small number or collections. A few taxa are reported as held in large numbers of collections, making up for a large proportion of the wild taxa collections reported, as shown in Table 7.

These 13 taxa account for 477 records, or 40% of all reported wild source collections. No wild source or cultivated from wild source Critically Endangered (CR) taxa are reported to be held in more than 20 collections. The best represented Critically Endangered taxon with 17 reported collections of wild source or cultivated from wild source material is *Torreya taxifolia*. While a few taxa are represented in a large number of, and thus very secure, wild sourced collections, the majority of wild sourced taxa are limited to a small number of collections, which limits their conservation value.

The existence of records of unknown source (ca. 450 records[14]) in the additional information provided suggests a need for improved record management, and/or may represent old collections for which accession information was not collected or has been lost.

Number of individuals

In addition to being of documented wild source, *ex situ* collections must involve enough material to be genetically representative of wild populations to be suitable for recovery and restoration programmes. This lowers the risk of reducing the gene pool when reintroductions are carried out. Guerrant *et al*. (2004) recommend collecting material from ca. 50 individuals in ca. 50 populations for threatened taxa, but the number of individuals needed to capture adequate genetic diversity varies a lot between species. Figure 7 illustrates that the majority of collections of threatened taxa of wild source or cultivated from wild material are based on low numbers of individuals and therefore would probably not provide sufficient genetic diversity to undertake reintroduction programmes without significant propagation efforts (79.5% of reported threatened taxa in collections of wild source material are limited to 5 or less individuals, compared to just 5.7% of threatened taxa collections reported as holding more than 20 individuals).

If a collection record is represented by only a single or small number of individuals it is also at greater risk of being lost to pest or disease infection, natural disasters, age or theft.

Looking specifically at the number of individuals cultivated from wild material, it is evident that specific collaborative cultivation programmes have been successful for some threatened conifer taxa, as large numbers (>50) of individuals are reported as cultivated from material of known wild source by single institutions, including:

- *Torreya taxifolia* (CR)
- *Wollemia nobilis* (CR)
- *Larix decidua* var. *polinica* (EN)
- *Metasequoia glyptostroboides* (EN)
- *Picea asperata* (VU)

[13] A record represents the occurrence of an individual taxon or accession(s) in a collection. This may represent a single individual, or multiple individuals or accessions of the same taxon.
[14] This is an estimate due to reporting inconsistencies by participating institutions.

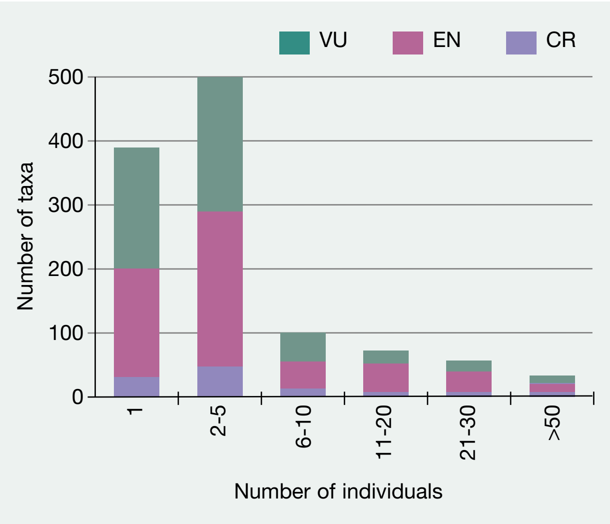


Figure 7: Number of individuals of wild or cultivated from wild material reported in 39 threatened taxa collections and ICCP sites by IUCN Red List status (Critically Endangered (CR), Endangered (EN) and Vulnerable (VU)).

However, cultivation programmes appear not to have been established for most wild collected threatened conifer taxa held in the collections that provided additional information, with the majority of collections limited to a small number of wild collected taxa (5 or fewer taxa).

It can be difficult to maintain a high number of individuals in an *ex situ* collection intended for recovery and restoration programmes, due to the financial, security and staff resources required. Another obstacle, particularly limiting for trees, and especially for fast growing taxa, is the space required to maintain a large number of individuals. These factors make maintaining large, genetically diverse collections particularly difficult for any institution with limited space or capacity.

Araucaria araucana, *the Monkey Puzzle tree. Endangered (EN), reported as held in 162* ex situ *collections worldwide.*

A mechanism for overcoming this is collaboration between institutions to share the goal of maintaining genetically diverse collections (see Case Study 3, p. 20).

The type of germplasm, although not collected as part of this survey, is another important factor in determining the conservation value of collections. However, it is assumed that most botanic garden and arboretum collections represent living plants. It is critical to maintain specimens through time to ensure pure lineages, viability, proper documentation, horticultural care, etc.

Recovery and restoration programmes

Institutions were also asked to indicate any taxa included in recovery or restoration programmes. Of the 39 responding institutions, six institutions indicated they were undertaking recovery and/or restoration programmes involving threatened conifer taxa. The following 13 threatened taxa were reported as included in recovery and/or restoration programmes (including taxa for which reintroduction programmes have been carried out and taxa for which appropriate and sufficient material has been cultivated with the aim of reintroduction):

- *Taxus floridana* (CR)
- *Torreya taxifolia* (CR)
- *Wollemia nobilis* (CR)
- *Araucaria araucana* (EN)
- *Fitzroya cupressoides* (EN)
- *Taxus chinensis* (EN)
- *Taxus wallichiana* var. *mairei* (EN)
- *Torreya jackii* (EN)
- *Xanthocyparis vietnamensis* (EN)
- *Pilgerodendron uviferum* (VU)
- *Prumnopitys andina* (VU)
- *Pseudotaxus chienii* (VU)
- *Taiwania cryptomeriodes* (VU)

The following taxa can be identified as *potentially available for* recovery and restoration programmes as large numbers (>50) of individuals of wild source or cultivated from wild source were reported by individual institutions in the additional information provided. However the genetic variability of such collections would need to be assessed before a restoration programme should go ahead:

- *Abies numidica* (CR)
- *Abies pinsapo* (EN)
- *Larix decidua* var. *polonica* (EN)
- *Metasequoia glyptostroboides* (EN)
- *Picea omorika* (EN)
- *Sequoia sempervirens* (EN)
- *Athrotaxis selaginoides* (VU)
- *Picea asperata* (VU)

With the additional information provided, 21 threatened taxa have been reported as used in, available for, or potentially available for recovery and restoration programmes. This represents 7.2% of threatened conifer taxa, which is far from reaching the GSPC Target 8 goal that 20% of threatened taxa be available for recovery and restoration programmes.

Case Study 4: Supporting conservation of wild populations of *Torreya taxifolia*.

Volunteer working on Torreya taxifolia *conservation programme at Atlanta Botanical Garden.*

Jennifer Cruse-Sanders, Atlanta Botanical Garden

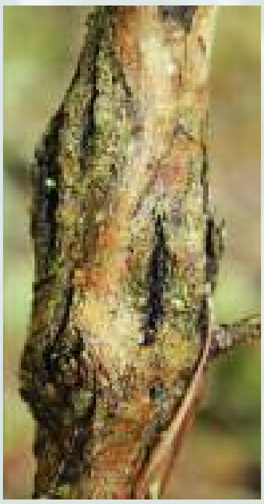
Torreya taxifolia, at the centre of the debate on assisted migration, is one of the rarest conifers in the world. For thousands of years, *T. taxifolia* was a large evergreen canopy tree endemic to ravine forests along the Apalachicola River that twists through the Florida panhandle in eastern North America. In the mid-Twentieth Century this species suffered a catastrophic decline as all reproductive age trees died, leaving only the remaining seedlings in the forest. In the decades that followed, this species did not recover. What remains is a population at approximately 0.3% of its original size, which is subjected to changes in hydrology, forest structure, heavy browsing by deer, loss of reproduction capability, as well as disease resulting in dieback in a manner reminiscent of American Chestnut following Chestnut Blight.

In 1984 this species was listed Endangered under the U.S. Endangered Species Act. It is currently listed as Critically Endangered on the IUCN Red List.

In 1990, the Atlanta Botanical Garden received 155 clones of *T. taxifolia* propagated from the remaining natural population by Arnold Arboretum and the Center for Plant Conservation. This material has been safeguarded at the Atlanta Botanical Garden during the past 23 years. Propagation efforts have increased the collection to almost 500 plants, 61 of which have matured to produce seeds and seedlings in cultivation. Beginning in 2008, Garden staff began a collaborative project with biologists and researchers at the Florida Park Service, University of Florida, and Georgia Institute of Technology. Current efforts include evaluation and mapping of 645 trees in the wild. Among wild trees there is a positive relationship between stem length and incidence of stem canker. Plant pathology research at the University of Florida has identified a new species of Fusarium, *Fusarium torrayae*, as the disease-causing agent. Future research will determine the host range of the disease and offer insights on its origins.

Field surveys have found that stem damage from deer antler rubbing is a significant source of stress in addition to disease, and is causing severe impacts to more than 50% of trees. Efforts at understanding ecological requirements of this species for reintroduction include caging the trees to protect them from deer damage. To date 21.6% of surveyed wild trees have been caged for protection. Although the majority of habitat for *T. taxifolia* is protected in state parks or by The Nature Conservancy, until damage from deer and stem canker can be controlled, recovery of the species is dependent on *ex situ* conservation efforts.

One of the limiting factors to *ex situ* conservation of this species is the inability to use conventional seed storage techniques for preserving germplasm. *Torreya taxifolia* produces recalcitrant wet seeds that cannot be dried for storage in freezers. Therefore, until recently the only way to maintain *ex situ* germplasm was through living collections. In collaboration with Georgia Institute of Technology, a somatic embryogenesis tissue culture system was developed to initiate cultures, produce somatic seedlings and cryogenically store cultures of *T. taxifolia*. Large numbers of somatic embryos and resulting seedlings can be developed in culture from a single seed. One of the lessons learned was that the water potential (-MPa) of *T. taxifolia* gametophyte tissue rises greatly, in contrast to many other coniferous tree seeds, during seed after-ripening, and mimicry of this rise *in vitro* is necessary to continue development of somatic embryos to produce new seedlings in culture. All of the genotypes tested for cryopreservation were successfully recovered after retrieval from liquid nitrogen and can provide material for disease research, restoration or establishment of seed nurseries for conservation. Over the past five years significant progress has been made in developing a variety of techniques for conservation of this critically imperilled species. These collaborative projects have resulted in scientific publications (for example: Aoki *et al*., 2013; and Ma *et al*., 2012), presentations and educational materials for the public.



Stem canker affecting Torreya taxifolia. (Credit: Jennifer Cruse-Sanders, Atlanta Botanical Garden)

Although this is based only on information provided by survey participants, it is clear that much more work is needed to move towards preparation for and practical implementation of recovery and restoration programmes, particularly for Critically Endangered (CR) and Endangered (EN) taxa for which wild populations are most threatened.

Before carrying out any reintroduction or restoration programme, as well as cultivation of appropriate material, thorough research is needed to develop propagation and reintroduction protocols and enable in-depth *in situ* monitoring. This requires further capacity and although botanic gardens are well placed to undertake research and carry out recovery programmes, this survey shows there are limited examples where *ex situ* collections have progressed to the stage of recovery programmes.

Tsuga sieboldii. *Near Threatened (NT), reported as held in 68* ex situ *collections worldwide.*

Recommendations for moving towards achievement of the 20% restoration and recovery goal are provided in the Conclusions and Recommendations section. Case Studies 4 (p. 23) and 5 (p. 25) provide examples of botanic garden led recovery and restoration programmes.

It is important to note that although collections of horticultural source and collections with a single individual or few individuals hold limited value for direct conservation action, these collections still hold great value in terms of indirect conservation, through research, horticulture and education. This is explored further and recommendations for small collection management are made in the Conclusions and Recommendations section (p. 27).

Pinus nigra *ssp. laricio. Least Concern (LC), reported as held in 11* ex situ *collections worldwide.*

Limitations

The purpose of this survey is to provide an overview of *ex situ* collections of conifers, particularly threatened taxa. The survey does not attempt to provide an in-depth analysis of existing collections, although such an analysis would be beneficial to further understand the conservation value of existing collections and further advise future collection efforts and development.

It is firstly important to note that the accuracy of this survey is heavily dependent on the amount and quality of data submitted to BGCI's PlantSearch database. It is also important to note that this analysis presents a snapshot in time and the dynamic nature of living collections means that the number of taxa and specimens in collections will vary over time. Presence or absence from *ex situ* collections is particularly unstable for taxa represented only in a single or small number of collections.

There are a number of additional limitations to this survey, both to the quality of data used and the research methods employed:

Participation - The survey focused on, but was not limited to, capturing information from *ex situ* conifer collections held in botanic gardens and arboreta. Conifers are popular ornamental and landscaping trees and many occur in private collections which have likely been under-represented in this survey. It is likely that additional taxa records of threatened conifer taxa exist in private or other collections not included in this survey. The provenance and plant records management of these collections would further determine the conservation value of the collections.

Outreach method - Survey announcements were only circulated in English and via a limited electronic method. This was the best option available but may have excluded some potential participants.

Case Study 5: *Ex situ* conservation of threatened *Taxus* species in Lushan Botanical Garden and *Pseudotaxus chienii* reinforcement to Jinggangshan National Nature Reserve

Peng Yansong, Lushan Botanical Garden, China

The majority of Chinese Taxaceae species are listed as threatened on the IUCN Red List. Most of the trees are small or even shrub-like because they grow at high altitudes and on exposed ridges. The populations of these species have been reducing each year.

Example species:

Pseudotaxus chienii, is the only species of this genus, but it is closely related to other yews in the genus Taxus. It is endemic to southern China, occurring in Fujian, northern Guangdong, northern Guangxi, Hunan, Southwest Jiangxi and southern Zhejiang. Only 10 populations remain in China. The species is listed as Vulnerable on the IUCN Red List and it is noted that it has undergone a suspected population reduction in the past three generations (>90 years) of more than 30% due to exploitation and habitat loss (it is uncertain if the reduction has exceeded the 50% threshold required for listing the species as Endangered, although it was previously assessed in this higher threat category) (IUCN, 2013a). As well as the threat of habitat loss, *Pseudotaxus chienii* naturally occurs at a low density, and has poor regeneration ability, a senescent population type, low seed germination and experiences high mortality of seedlings and samplings. It is crucial to propagate this species by sexual reproduction and maintain a safe *ex situ* collection of the species.

A number of activities were undertaken by Lushan Botanical Garden to conserve these threatened species. For example, additional Taxaceae species were brought into the arboretum of Lushan Botanical Garden with labels for public outreach.

Germination and propagation studies were also undertaken and a viable stock of plants was built up to prepare for recovery and restoration programmes for some Taxaceae species. This included 50 seedlings of *P. chienii* that were propagated from seed and reintroduced to Jinggangshan National Nature Reserve. Monitoring was undertaken at reintroduction sites with the aim of reaching 80% survival rates.

Further studies on the intraspecific and interspecific competition in natural communities of *P. chienii* were undertaken in Mount Jinggangshan. At restoration sites, local communities were involved in conservation activities, including a reinforcement programme for threatened Chinese Yew species, to raise awareness and knowledge of natural resource management.

To further support conservation work and public engagement, a workshop on the reintroduction of threatened plants to Jinggangshan National Nature Reserve was held in August 2011, involving 150 representatives from research institutes, universities and botanic gardens in China, and experts from the IUCN/SSC Conifer Specialist Group. Handbooks were produced on how to protect Chinese rare *Taxus* species. Two hundred copies were distributed to participants of the workshop.

Reintroduction of Pseudotaxus chienii *at Mount Jinggangshan, China. (Credit: BGCI China)*

PlantSearch – PlantSearch is the only tool available for measuring progress towards Target 8 of the GSPC at a global level, however there are number of limitations to its current capabilities which may affect survey outcomes to some degree. These include potentially out of date records stored in and provided to PlantSearch, issues with verification of plant names contributed to PlantSearch, and lack of detailed provenance data for collections recorded in PlantSearch. These have been recognised by BGCI in this and previous *ex situ* surveys, and work is ongoing to improve PlantSearch functionality and ability to further assess the conservation value of collections.

Sciadopitys verticillata. *Near Threatened (NT), reported as held in 156* ex situ *collections worldwide.*

Thuja koraiensis at the Royal Botanic Gardens, Kew, UK. Vulnerable (VU), reported as held in 92 ex situ collections worldwide.

Unplaced records - This survey has, as far as possible, endeavoured to incorporate records within PlantSearch, with slight alterations to the spellings of accepted names in the Conifer Database (Farjon, 2013). This was achieved by searching for a *near* match within PlantSearch records as well as an exact match. This assessment has also endeavoured to incorporate records listed in PlantSearch under their synonyms rather than accepted names. Where conifer records could not be matched to accepted names or synonyms, as listed in the Conifer Database, these were classified as unplaced names. Where synonyms linked to more than one accepted name, these plant records could not be assigned to a particular accepted name and were therefore included in the unplaced records category. Accounting for these unplaced names would require contacting each institution and this was not possible within the scope of this survey. Some threatened taxa may therefore be held in collections, but with a different name to those on the Conifer Database. As well as potentially affecting the results of this survey, this highlights the issues of taxonomy common to many plant groups and potential problems caused by different taxonomy and resources used by different institutions.

Records management in participating institutions – There is a risk that some of the taxa held in collections may have been misidentified or mislabelled by participating institutions, thereby affecting the accuracy of the information used in this survey.

Unavailability of collections data in electronic format – Not all gardens are able to provide electronic lists of taxa to PlantSearch. This may have excluded additional collection holders from participating in the survey.

Additional information provided – Additional information on provenance and number of individuals per collection was requested for threatened conifer taxa. As the conservation assessments were updated in July 2013, with some new taxa now being recognised as threatened, institutions that submitted data prior to the publication of the updated assessments may not have provided information on these taxa, despite them being represented in their collections. These taxa may therefore be under-represented in the analysis of collections provenance.

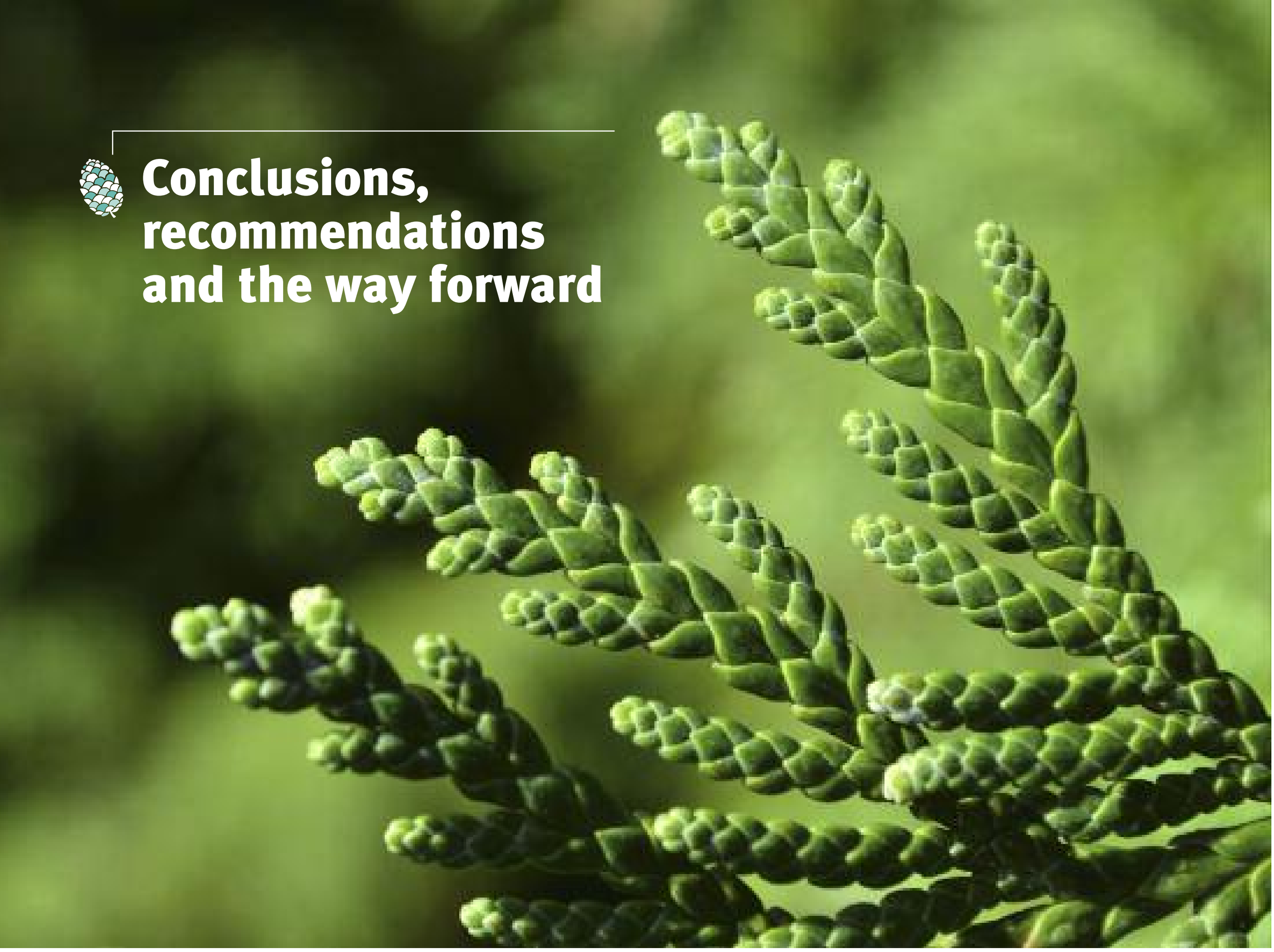
Cultivars – An analysis was undertaken to determine collection balance in terms of threatened taxa, versus non-threatened taxa and cultivars. Although PlantSearch does accept cultivar records (provided that the stem of the record is accepted by PlantSearch) this is not the main focus of PlantSearch, nor the focus of calls to submit information to PlantSearch. The number of cultivars represented in PlantSearch may therefore be under-represented, if institutions select to only upload the botanical taxa held in their collection.

Current condition of accessions reported – Information was not gathered on the current health of collection material, some of the taxa could therefore be failing in health and therefore of limited value to conservation. Gathering this information could also potentially highlight geographic regions where certain taxa survive better or worse.

Dynamic nature of collections – As living collections are constantly changing, some individuals will be lost and new accessions will be added through time. This analysis therefore only represents a snap-shot of the current status of *ex situ* collections and it should be recognised that the status of collections is subject to frequent change.

Sequoia sempervirens showing good regeneration capacity following burning in the Santa Lucia Range, California, U.S.A. Endangered (EN), reported as held in 169 ex situ collections worldwide. (Credit: Garth Holmann, University of Maine).

Conclusions, recommendations and the way forward



Thuja koraiensis. *Vulnerable (VU), reported as held in 92* ex situ *collections worldwide.*

The findings of this survey indicate that, although the *ex situ* component of the GSPC Target 8 is being met for conifers with more than 75% of threatened taxa represented in *ex situ* collections, many threatened taxa are limited to a single or small number of collections. This greatly limits the security and overall conservation value of such collections. Additionally, a majority of conifer collections do not hold material that is suitable for recovery and restoration programmes, as much of it is not of wild source. Further, much of the reported wild source material is probably not genetically diverse. Much work is clearly needed to progress towards meeting the recovery and restoration component of Target 8: to have 20% of threatened taxa available for such programmes by 2020.

While some conifer taxa are represented in a large number of collections worldwide, many threatened taxa for which conservation measures are urgently required are reported to be present in low numbers in very few collections. *Ex situ* collections also report a large number of cultivars, which despite holding great aesthetic value, hold limited value for conservation. A shift in collection focus is needed for *ex situ* collections to achieve greater value for threatened conifer conservation.

Ex situ conservation efforts for threatened conifer taxa require increased efforts and resources to collect appropriate levels of genetic diversity from remaining wild populations and properly maintain them in *ex situ* collections through time. Obstacles to building *ex situ* collections include, for example, inaccessible wild populations, difficulty getting permits for collection, low number of individuals from which to collect seed and specific or unknown environmental requirements for survival/propagation in *ex situ* collections.

Results of this survey show an encouraging number of threatened conifer taxa that have been successfully brought into *ex situ* collections. The case studies included in this report demonstrate several successful *ex situ* conservation and cultivation programmes being prepared for recovery and restoration applications for some threatened conifer taxa. These conservation efforts can provide important models for the conservation of other threatened taxa, particularly the most threatened conifer taxa highlighted as priorities in this report.

Collections that hold limited direct value to conservation do present opportunities in terms of indirect value to conservation which should not be overlooked. Such collections may, for example, be based on taxa that are not threatened, hold a small number of individuals or are sourced from horticultural material. If managed effectively, such collections can hold great indirect conservation value, for example, through education and interpretation programmes to tell the stories of threatened plants and increase awareness, and research programmes to learn more about threatened species biology, propagation protocols, etc. The Recommendations section (p. 28) provides specific ideas for education and research programmes using threatened plants of non-wild source.

Recommendations

Using the findings of the current analysis and taking advice from the case studies presented in this report, a number of specific recommendations are provided to further conservation of threatened taxa, particularly through *ex situ* conservation. Readers of this report are also encouraged to consult 'Integrated conservation of tree species by botanic gardens: A reference manual' (Oldfield and Newton, 2012) which provides a step-by-step guide to the integrated conservation of tree species.

Collection focus

To be of greatest direct conservation value, available resources should be used to maintain threatened taxa (CR, EN and VU; IUCN) in collections, especially taxa that cannot be seed banked (exceptional species). Annex II (p. 44) highlights threatened taxa currently reported as absent from collections or maintained in a small number of collections. These taxa should be brought into *ex situ* collections as a matter of urgency. Collection efforts should be coordinated between institutions and materials shared among collections to increase security of holdings. Non-threatened taxa can also be of indirect benefit to conservation of related or similar threatened taxa through education and research programmes.

Identification of taxa

Accurate identification of taxa is essential when collecting material from the wild and when determining what is held within a collection. The existence of 'unplaced' conifer records held in PlantSearch indicate problems with identification of taxa and are likely due to the multiple taxonomic changes over time which have no doubt incurred confusion and mislabelling of collections. Collectors and collection holders are advised to contact experts to verify collections and resolve such discrepancies and uncertainties. Experts and organisational contacts can be identified through the various links outlined in the Useful Resources section (p. 31).

Source of material

For collections to be of greatest direct value to conservation they should focus on material of documented wild source. Appropriate wild-collecting guidelines have been developed and should be followed especially when collecting threatened taxa to avoid unnecessary harm to remaining wild populations. The Global Trees Campaign (GTC) website provides guidance on seed collections from threatened tree species and other useful resources (see link in Useful Resources section, p. 31). Cultivated material of known wild source also holds great direct value to recovery and restoration programmes. Cultivation from wild material and increasing the number of individuals held within collections increases the security of *ex situ* holdings and can produce material for reintroduction purposes. It is also worth noting that *ex situ* material of horticultural or unknown source can support conservation objectives through critical research and education programmes.

Picea breweriana*. Vulnerable (VU), reported as held in 95 ex situ collections worldwide. (Credit: Garth Holmann, University of Maine)*

Ensuring collections are genetically viable

To ensure *ex situ* material is genetically representative of wild populations, the following guidelines (adapted from Guerrant *et. al*., 2004) represent the ideal sample size able to serve a broad range of purposes. It is recognised that in practice, particularly for the most critically threatened taxa, sample sizes will often be very small so these ideal sample sizes will probably not be possible, but efforts should be made to follow this guidance as far as possible:

> *For taxa with 50 or fewer populations, wild collections should be made from as many populations as resources allow, up to all 50. For taxa with more than 50 populations, collections should be made from as many populations as is practical, up to 50.*
>
> *For populations with 50 or fewer individuals, collections should be made from all known individuals (seeds/cuttings not removal of the whole plant). For populations with more than 50 individuals, collections should be made from 50 individuals.*

Further investigation into genetic potential within existing *ex situ* collections would provide a fuller understanding of their genetic representativeness. This should be taken forward for particular threatened taxa of interest to fully establish the current availability of valuable material for recovery programmes already within *ex situ* collections and the needs of future *ex situ* efforts.

Type of material

Maintaining *ex situ* collections of seeds requires less space and lowers financial and staff requirements to care for a given *ex situ* collection. More specimens and therefore more genetic diversity can be effectively conserved as seed collections. Even in light of more efficient and effective storage methods, living plants still play a vital role in *ex situ* conservation. Plant specimens should be maintained in collections for research, display and education purposes, and cultivating material for restoration programmes. Exceptional species (unable to be seed banked) that are threatened in the wild are especially dependent upon living collections for *ex situ* conservation (Pence, 2013). For exceptional species, efficient *ex situ* storage is more challenging and usually requires testing on a species-by-species basis to develop protocols for long-term storage of tissues or seeds.

Multiple *ex situ* collections

Threatened species should be maintained across as many *ex situ* collections as possible to reduce the risk of loss through natural disaster, theft, or pests and disease, etc. Sharing collected or cultivated material across institutions increases the security of material and allows for sharing of information and responsibility. See Case Study 3 (p. 20) for an example of successful partnership across *ex situ* institutions. *Ex situ* collections are also important tools for studying the effect of climate change and pests and diseases on plants and plant communities. International coordination and communication, such as through BGCI and the International Plant Sentinel Network (IPSN (BGCI, 2013)), are essential for sharing knowledge, to focus efforts and to mitigate current and potential threats across international borders.

Curation and maintenance of collections

Without proper curatorial records management and horticultural maintenance, the conservation value of collections, or a collection itself, can be lost. All staff caring for *ex situ* collections should be well trained to monitor specimens through time and avoid unnecessary loss of material and associated information. Collaboration between institutions for training and capacity building should be encouraged. Accurate record keeping is essential if *ex situ* collections are to be of value to direct conservation activities such as recovery and restoration efforts. Collection inventories should be carried out regularly to track the dynamic nature of living collections, maintain associations to and build relevant plant records, and monitor health of specimens through time. Up-to-date records and inventories will provide an accurate picture of threatened species in an *ex situ* collection and enhance a collection's conservation value and potential applications.

Sharing accurate collections data more broadly

Sharing collection information more broadly allows potential users to find and access collections for research, education, horticulture and conservation. BGCI's PlantSearch database is the only global database of plants in cultivation and is free to contribute to and access. All collection holders who do not currently maintain a list of taxa in their collections in BGCI's PlantSearch database are encouraged to upload their collection list to ensure analyses such as this one are as comprehensive as possible. Institutions are encouraged to regularly update their PlantSearch list to ensure their records are as accurate and up-to-date as possible.

Research - propagation and storage techniques

Public gardens and similar *ex situ* plant collections hold vast amounts of knowledge on how to grow and propagate plants. Collections should work to document and share that information with the broader community. Where facilities are available, research should be undertaken to establish seed germination and other propagation protocols, seed storage requirements and care and cultivation guidelines, particularly for threatened taxa. For the most threatened taxa, research should initially focus on closely related non-threatened taxa, if available, to reduce the risk of losing valuable conservation material (Oldfield and Newton, 2012). When non-threatened congeners are not available, initial trials should be carried out on small samples to limit loss of material. Research results and acquired knowledge on how to grow, store seed, and propagate rare species should be made available to support the management and development of additional *ex situ* collections of threatened species.

Communication between scientific and conservation institutions is also key to furthering conservation efforts of conifer taxa. Results of research trials should be shared widely between institutions to avoid duplication of efforts, unnecessary loss of plant material and ensure *ex situ* collections move towards being able to achieve successful recovery and restoration programmes, particularly for threatened taxa.

Wollemia nobilis *at the Royal Botanic Gardens, Kew. Critically Endangered (CR), reported as held in 96* ex situ *collections worldwide.*

Research – reintroduction protocols

Following successful propagation of genetically representative material, reintroductions should be carried out with care, involving site preparation, management of invasive species and pests, and a long term monitoring plan. It is advisable to carry out small scale reintroductions first, monitoring successes and failures, rather than to plant out a large amount of propagated material and risk losing it. Kaye (2008) presents a concise step-by-step strategy for guiding plant reintroductions which should be used as an aid to planning reintroductions.

Partnerships for conservation

Valuable partnerships aimed at establishing multiple *ex situ* collection locations can increase species security, ability to undertake research and sharing of information. Partnerships should also be developed with organisations or communities working in areas where a reintroduction is possible. This will ensure increased understanding of the aims of a programme, longevity and scope of a programme and can have indirect benefits such as increased protection of existing wild populations.

Education programmes

Public facing *ex situ* conservation institutions have an obligation to educate and outreach to the public, as well as the wider conservation community and scientists. Many botanic gardens and arboreta around the world are well placed to do this. Increased communication about the threats facing plants, how to mitigate threats and how to carry out successful conservation should be a key priority of all *ex situ* institutions. For example, education programmes at public gardens and similar organizations further threatened conifer conservation by raising awareness of the impact of overexploitation of conifer taxa for timber and the availability of wood products from sustainable sources. Education programmes can also highlight threats posed to conifer taxa by pests and diseases, and teach visitors how to detect and report signs of infection and disease and potentially prevent the spread of pests and diseases. Botanic gardens and arboreta can also present important information on threatened species and the value of plant conservation through labelling and interpretation signs in collections, as well as the production of literature, guidance, websites and social media. For example, BGCI US's Care for the Rare program (www.bgci.org/usa/CareForTheRare (BGCI US, 2013)) offers free interpretation resources and a sign library of threatened species.

Scope for further analysis

Further analysis of the geographical distribution of collections compared to the natural distribution of taxa would be valuable, as Target 8 of the GSPC advises that *ex situ* collections are preferentially maintained within the country of origin of the taxa in question. This analysis could be undertaken by using data collected for this report, GardenSearch records for participating institutions (these are geo-referenced) and IUCN Red List assessment range maps. This analysis could also highlight hotspot areas where the majority of collections exist.

It would also be valuable to collection data on the type of material held within collections (whole plants, seeds, etc.) and the health of material. As well as providing further information to determine the conservation value of collections, this information would highlight where living plant collections of particular taxa survive better and help prioritise future collection planning.

Taking action

Botanic gardens, arboreta and other *ex situ* conservation institutions are well prepared to expand conservation efforts for threatened conifers. This report has outlined valuable ongoing *ex situ* collection work, however increased efforts are needed to move beyond simply holding taxa within *ex situ* collections, to having appropriate genetically representative and documented material available for recovery and restoration programmes.

The existence of examples of successful reintroduction, and coordinated approaches to *ex situ* conservation of threatened taxa, is encouraging. Such examples illustrate the potential and scientific ability within botanic gardens to not only fully achieve Target 8 of the GSPC for conifer taxa by 2020, but to go beyond this and have more than 75% of threatened conifer taxa maintained in well documented and secure *ex situ* collections and more than 20% of threatened conifer taxa available for recovery and restoration programmes.

The priority taxa lists included in this report can be used to develop and refine *ex situ* collection priorities. As a matter of urgency, *ex situ* conservation must be secured for all Critically Endangered (CR) taxa, for which *ex situ* conservation is a priority due to their risk of extinction in the wild.

Building on the existing interest in conifers and the horticultural and scientific knowledge harboured in botanic gardens and arboreta around the world, space and resources within *ex situ* conservation institutions should be geared towards conservation of threatened and exceptional taxa as far as is possible. A shift in focus from cultivars to threatened taxa, will drive progress towards achieving conservation aims.

The case studies presented in this report highlight a growing practice of moving beyond *ex situ* collections for display, to focusing collections on combating particular threats, overcoming issues such as recalcitrant seeds, and propagating genetically viable material to support *in situ* populations. By following the models developed by these exemplar institutions, additional institutions can achieve similar conservation successes for additional threatened taxa. The report has also identified important sources of information and resources specifically focusing on threatened conifer taxa or threatened trees more broadly, for supporting such efforts (see Useful Resources and References sections, p. 31-34).

It is hoped that the findings, recommendations, case studies and resources highlighted in this report will support the vital efforts of *ex situ* collections and help them to fully meet the GSPC Target 8 and ensure the survival of threatened conifers worldwide.

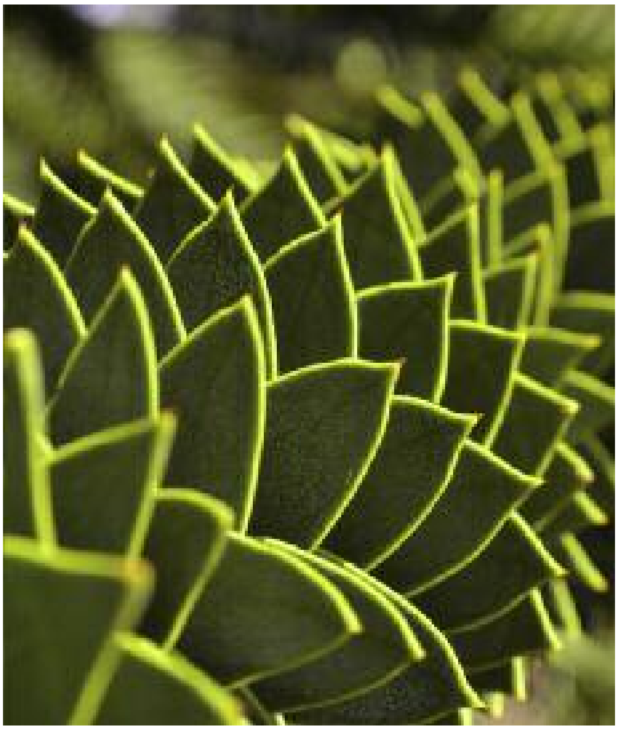
Useful Resources

American Conifer Society
The American Conifer Society's mission is the development, conservation and propagation of conifers, the standardization of nomenclature and the education of the public. The Society has a particular focus on conifers that are dwarf or unusual: http://www.conifersociety.org/

Bedgebury Conifer Conservation Project
The Bedgebury National Pinetum leads the Bedgebury Conifer Conservation Project, in collaboration with ICCP: http://www.forestry.gov.uk/forestry/infd-8rgek8

BGCI GardenSearch database
GardenSearch contains profiles of over 3,000 botanic gardens from around the world, allowing users to identify location and particular expertise held within botanic gardens. The only global source of information on the world's botanic gardens: www.bgci.org/garden_search.php

BGCI PlantSearch database
PlantSearch is compiled from lists of living collections submitted to BGCI by the world's botanic gardens and similar organizations. The database currently includes over 1 million records. This database allows users to identify how many institutions report holding a living collection of the taxon of interest and also allows users to send a blind request to these institutions to request plant material or information on propagation and care techniques: www.bgci.org/plant_search.php



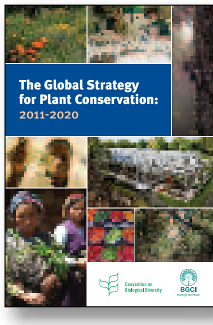
Conifer Database in BRAHMS
The Conifer Database in BRAHMS (Farjon, 2013) provides a list of accepted conifer names and synonyms, as used to undertake the IUCN Red List assessments and this survey. The database is publically available for download from BRAHMS. (The Encyclopaedia of Life will soon be updated to align with this taxonomy as well): http://herbaria.plants.ox.ac.uk/bol/BRAHMS/Sample/Conifers

The BRAHMS Training Guide uses examples from the Conifer Database: http://herbaria.plants.ox.ac.uk/bol/content/documentation/BRAHMStraining2010.pdf

Conifer Atlas
An atlas of the world's conifers providing distribution maps and additional information for all conifer taxa has recently been published: Farjon, A. and Filer, D. (2013) An Atlas of The World's Conifers: An analysis of their distribution, biogeography, diversity and conservation status. Brill, Leiden & Boston

Ecological Restoration Alliance website
The newly established Ecological Restoration Alliance of Botanic Gardens (ERA), coordinated by BGCI, aims to restore 100 degraded habitats and damaged ecosystems worldwide. More information and examples of current work can be found on the ERA website: www.erabg.org

Global Strategy for Plant Conservation
The GSPC toolkit was developed by BGCI to support implementation of the Strategy. This provides further information, guidance and links to resources for all GSPC Targets and links to the full GSPC Brochure and shorter GSPC Guide, available in multiple languages: www.plants2020.net



Global Trees Campaign
The Global Trees Campaign is a joint initiative led by BGCI and Fauna and Flora International (FFI), to save the world's threatened tree species. The newly redeveloped Global Trees Campaign website provides information about projects, profiles of threatened tree species and useful resources for threatened tree conservation: www.globaltrees.org

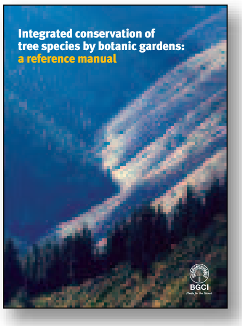
The Gymnosperm Database
This online resource provides information on the classification, description, ecology and uses of conifers: http://www.conifers.org/

Araucaria araucana, *the Monkey Puzzle tree. Endangered (EN), reported as held in 162* ex situ *collections worldwide.*

ICCP and iCONic Project

Further information about the International Conifer Conservation Programme (ICCP) led by the Royal Botanic Garden Edinburgh can be found here: http://www.rbge.org.uk/science/genetics-and-conservation/international-conifer-conservation-programme

And further information about the iCONic Project can be found here: http://www.iconictrees.org/our-story/conifers-under-threat



Integrated conservation of tree species by botanic gardens: A reference manual

Readers of this report are advised to also consult 'Integrated conservation of tree species by botanic gardens: a reference manual' (Oldfield and Newton, 2012), recently published by BGCI which provides detailed information on conservation approaches available for tree species, including guidance for *in situ* measures, *ex situ* conservation, ecological restoration and reintroduction and a step-by-step guide to integrated conservation of tree species. This resource is of great relevance to conservation of threatened conifer taxa. Available online at: http://www.bgci.org/files/Worldwide/News/SeptDec12/tree_species_low.pdf

IUCN Red List of Threatened Species

Up-to-date conservation assessments for all conifer taxa and other tree taxa are available on the IUCN Red List of Threatened Species. Searches can be conducted by species, family, region, etc. and full assessments are available providing full documentation and explanation of conservation status. The IUCN Red List website also contains information about the IUCN Red List Categories and Criteria and training materials for undertaking Red List assessments: www.iucnredlist.org

Sampled Red List Index for Plants

The Sampled Red List Index for Plants aims to determine the status of biodiversity, how it changes over time, and the extinction risk of individual species. The Sampled Red List Index for Plants is based on a sample of 7,000 plant species, including all conifer species: www.threatenedplants.myspecies.info

Threatened conifers of the world

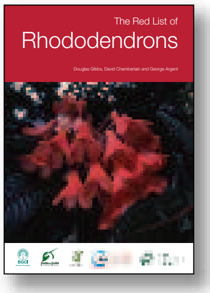
A new web resource focusing on the 211 globally threatened conifer species is available here: http://threatenedconifers.rbge.org.uk/

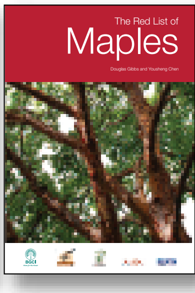
USDA Forest Service

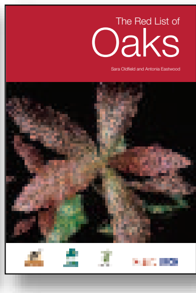
The USDA Forest Service, under the leadership of Chief Tom Tidwell, is entrusted with 193 million acres of national forests and grasslands. Much of this land is important habitat for native conifer species. The mission of the agency is to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations. The agency is dedicated to the improvement of water resources, development of climate change resiliency, creation of jobs that will sustain communities, and restoration and enhancement of landscapes: http://www.fs.fed.us/

Red Lists produced by BGCI / GTC

These are available to download from the BGCI and GTC websites.







The Red List of Magnoliaceae (2007): http://globaltrees.org/resources/red-list-magnoliaceae/
The Red List of Maples (2009): http://globaltrees.org/resources/red-list-maples/
The Red List of Oaks (2007): http://globaltrees.org/resources/red-list-oaks/
The Red List of Rhododendrons (2011): http://globaltrees.org/resources/red-list-rhododendrons/
The Red List of Trees from Central Asia (2009) (also available in Russian): http://globaltrees.org/resources/red-list-trees-central-asia/
The Red List of Endemic Trees and Shrubs of Ethiopia and Eritrea (2005): http://globaltrees.org/resources/red-list-endemic-trees-shrubs-ethiopia-eritrea/
The Red List of Trees of Guatemala (2006): http://globaltrees.org/resources/red-list-trees-guatemala/
The Red List of Mexican Cloud Forest Trees (2011): http://globaltrees.org/resources/red-list-mexican-cloud-forest/

Additional *ex situ* surveys carried out by BGCI / GTC

These are all available to download from the BGCI and GTC websites.

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Global *ex situ* survey of Maple collections (2010): http://globaltrees.org/resources/global-survey-ex-situ-maple-collections/
Global *ex situ* survey of Oak collections (2009): http://globaltrees.org/resources/global-survey-ex-situ-oak-collections/
Global *ex situ* survey of Rhododendron collections (2012): http://globaltrees.org/resources/global-survey-ex-situ-rhododendron-collections/
Global *ex situ* survey of Zelkova collections (2010): http://globaltrees.org/resources/global-survey-ex-situ-zelkova-collections/

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Picea omorika *growing in Mustila Arboretum, Finland. Endangered (EN), reported as held in 209* ex situ *collections worldwide. (Credit: Garth Holmann, University of Maine)*

Annexes

Annex I: IUCN assessed conifer taxa with number of reported *ex situ* collections and IUCN Red List status

This list is available electronically upon request. 'Number of *ex situ* collections' column refers to PlantSearch records and records supplied by International Conifer Conservation Programme (ICCP) sites.

Family	Taxon name	No. of *ex situ* collections	IUCN Red List status
Araucariaceae	*Agathis atropurpurea*	11	NT
Araucariaceae	*Agathis borneensis*	7	EN
Araucariaceae	*Agathis dammara*	38	VU
Araucariaceae	*Agathis flavescens*	1	VU
Araucariaceae	*Agathis kinabaluensis*	2	EN
Araucariaceae	*Agathis labillardierei*	2	NT
Araucariaceae	*Agathis lanceolata*	17	VU
Araucariaceae	*Agathis lenticula*	1	VU
Araucariaceae	*Agathis macrophylla*	26	EN
Araucariaceae	*Agathis microstachya*	14	NT
Araucariaceae	*Agathis montana*	6	NT
Araucariaceae	*Agathis moorei*	25	VU
Araucariaceae	*Agathis orbicula*	0	EN
Araucariaceae	*Agathis ovata*	13	EN
Araucariaceae	*Agathis robusta*	69	LC
Araucariaceae	*Agathis robusta* ssp. *nesophila*	0	VU
Araucariaceae	Agathis robusta ssp. robusta	8	LC
Araucariaceae	*Agathis silbae*	3	NT
Araucariaceae	*Araucaria angustifolia*	89	CR
Araucariaceae	*Araucaria araucana*	162	EN
Araucariaceae	*Araucaria bernieri*	11	VU
Araucariaceae	*Araucaria bidwillii*	104	LC
Araucariaceae	*Araucaria biramulata*	14	VU
Araucariaceae	*Araucaria columnaris*	54	LC
Araucariaceae	*Araucaria cunninghamii*	80	LC
Araucariaceae	*Araucaria cunninghamii* var. *cunninghamii*	11	LC
Araucariaceae	*Araucaria cunninghamii* var. *papuana*	2	LC
Araucariaceae	*Araucaria heterophylla*	137	VU
Araucariaceae	*Araucaria humboldtensis*	8	EN
Araucariaceae	*Araucaria hunsteinii*	25	NT
Araucariaceae	*Araucaria laubenfelsii*	17	NT
Araucariaceae	*Araucaria luxurians*	22	EN
Araucariaceae	*Araucaria montana*	18	VU
Araucariaceae	*Araucaria muelleri*	15	EN
Araucariaceae	*Araucaria nemorosa*	20	CR
Araucariaceae	*Araucaria rulei*	25	EN
Araucariaceae	*Araucaria schmidii*	5	VU
Araucariaceae	*Araucaria scopulorum*	12	EN
Araucariaceae	*Araucaria subulata*	16	NT
Araucariaceae	*Wollemia nobilis*	96	CR
Cephalotaxaceae	*Cephalotaxus fortunei*	102	LC

Family	Taxon name	No. of *ex situ* collections	IUCN Red List status
Cephalotaxaceae	*Cephalotaxus fortunei* var. *alpina*	6	NT
Cephalotaxaceae	*Cephalotaxus fortunei* var. *fortunei*	1	LC
Cephalotaxaceae	*Cephalotaxus hainanensis*	3	EN
Cephalotaxaceae	*Cephalotaxus harringtonii*	19	LC
Cephalotaxaceae	*Cephalotaxus harringtonii* var. *harringtonii*	55	LC
Cephalotaxaceae	*Cephalotaxus harringtonii* var. *nana*	9	LC
Cephalotaxaceae	*Cephalotaxus harringtonii* var. *wilsoniana*	21	EN
Cephalotaxaceae	*Cephalotaxus lanceolata*	4	EN
Cephalotaxaceae	*Cephalotaxus latifolia*	1	NT
Cephalotaxaceae	*Cephalotaxus mannii*	7	VU
Cephalotaxaceae	*Cephalotaxus oliveri*	15	VU
Cephalotaxaceae	*Cephalotaxus sinensis*	56	LC
Cupressaceae	*Actinostrobus acuminatus*	6	NT
Cupressaceae	*Actinostrobus arenarius*	10	LC
Cupressaceae	*Actinostrobus pyramidalis*	20	LC
Cupressaceae	*Athrotaxis cupressoides*	28	VU
Cupressaceae	*Athrotaxis laxifolia*	12	EN
Cupressaceae	*Athrotaxis selaginoides*	32	VU
Cupressaceae	*Austrocedrus chilensis*	55	NT
Cupressaceae	*Callitris baileyi*	5	NT
Cupressaceae	*Callitris canescens*	11	LC
Cupressaceae	*Callitris columellaris*	50	LC
Cupressaceae	*Callitris drummondii*	9	NT
Cupressaceae	*Callitris endlicheri*	29	LC
Cupressaceae	*Callitris macleayana*	11	LC
Cupressaceae	*Callitris monticola*	9	VU
Cupressaceae	*Callitris muelleri*	10	LC
Cupressaceae	*Callitris neocaledonica*	0	NT
Cupressaceae	*Callitris oblonga*	41	VU
Cupressaceae	*Callitris preissii*	29	LC
Cupressaceae	*Callitris rhomboidea*	49	LC
Cupressaceae	*Callitris roei*	9	NT
Cupressaceae	*Callitris sulcata*	1	EN
Cupressaceae	*Callitris verrucosa*	14	LC
Cupressaceae	*Calocedrus decurrens*	174	LC
Cupressaceae	*Calocedrus formosana*	30	EN
Cupressaceae	*Calocedrus macrolepis*	29	NT
Cupressaceae	*Calocedrus rupestris*	6	EN
Cupressaceae	*Chamaecyparis formosensis*	49	EN
Cupressaceae	*Chamaecyparis lawsoniana*	160	NT
Cupressaceae	*Chamaecyparis obtusa*	141	NT

Family	Taxon name	No. of *ex situ* collections	IUCN Red List status
Cupressaceae	*Chamaecyparis obtusa* var. *formosana*	59	VU
Cupressaceae	*Chamaecyparis obtusa* var. *obtusa*	13	NT
Cupressaceae	*Chamaecyparis pisifera*	132	LC
Cupressaceae	*Chamaecyparis thyoides*	98	LC
Cupressaceae	*Chamaecyparis thyoides* var. *henryae*	6	LC
Cupressaceae	*Chamaecyparis thyoides* var. *thyoides*	5	LC
Cupressaceae	*Cryptomeria japonica*	189	NT
Cupressaceae	*Cunninghamia konishii*	65	EN
Cupressaceae	*Cunninghamia lanceolata*	149	LC
Cupressaceae	*Cupressus arizonica*	89	LC
Cupressaceae	*Cupressus arizonica* var. *arizonica*	18	LC
Cupressaceae	*Cupressus arizonica* var. *glabra*	57	NT
Cupressaceae	*Cupressus arizonica* var. *montana*	23	CR
Cupressaceae	*Cupressus arizonica* var. *nevadensis*	22	EN
Cupressaceae	*Cupressus arizonica* var. *stephensonii*	28	CR
Cupressaceae	*Cupressus bakeri*	50	VU
Cupressaceae	*Cupressus cashmeriana*	90	NT
Cupressaceae	*Cupressus chengiana*	36	VU
Cupressaceae	*Cupressus chengiana* var. *chengiana*	7	VU
Cupressaceae	*Cupressus chengiana* var. *jiangensis*	2	CR
Cupressaceae	*Cupressus duclouxiana*	39	DD
Cupressaceae	*Cupressus dupreziana*	54	EN
Cupressaceae	*Cupressus dupreziana* var. *atlantica*	25	CR
Cupressaceae	*Cupressus dupreziana* var. *dupreziana*	10	CR
Cupressaceae	*Cupressus funebris*	65	DD
Cupressaceae	*Cupressus goveniana*	48	EN
Cupressaceae	*Cupressus goveniana* var. *abramsiana*	27	CR
Cupressaceae	*Cupressus goveniana* var. *goveniana*	20	EN
Cupressaceae	*Cupressus guadalupensis*	30	EN
Cupressaceae	*Cupressus guadalupensis* var. *forbesii*	29	EN
Cupressaceae	*Cupressus guadalupensis* var. *guadalupensis*	3	EN
Cupressaceae	*Cupressus lusitanica*	65	LC
Cupressaceae	*Cupressus lusitanica* var. *benthamii*	13	NT
Cupressaceae	*Cupressus lusitanica* var. *lusitanica*	4	LC
Cupressaceae	*Cupressus macnabiana*	36	LC
Cupressaceae	*Cupressus macrocarpa*	96	VU
Cupressaceae	*Cupressus sargentii*	39	VU
Cupressaceae	*Cupressus sempervirens*	154	LC
Cupressaceae	*Cupressus torulosa*	63	LC
Cupressaceae	*Cupressus torulosa* var. *gigantea*	3	VU
Cupressaceae	*Cupressus torulosa* var. *torulosa*	14	LC
Cupressaceae	*Diselma archeri*	32	LC
Cupressaceae	*Fitzroya cupressoides*	63	EN
Cupressaceae	*Fokienia hodginsii*	61	VU
Cupressaceae	*Glyptostrobus pensilis*	77	CR
Cupressaceae	*Juniperus angosturana*	3	VU
Cupressaceae	*Juniperus arizonica*	3	LC
Cupressaceae	*Juniperus ashei*	27	LC
Cupressaceae	*Juniperus ashei* var. *ashei*	0	LC
Cupressaceae	*Juniperus ashei* var. *ovata*	0	NT
Cupressaceae	*Juniperus barbadensis*	3	VU
Cupressaceae	*Juniperus barbadensis* var. *barbadensis*	1	CR
Cupressaceae	*Juniperus barbadensis* var. *lucayana*	2	VU
Cupressaceae	*Juniperus bermudiana*	33	CR
Cupressaceae	*Juniperus blancoi*	1	NT
Cupressaceae	*Juniperus blancoi* var. *blancoi*	0	VU
Cupressaceae	*Juniperus blancoi* var. *huehuentensis*	0	VU
Cupressaceae	*Juniperus blancoi* var. *mucronata*	0	VU
Cupressaceae	*Juniperus brevifolia*	10	VU
Cupressaceae	*Juniperus californica*	19	LC
Cupressaceae	*Juniperus cedrus*	43	EN
Cupressaceae	*Juniperus chinensis*	129	LC
Cupressaceae	*Juniperus chinensis* var. *chinensis*	1	LC
Cupressaceae	*Juniperus chinensis* var. *sargentii*	43	LC
Cupressaceae	*Juniperus chinensis* var. *tsukusiensis*	0	DD
Cupressaceae	*Juniperus coahuilensis*	3	LC
Cupressaceae	*Juniperus comitana*	0	EN
Cupressaceae	*Juniperus communis*	162	LC
Cupressaceae	*Juniperus communis* var. *communis*	78	LC
Cupressaceae	*Juniperus communis* var. *depressa*	54	LC
Cupressaceae	*Juniperus communis* var. *megistocarpa*	0	LC
Cupressaceae	*Juniperus communis* var. *nipponica*	1	LC
Cupressaceae	*Juniperus communis* var. *saxatilis*	69	LC
Cupressaceae	*Juniperus convallium*	0	LC
Cupressaceae	*Juniperus convallium* var. *convallium*	4	LC
Cupressaceae	*Juniperus convallium* var. *microsperma*	0	DD
Cupressaceae	*Juniperus deppeana*	23	LC
Cupressaceae	*Juniperus deppeana* var. *deppeana*	0	LC
Cupressaceae	*Juniperus deppeana* var. *pachyphlaea*	9	LC
Cupressaceae	*Juniperus deppeana* var. *robusta*	0	VU
Cupressaceae	*Juniperus deppeana* var. *sperryi*	2	CR
Cupressaceae	*Juniperus deppeana* var. *zacatecensis*	0	EN
Cupressaceae	*Juniperus drupacea*	25	LC
Cupressaceae	*Juniperus durangensis*	0	LC
Cupressaceae	*Juniperus excelsa*	43	LC
Cupressaceae	*Juniperus excelsa* ssp. *excelsa*	2	LC
Cupressaceae	*Juniperus excelsa* ssp. *polycarpos*	13	LC
Cupressaceae	*Juniperus flaccida*	13	LC
Cupressaceae	*Juniperus flaccida* var. *flaccida*	0	LC
Cupressaceae	*Juniperus flaccida* var. *martinezii*	0	VU
Cupressaceae	*Juniperus flaccida* var. *poblana*	5	NT
Cupressaceae	*Juniperus foetidissima*	16	LC
Cupressaceae	*Juniperus formosana*	33	LC
Cupressaceae	*Juniperus gamboana*	0	EN
Cupressaceae	*Juniperus gracilior*	1	EN
Cupressaceae	*Juniperus gracilior* var. *ekmanii*	0	CR
Cupressaceae	*Juniperus gracilior* var. *gracilior*	0	EN
Cupressaceae	*Juniperus gracilior* var. *urbaniana*	0	EN
Cupressaceae	*Juniperus horizontalis*	85	LC
Cupressaceae	*Juniperus indica*	14	LC
Cupressaceae	*Juniperus indica* var. *caespitosa*	0	LC
Cupressaceae	*Juniperus indica* var. *indica*	7	LC
Cupressaceae	*Juniperus jaliscana*	0	EN
Cupressaceae	*Juniperus komarovii*	3	LC
Cupressaceae	*Juniperus monosperma*	28	LC
Cupressaceae	*Juniperus monticola*	0	LC
Cupressaceae	*Juniperus occidentalis*	33	LC

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Cupressaceae	*Juniperus occidentalis* var. *australis*	6	LC
Cupressaceae	*Juniperus occidentalis* var. *occidentalis*	4	LC
Cupressaceae	*Juniperus osteosperma*	16	LC
Cupressaceae	*Juniperus oxycedrus*	47	LC
Cupressaceae	*Juniperus oxycedrus* ssp. *macrocarpa*	21	LC
Cupressaceae	*Juniperus oxycedrus* ssp. *oxycedrus*	16	LC
Cupressaceae	*Juniperus oxycedrus* var. *transtagana*	0	NT
Cupressaceae	*Juniperus phoenicea*	60	LC
Cupressaceae	*Juniperus phoenicea* ssp. *phoenicea*	6	LC
Cupressaceae	*Juniperus phoenicea* ssp. *turbinata*	5	NT
Cupressaceae	*Juniperus pinchotii*	0	LC
Cupressaceae	*Juniperus pingii*	8	NT
Cupressaceae	*Juniperus pingii* var. *chengii*	0	DD
Cupressaceae	*Juniperus pingii* var. *miehei*	0	DD
Cupressaceae	*Juniperus pingii* var. *pingii*	1	VU
Cupressaceae	*Juniperus pingii* var. *wilsonii*	17	NT
Cupressaceae	*Juniperus procera*	36	LC
Cupressaceae	*Juniperus procumbens*	67	LC
Cupressaceae	*Juniperus przewalskii*	2	LC
Cupressaceae	*Juniperus pseudosabina*	36	LC
Cupressaceae	*Juniperus recurva*	18	LC
Cupressaceae	*Juniperus recurva* var. *coxii*	29	NT
Cupressaceae	*Juniperus recurva* var. *recurva*	6	LC
Cupressaceae	*Juniperus rigida*	98	LC
Cupressaceae	*Juniperus rigida* ssp. *conferta*	21	LC
Cupressaceae	*Juniperus rigida* ssp. *rigida*	0	LC
Cupressaceae	*Juniperus sabina*	119	LC
Cupressaceae	*Juniperus sabina* var. *arenaria*	0	LC
Cupressaceae	*Juniperus sabina* var. *davurica*	20	LC
Cupressaceae	*Juniperus sabina* var. *sabina*	15	LC
Cupressaceae	*Juniperus saltillensis*	0	EN
Cupressaceae	*Juniperus saltuaria*	2	LC
Cupressaceae	*Juniperus saxicola*	1	CR
Cupressaceae	*Juniperus scopulorum*	67	LC
Cupressaceae	*Juniperus semiglobosa*	16	LC
Cupressaceae	*Juniperus squamata*	56	LC
Cupressaceae	*Juniperus standleyi*	1	EN
Cupressaceae	*Juniperus taxifolia*	3	NT
Cupressaceae	*Juniperus thurifera*	27	LC
Cupressaceae	*Juniperus tibetica*	9	VU
Cupressaceae	*Juniperus virginiana*	191	LC
Cupressaceae	*Juniperus virginiana* var. *silicicola*	21	LC
Cupressaceae	*Juniperus virginiana* var. *virginiana*	19	LC
Cupressaceae	*Libocedrus austrocaledonica*	1	NT
Cupressaceae	*Libocedrus bidwillii*	22	NT
Cupressaceae	*Libocedrus chevalieri*	2	CR
Cupressaceae	*Libocedrus plumosa*	24	NT
Cupressaceae	*Libocedrus yateensis*	5	EN
Cupressaceae	*Metasequoia glyptostroboides*	316	EN
Cupressaceae	*Microbiota decussata*	174	LC
Cupressaceae	*Neocallitropsis pancheri*	9	EN
Cupressaceae	*Papuacedrus papuana*	10	LC
Cupressaceae	*Papuacedrus papuana* var. *arfakensis*	6	NT
Cupressaceae	*Papuacedrus papuana* var. *papuana*	3	LC
Cupressaceae	*Pilgerodendron uviferum*	41	VU
Cupressaceae	*Platycladus orientalis*	190	NT
Cupressaceae	*Sequoia sempervirens*	169	EN
Cupressaceae	*Sequoiadendron giganteum*	181	EN
Cupressaceae	*Taiwania cryptomerioides*	94	VU
Cupressaceae	*Taxodium distichum*	225	LC
Cupressaceae	*Taxodium distichum* var. *distichum*	29	LC
Cupressaceae	*Taxodium distichum* var. *imbricarium*	40	LC
Cupressaceae	*Taxodium mucronatum*	93	LC
Cupressaceae	*Tetraclinis articulata*	73	LC
Cupressaceae	*Thuja koraiensis*	92	VU
Cupressaceae	*Thuja occidentalis*	177	LC
Cupressaceae	*Thuja plicata*	172	LC
Cupressaceae	*Thuja standishii*	87	NT
Cupressaceae	*Thuja sutchuenensis*	11	EN
Cupressaceae	*Thujopsis dolabrata*	101	LC
Cupressaceae	*Thujopsis dolabrata* var. *dolabrata*	4	LC
Cupressaceae	*Thujopsis dolabrata* var. *hondae*	15	LC
Cupressaceae	*Widdringtonia cedarbergensis*	33	CR
Cupressaceae	*Widdringtonia nodiflora*	49	LC
Cupressaceae	*Widdringtonia schwarzii*	28	NT
Cupressaceae	*Widdringtonia whytei*	4	CR
Cupressaceae	*Xanthocyparis nootkatensis*	44	LC
Cupressaceae	*Xanthocyparis vietnamensis*	17	EN
Phyllocladaceae	*Phyllocladus aspleniifolius*	20	LC
Phyllocladaceae	*Phyllocladus hypophyllus*	9	LC
Phyllocladaceae	*Phyllocladus toatoa*	6	LC
Phyllocladaceae	*Phyllocladus trichomanoides*	28	LC
Phyllocladaceae	*Phyllocladus trichomanoides* var. *alpinus*	31	LC
Phyllocladaceae	*Phyllocladus trichomanoides* var. *trichomanoides*	2	LC
Pinaceae	*Abies alba*	135	LC
Pinaceae	*Abies amabilis*	47	LC
Pinaceae	*Abies balsamea*	106	LC
Pinaceae	*Abies balsamea* var. *balsamea*	8	LC
Pinaceae	*Abies balsamea* var. *phanerolepis*	38	DD
Pinaceae	*Abies beshanzuensis*	2	CR
Pinaceae	*Abies bracteata*	35	NT
Pinaceae	*Abies cephalonica*	102	LC
Pinaceae	*Abies chensiensis*	32	LC
Pinaceae	*Abies chensiensis* ssp. *chensiensis*	1	LC
Pinaceae	*Abies chensiensis* ssp. *salouenensis*	15	LC
Pinaceae	*Abies chensiensis* ssp. *yulongxueshanensis*	2	LC
Pinaceae	*Abies cilicica*	62	NT
Pinaceae	*Abies cilicica* ssp. *cilicica*	8	NT
Pinaceae	*Abies cilicica* ssp. *isaurica*	32	VU
Pinaceae	*Abies concolor*	182	LC
Pinaceae	*Abies delavayi*	32	LC
Pinaceae	*Abies delavayi* ssp. *fansipanensis*	2	CR
Pinaceae	*Abies delavayi* var. *delavayi*	0	LC
Pinaceae	*Abies delavayi* var. *motuoensis*	2	LC
Pinaceae	*Abies delavayi* var. *nukiangensis*	3	NT
Pinaceae	*Abies densa*	12	LC

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Pinaceae	*Abies durangensis*	8	LC
Pinaceae	*Abies durangensis* var. *coahuilensis*	11	VU
Pinaceae	*Abies fabri*	34	VU
Pinaceae	*Abies fabri* ssp. *fabri*	1	VU
Pinaceae	*Abies fabri* ssp. *minensis*	3	VU
Pinaceae	*Abies fanjingshanensis*	2	EN
Pinaceae	*Abies fargesii*	26	LC
Pinaceae	*Abies fargesii* var. *fargesii*	0	LC
Pinaceae	*Abies fargesii* var. *faxoniana*	13	VU
Pinaceae	*Abies fargesii* var. *sutchuenensis*	5	LC
Pinaceae	*Abies firma*	98	LC
Pinaceae	*Abies forrestii*	5	LC
Pinaceae	*Abies forrestii* var. *ferreana*	7	LC
Pinaceae	*Abies forrestii* var. *forrestii*	11	NT
Pinaceae	*Abies forrestii* var. *georgei*	37	LC
Pinaceae	*Abies forrestii* var. *smithii*	5	NT
Pinaceae	*Abies fraseri*	97	EN
Pinaceae	*Abies grandis*	115	LC
Pinaceae	*Abies guatemalensis*	15	EN
Pinaceae	*Abies guatemalensis* var. *guatemalensis*	6	EN
Pinaceae	*Abies guatemalensis* var. *jaliscana*	2	NT
Pinaceae	*Abies hickelii*	1	EN
Pinaceae	*Abies hickelii* var. *hickelii*	0	EN
Pinaceae	*Abies hickelii* var. *oaxacana*	3	EN
Pinaceae	*Abies hidalgensis*	0	VU
Pinaceae	*Abies holophylla*	85	NT
Pinaceae	*Abies homolepis*	106	NT
Pinaceae	*Abies homolepis* var. *homolepis*	2	NT
Pinaceae	*Abies homolepis* var. *umbellata*	15	DD
Pinaceae	*Abies kawakamii*	29	NT
Pinaceae	*Abies koreana*	164	EN
Pinaceae	*Abies lasiocarpa*	78	LC
Pinaceae	*Abies lasiocarpa* var. *arizonica*	58	LC
Pinaceae	*Abies lasiocarpa* var. *lasiocarpa*	6	LC
Pinaceae	*Abies magnifica*	26	LC
Pinaceae	*Abies magnifica* var. *magnifica*	1	LC
Pinaceae	*Abies magnifica* var. *shastensis*	20	LC
Pinaceae	*Abies mariesii*	29	LC
Pinaceae	*Abies nebrodensis*	49	CR
Pinaceae	*Abies nephrolepis*	57	LC
Pinaceae	*Abies nordmanniana*	131	LC
Pinaceae	*Abies nordmanniana* ssp. *equi-trojani*	87	EN
Pinaceae	*Abies nordmanniana* ssp. *nordmanniana*	11	LC
Pinaceae	*Abies numidica*	71	CR
Pinaceae	*Abies pindrow*	46	LC
Pinaceae	*Abies pindrow* var. *brevifolia*	8	DD
Pinaceae	*Abies pindrow* var. *pindrow*	1	LC
Pinaceae	*Abies pinsapo*	130	EN
Pinaceae	*Abies pinsapo* var. *marocana*	37	EN
Pinaceae	*Abies pinsapo* var. *pinsapo*	38	EN
Pinaceae	*Abies procera*	74	LC
Pinaceae	*Abies recurvata*	33	VU
Pinaceae	*Abies recurvata* var. *ernestii*	37	VU
Pinaceae	*Abies recurvata* var. *recurvata*	5	VU

Family	Taxon name	No. of *ex situ* collections	IUCN Red List status
Pinaceae	*Abies religiosa*	28	LC
Pinaceae	*Abies sachalinensis*	70	LC
Pinaceae	*Abies sachalinensis* var. *gracilis*	6	DD
Pinaceae	*Abies sachalinensis* var. *mayriana*	18	LC
Pinaceae	*Abies sachalinensis* var. *nemorensis*	1	DD
Pinaceae	*Abies sachalinensis* var. *sachalinensis*	2	LC
Pinaceae	*Abies sibirica*	71	LC
Pinaceae	*Abies sibirica* ssp. *semenovii*	10	LC
Pinaceae	*Abies sibirica* ssp. *sibirica*	0	LC
Pinaceae	*Abies spectabilis*	39	NT
Pinaceae	*Abies squamata*	31	VU
Pinaceae	*Abies veitchii*	90	LC
Pinaceae	*Abies veitchii* var. *sikokiana*	12	VU
Pinaceae	*Abies veitchii* var. *veitchii*	9	LC
Pinaceae	*Abies vejarii*	11	NT
Pinaceae	*Abies vejarii* var. *macrocarpa*	1	VU
Pinaceae	*Abies vejarii* var. *mexicana*	4	VU
Pinaceae	*Abies vejarii* var. *vejarii*	0	VU
Pinaceae	*Abies yuanbaoshanensis*	1	CR
Pinaceae	*Abies ziyuanensis*	7	EN
Pinaceae	*Cathaya argyrophylla*	36	VU
Pinaceae	*Cedrus atlantica*	140	EN
Pinaceae	*Cedrus deodara*	162	LC
Pinaceae	*Cedrus libani*	158	VU
Pinaceae	*Cedrus libani* var. *brevifolia*	30	VU
Pinaceae	*Cedrus libani* var. *libani*	23	VU
Pinaceae	*Keteleeria davidiana*	41	LC
Pinaceae	*Keteleeria davidiana* var. *davidiana*	20	LC
Pinaceae	*Keteleeria davidiana* var. *formosana*	3	EN
Pinaceae	*Keteleeria evelyniana*	34	VU
Pinaceae	*Keteleeria fortunei*	23	NT
Pinaceae	*Larix decidua*	153	LC
Pinaceae	*Larix decidua* var. *carpatica*	2	LC
Pinaceae	*Larix decidua* var. *decidua*	3	LC
Pinaceae	*Larix decidua* var. *polonica*	38	EN
Pinaceae	*Larix gmelinii*	60	LC
Pinaceae	*Larix gmelinii* var. *gmelinii*	25	LC
Pinaceae	*Larix gmelinii* var. *japonica*	39	LC
Pinaceae	*Larix gmelinii* var. *olgensis*	43	NT
Pinaceae	*Larix gmelinii* var. *principis-rupprechtii*	37	LC
Pinaceae	*Larix griffithii*	14	LC
Pinaceae	*Larix griffithii* var. *griffithii*	11	LC
Pinaceae	*Larix griffithii* var. *speciosa*	2	NT
Pinaceae	*Larix kaempferi*	135	LC
Pinaceae	*Larix laricina*	127	LC
Pinaceae	*Larix lyallii*	9	LC
Pinaceae	*Larix mastersiana*	7	EN
Pinaceae	*Larix occidentalis*	56	LC
Pinaceae	*Larix potaninii*	23	LC
Pinaceae	*Larix potaninii* var. *chinensis*	3	VU
Pinaceae	*Larix potaninii* var. *himalaica*	6	NT
Pinaceae	*Larix potaninii* var. *macrocarpa*	0	LC
Pinaceae	*Larix potaninii* var. *potaninii*	0	LC
Pinaceae	*Larix sibirica*	91	LC

Family	Taxon name	No. of *ex situ* collections	IUCN Red List status
Pinaceae	*Nothotsuga longibracteata*	17	NT
Pinaceae	*Picea abies*	203	LC
Pinaceae	*Picea abies* var. *abies*	5	LC
Pinaceae	*Picea abies* var. *acuminata*	4	LC
Pinaceae	*Picea alcoquiana*	29	NT
Pinaceae	*Picea alcoquiana* var. *acicularis*	6	EN
Pinaceae	*Picea alcoquiana* var. *alcoquiana*	27	NT
Pinaceae	*Picea alcoquiana* var. *reflexa*	6	EN
Pinaceae	*Picea asperata*	106	VU
Pinaceae	*Picea asperata* var. *asperata*	1	VU
Pinaceae	*Picea asperata* var. *notabilis*	19	EN
Pinaceae	*Picea asperata* var. *ponderosa*	6	CR
Pinaceae	*Picea aurantiaca*	2	EN
Pinaceae	*Picea brachytyla*	55	VU
Pinaceae	*Picea brachytyla* var. *brachytyla*	5	VU
Pinaceae	*Picea brachytyla* var. *complanata*	9	VU
Pinaceae	*Picea breweriana*	95	VU
Pinaceae	*Picea chihuahuana*	35	EN
Pinaceae	*Picea crassifolia*	22	LC
Pinaceae	*Picea engelmannii*	89	LC
Pinaceae	*Picea engelmannii* ssp. *mexicana*	23	EN
Pinaceae	*Picea farreri*	8	VU
Pinaceae	*Picea glauca*	146	LC
Pinaceae	*Picea glauca* var. *albertiana*	1	LC
Pinaceae	*Picea glauca* var. *glauca*	25	LC
Pinaceae	*Picea glehnii*	77	LC
Pinaceae	*Picea jezoensis*	66	LC
Pinaceae	*Picea jezoensis* ssp. *hondoensis*	0	LC
Pinaceae	*Picea jezoensis* ssp. *jezoensis*	6	LC
Pinaceae	*Picea koraiensis*	31	LC
Pinaceae	*Picea koraiensis* var. *koraiensis*	3	LC
Pinaceae	*Picea koraiensis* var. *pungsanensis*	0	DD
Pinaceae	*Picea koyamae*	47	CR
Pinaceae	*Picea likiangensis*	66	VU
Pinaceae	*Picea likiangensis* var. *hirtella*	5	EN
Pinaceae	*Picea likiangensis* var. *likiangensis*	4	VU
Pinaceae	*Picea likiangensis* var. *montigena*	16	DD
Pinaceae	*Picea likiangensis* var. *rubescens*	37	VU
Pinaceae	*Picea linzhiensis*	6	NT
Pinaceae	*Picea mariana*	99	LC
Pinaceae	*Picea martinezii*	9	EN
Pinaceae	*Picea maximowiczii*	24	EN
Pinaceae	*Picea maximowiczii* var. *maximowiczii*	4	EN
Pinaceae	*Picea maximowiczii* var. *senanensis*	2	DD
Pinaceae	*Picea meyeri*	51	NT
Pinaceae	*Picea morrisonicola*	34	VU
Pinaceae	*Picea neoveitchii*	17	CR
Pinaceae	*Picea obovata*	77	LC
Pinaceae	*Picea omorika*	209	EN
Pinaceae	*Picea orientalis*	142	LC
Pinaceae	*Picea pungens*	145	LC
Pinaceae	*Picea purpurea*	52	NT
Pinaceae	*Picea retroflexa*	30	EN
Pinaceae	*Picea rubens*	79	LC

Family	Taxon name	No. of *ex situ* collections	IUCN Red List status
Pinaceae	*Picea schrenkiana*	61	LC
Pinaceae	*Picea schrenkiana* ssp. *schrenkiana*	0	LC
Pinaceae	*Picea schrenkiana* ssp. *tianschanica*	5	LC
Pinaceae	*Picea sitchensis*	113	LC
Pinaceae	*Picea smithiana*	77	LC
Pinaceae	*Picea spinulosa*	20	LC
Pinaceae	*Picea torano*	33	VU
Pinaceae	*Picea wilsonii*	76	LC
Pinaceae	*Pinus albicaulis*	23	EN
Pinaceae	*Pinus amamiana*	0	EN
Pinaceae	*Pinus aristata*	88	LC
Pinaceae	*Pinus arizonica*	9	LC
Pinaceae	*Pinus arizonica* var. *cooperi*	7	VU
Pinaceae	*Pinus arizonica* var. *stormiae*	3	VU
Pinaceae	*Pinus armandii*	101	LC
Pinaceae	*Pinus armandii* var. *armandii*	8	LC
Pinaceae	*Pinus armandii* var. *dabeshanensis*	9	VU
Pinaceae	*Pinus armandii* var. *mastersiana*	23	EN
Pinaceae	*Pinus attenuata*	44	LC
Pinaceae	Pinus *ayacahuite*	42	LC
Pinaceae	*Pinus ayacahuite* var. *veitchii*	6	NT
Pinaceae	*Pinus balfouriana*	15	NT
Pinaceae	*Pinus banksiana*	119	LC
Pinaceae	*Pinus bhutanica*	11	LC
Pinaceae	*Pinus brutia*	35	LC
Pinaceae	*Pinus brutia* var. *brutia*	8	LC
Pinaceae	*Pinus brutia* var. *eldarica*	35	NT
Pinaceae	*Pinus brutia* var. *pendulifolia*	0	LC
Pinaceae	*Pinus brutia* var. *pityusa*	25	VU
Pinaceae	*Pinus bungeana*	140	LC
Pinaceae	*Pinus canariensis*	62	LC
Pinaceae	*Pinus caribaea*	18	LC
Pinaceae	*Pinus caribaea* var. *bahamensis*	2	VU
Pinaceae	*Pinus caribaea* var. *caribaea*	4	EN
Pinaceae	*Pinus caribaea* var. *hondurensis*	6	LC
Pinaceae	*Pinus cembra*	142	LC
Pinaceae	*Pinus cembroides*	35	LC
Pinaceae	*Pinus cembroides* ssp. *lagunae*	1	VU
Pinaceae	*Pinus cembroides* ssp. *orizabensis*	1	EN
Pinaceae	*Pinus clausa*	5	LC
Pinaceae	*Pinus contorta*	73	LC
Pinaceae	*Pinus contorta* var. *contorta*	39	LC
Pinaceae	*Pinus contorta* var. *latifolia*	3	LC
Pinaceae	*Pinus contorta* var. *murrayana*	35	LC
Pinaceae	*Pinus coulteri*	82	NT
Pinaceae	*Pinus cubensis*	4	LC
Pinaceae	*Pinus culminicola*	8	EN
Pinaceae	*Pinus dalatensis*	0	NT
Pinaceae	*Pinus densata*	21	LC
Pinaceae	*Pinus densiflora*	130	LC
Pinaceae	*Pinus devoniana*	19	LC
Pinaceae	*Pinus douglasiana*	2	LC
Pinaceae	*Pinus durangensis*	17	NT
Pinaceae	*Pinus echinata*	51	LC

Family	Taxon name	No. of *ex situ* collections	IUCN Red List status
Pinaceae	*Pinus edulis*	61	LC
Pinaceae	*Pinus elliottii*	34	LC
Pinaceae	*Pinus elliottii* var. *densa*	3	NT
Pinaceae	*Pinus elliottii* var. *elliottii*	0	LC
Pinaceae	*Pinus engelmannii*	26	LC
Pinaceae	*Pinus fenzeliana*	6	NT
Pinaceae	*Pinus flexilis*	100	LC
Pinaceae	*Pinus flexilis* var. *reflexa*	10	NT
Pinaceae	*Pinus gerardiana*	29	NT
Pinaceae	*Pinus glabra*	22	LC
Pinaceae	*Pinus greggii*	31	VU
Pinaceae	*Pinus greggii* var. *australis*	0	EN
Pinaceae	*Pinus greggii* var. *greggii*	0	NT
Pinaceae	*Pinus halepensis*	77	LC
Pinaceae	*Pinus hartwegii*	33	LC
Pinaceae	*Pinus heldreichii*	141	LC
Pinaceae	*Pinus henryi*	9	NT
Pinaceae	*Pinus herrerae*	2	LC
Pinaceae	*Pinus hwangshanensis*	19	LC
Pinaceae	*Pinus jaliscana*	0	NT
Pinaceae	*Pinus jeffreyi*	108	LC
Pinaceae	*Pinus kesiya*	10	LC
Pinaceae	*Pinus kesiya* var. *kesiya*	4	LC
Pinaceae	*Pinus kesiya* var. *langbianensis*	5	LC
Pinaceae	*Pinus koraiensis*	127	LC
Pinaceae	*Pinus krempfii*	2	VU
Pinaceae	*Pinus lambertiana*	41	LC
Pinaceae	*Pinus latteri*	0	NT
Pinaceae	*Pinus lawsonii*	4	LC
Pinaceae	*Pinus leiophylla*	12	LC
Pinaceae	*Pinus leiophylla* var. *chihuahuana*	5	LC
Pinaceae	*Pinus leiophylla* var. *leiophylla*	0	LC
Pinaceae	*Pinus longaeva*	21	LC
Pinaceae	*Pinus luchuensis*	4	LC
Pinaceae	*Pinus lumholtzii*	8	NT
Pinaceae	*Pinus luzmariae*	0	LC
Pinaceae	*Pinus massoniana*	32	LC
Pinaceae	*Pinus massoniana* var. *hainanensis*	2	CR
Pinaceae	*Pinus massoniana* var. *massoniana*	0	LC
Pinaceae	*Pinus maximartinezii*	24	EN
Pinaceae	*Pinus maximinoi*	7	LC
Pinaceae	*Pinus merkusii*	5	VU
Pinaceae	*Pinus monophylla*	42	LC
Pinaceae	*Pinus montezumae*	43	LC
Pinaceae	*Pinus montezumae* var. *gordoniana*	0	LC
Pinaceae	*Pinus montezumae* var. *montezumae*	2	LC
Pinaceae	*Pinus monticola*	81	NT
Pinaceae	*Pinus morrisonicola*	16	NT
Pinaceae	*Pinus mugo*	151	LC
Pinaceae	*Pinus mugo* ssp. *mugo*	201	LC
Pinaceae	*Pinus mugo* ssp. *rotundata*	23	EN
Pinaceae	*Pinus muricata*	66	VU
Pinaceae	*Pinus nelsonii*	5	EN
Pinaceae	*Pinus nigra*	166	LC

Family	Taxon name	No. of *ex situ* collections	IUCN Red List status
Pinaceae	*Pinus nigra* ssp. *dalmatica*	9	EN
Pinaceae	*Pinus nigra* ssp. *laricio*	11	LC
Pinaceae	*Pinus nigra* ssp. *nigra*	13	LC
Pinaceae	*Pinus nigra* ssp. *pallasiana*	74	LC
Pinaceae	*Pinus nigra* ssp. *salzmannii*	40	LC
Pinaceae	*Pinus occidentalis*	3	EN
Pinaceae	*Pinus oocarpa*	18	LC
Pinaceae	*Pinus palustris*	56	EN
Pinaceae	*Pinus parviflora*	93	LC
Pinaceae	*Pinus parviflora* var. *parviflora*	3	LC
Pinaceae	*Pinus parviflora* var. *pentaphylla*	11	LC
Pinaceae	*Pinus patula*	58	LC
Pinaceae	*Pinus peuce*	98	NT
Pinaceae	*Pinus pinaster*	73	LC
Pinaceae	*Pinus pinaster* ssp. *escarena*	10	LC
Pinaceae	*Pinus pinaster* ssp. *pinaster*	0	LC
Pinaceae	*Pinus pinaster* ssp. *renoui*	0	EN
Pinaceae	*Pinus pinceana*	12	LC
Pinaceae	*Pinus pinea*	107	LC
Pinaceae	*Pinus ponderosa*	154	LC
Pinaceae	*Pinus ponderosa* var. *ponderosa*	23	LC
Pinaceae	*Pinus ponderosa* var. *scopulorum*	2	LC
Pinaceae	*Pinus praetermissa*	0	NT
Pinaceae	*Pinus pringlei*	1	LC
Pinaceae	*Pinus pseudostrobus*	31	LC
Pinaceae	*Pinus pseudostrobus* var. *apulcensis*	18	LC
Pinaceae	*Pinus pseudostrobus* var. *pseudostrobus*	6	LC
Pinaceae	*Pinus pumila*	81	LC
Pinaceae	*Pinus pungens*	37	LC
Pinaceae	*Pinus quadrifolia*	16	LC
Pinaceae	*Pinus radiata*	93	EN
Pinaceae	*Pinus radiata* var. *binata*	14	VU
Pinaceae	*Pinus radiata* var. *radiata*	6	EN
Pinaceae	*Pinus remota*	4	LC
Pinaceae	*Pinus resinosa*	93	LC
Pinaceae	*Pinus rigida*	107	LC
Pinaceae	*Pinus roxburghii*	26	LC
Pinaceae	*Pinus rzedowskii*	1	VU
Pinaceae	*Pinus sabiniana*	50	LC
Pinaceae	*Pinus serotina*	22	LC
Pinaceae	*Pinus sibirica*	67	LC
Pinaceae	*Pinus squamata*	0	CR
Pinaceae	*Pinus strobiformis*	59	LC
Pinaceae	*Pinus strobus*	193	LC
Pinaceae	*Pinus strobus* var. *chiapensis*	10	EN
Pinaceae	*Pinus strobus* var. *strobus*	2	LC
Pinaceae	*Pinus sylvestris*	186	LC
Pinaceae	*Pinus sylvestris* var. *hamata*	34	LC
Pinaceae	*Pinus sylvestris* var. *mongolica*	48	LC
Pinaceae	*Pinus tabuliformis*	68	LC
Pinaceae	*Pinus tabuliformis* var. *mukdensis*	6	LC
Pinaceae	*Pinus tabuliformis* var. *tabuliformis*	1	LC
Pinaceae	*Pinus tabuliformis* var. *umbraculifera*	0	NT
Pinaceae	*Pinus taeda*	85	LC

Family	Taxon name	No. of *ex situ* collections	IUCN Red List status
Pinaceae	*Pinus taiwanensis*	37	LC
Pinaceae	*Pinus taiwanensis* var. *fragilissima*	0	NT
Pinaceae	*Pinus taiwanensis* var. *taiwanensis*	0	LC
Pinaceae	*Pinus tecunumanii*	6	VU
Pinaceae	*Pinus teocote*	13	LC
Pinaceae	*Pinus thunbergii*	110	LC
Pinaceae	*Pinus torreyana*	40	CR
Pinaceae	*Pinus torreyana* ssp. *insularis*	1	VU
Pinaceae	*Pinus torreyana* ssp. *torreyana*	7	CR
Pinaceae	*Pinus tropicalis*	1	VU
Pinaceae	*Pinus uncinata*	50	LC
Pinaceae	*Pinus virginiana*	63	LC
Pinaceae	*Pinus wallichiana*	145	LC
Pinaceae	*Pinus wallichiana* var. *wallichiana*	0	LC
Pinaceae	*Pinus wangii*	1	EN
Pinaceae	*Pinus yunnanensis*	36	LC
Pinaceae	*Pinus yunnanensis* var. *pygmaea*	0	LC
Pinaceae	*Pinus yunnanensis* var. *yunnanensis*	2	LC
Pinaceae	*Pseudolarix amabilis*	126	VU
Pinaceae	*Pseudotsuga japonica*	6	EN
Pinaceae	*Pseudotsuga macrocarpa*	33	NT
Pinaceae	*Pseudotsuga menziesii*	157	LC
Pinaceae	*Pseudotsuga menziesii* var. *glauca*	85	LC
Pinaceae	*Pseudotsuga menziesii* var. *menziesii*	35	LC
Pinaceae	*Pseudotsuga sinensis*	25	VU
Pinaceae	*Pseudotsuga sinensis* var. *brevifolia*	2	VU
Pinaceae	*Pseudotsuga sinensis* var. *gaussenii*	11	DD
Pinaceae	*Pseudotsuga sinensis* var. *sinensis*	28	VU
Pinaceae	*Tsuga canadensis*	197	NT
Pinaceae	*Tsuga caroliniana*	76	NT
Pinaceae	*Tsuga chinensis*	76	LC
Pinaceae	*Tsuga chinensis* var. *chinensis*	30	LC
Pinaceae	*Tsuga chinensis* var. *oblongisquamata*	6	LC
Pinaceae	*Tsuga chinensis* var. *robusta*	0	DD
Pinaceae	*Tsuga diversifolia*	82	LC
Pinaceae	*Tsuga dumosa*	32	LC
Pinaceae	*Tsuga forrestii*	19	VU
Pinaceae	*Tsuga heterophylla*	97	LC
Pinaceae	*Tsuga mertensiana*	57	LC
Pinaceae	*Tsuga mertensiana* ssp. *grandicona*	0	LC
Pinaceae	*Tsuga mertensiana* ssp. *mertensiana*	3	LC
Pinaceae	*Tsuga sieboldii*	68	NT
Podocarpaceae	*Microcachrys tetragona*	36	LC
Podocarpaceae	*Podocarpus madagascariensis* var. *madagascariensis*	0	NT
Podocarpaceae	*Podocarpus orarius*	1	NT
Podocarpaceae	*Podocarpus sellowii* var. *angustifolius*	0	CR
Podocarpaceae	*Podocarpus sellowii* var. *sellowii*	0	EN
Podocarpaceae	*Retrophyllum minus*	0	EN
Podocarpaceae	*Acmopyle pancheri*	10	NT
Podocarpaceae	*Acmopyle sahniana*	6	CR
Podocarpaceae	*Afrocarpus dawei*	4	NT
Podocarpaceae	*Afrocarpus falcatus*	56	LC
Podocarpaceae	*Afrocarpus gracilior*	48	LC

Family	Taxon name	No. of *ex situ* collections	IUCN Red List status
Podocarpaceae	*Afrocarpus mannii*	14	VU
Podocarpaceae	*Afrocarpus usambarensis*	11	EN
Podocarpaceae	*Dacrycarpus cinctus*	2	LC
Podocarpaceae	*Dacrycarpus compactus*	5	LC
Podocarpaceae	*Dacrycarpus cumingii*	0	LC
Podocarpaceae	*Dacrycarpus dacrydioides*	50	LC
Podocarpaceae	*Dacrycarpus expansus*	1	LC
Podocarpaceae	*Dacrycarpus imbricatus*	20	LC
Podocarpaceae	*Dacrycarpus imbricatus* var. *imbricatus*	11	LC
Podocarpaceae	*Dacrycarpus imbricatus* var. *patulus*	5	LC
Podocarpaceae	*Dacrycarpus imbricatus* var. *robustus*	1	LC
Podocarpaceae	*Dacrycarpus kinabaluensis*	6	LC
Podocarpaceae	*Dacrycarpus steupii*	0	NT
Podocarpaceae	*Dacrycarpus vieillardii*	1	LC
Podocarpaceae	*Dacrydium araucarioides*	6	LC
Podocarpaceae	*Dacrydium balansae*	6	LC
Podocarpaceae	*Dacrydium beccarii*	3	LC
Podocarpaceae	*Dacrydium comosum*	0	EN
Podocarpaceae	*Dacrydium cornwallianum*	0	LC
Podocarpaceae	*Dacrydium cupressinum*	35	LC
Podocarpaceae	*Dacrydium elatum*	13	LC
Podocarpaceae	*Dacrydium ericoides*	0	LC
Podocarpaceae	*Dacrydium gibbsiae*	0	LC
Podocarpaceae	*Dacrydium gracile*	1	NT
Podocarpaceae	*Dacrydium guillauminii*	3	CR
Podocarpaceae	*Dacrydium leptophyllum*	0	VU
Podocarpaceae	*Dacrydium lycopodioides*	1	NT
Podocarpaceae	*Dacrydium magnum*	0	NT
Podocarpaceae	*Dacrydium medium*	0	VU
Podocarpaceae	*Dacrydium nausoriense*	4	EN
Podocarpaceae	*Dacrydium nidulum*	4	LC
Podocarpaceae	*Dacrydium novoguineense*	0	LC
Podocarpaceae	*Dacrydium pectinatum*	2	EN
Podocarpaceae	*Dacrydium spathoides*	0	NT
Podocarpaceae	*Dacrydium xanthandrum*	1	LC
Podocarpaceae	*Falcatifolium angustum*	0	EN
Podocarpaceae	*Falcatifolium falciforme*	3	NT
Podocarpaceae	*Falcatifolium gruezoi*	2	NT
Podocarpaceae	*Falcatifolium papuanum*	1	LC
Podocarpaceae	*Falcatifolium sleumeri*	0	NT
Podocarpaceae	*Falcatifolium taxoides*	7	LC
Podocarpaceae	*Halocarpus bidwillii*	23	LC
Podocarpaceae	*Halocarpus biformis*	11	LC
Podocarpaceae	*Halocarpus kirkii*	6	NT
Podocarpaceae	*Lagarostrobos franklinii*	27	LC
Podocarpaceae	*Lepidothamnus fonkii*	4	LC
Podocarpaceae	*Lepidothamnus intermedius*	5	LC
Podocarpaceae	*Lepidothamnus laxifolius*	13	LC
Podocarpaceae	*Manoao colensoi*	10	LC
Podocarpaceae	*Nageia fleuryi*	12	NT
Podocarpaceae	*Nageia maxima*	0	EN
Podocarpaceae	*Nageia motleyi*	3	VU
Podocarpaceae	*Nageia nagi*	51	NT
Podocarpaceae	*Nageia wallichiana*	6	LC

Family	Taxon name	No. of *ex situ* collections	IUCN Red List status
Podocarpaceae	*Parasitaxus usta*	0	VU
Podocarpaceae	*Pherosphaera fitzgeraldii*	31	CR
Podocarpaceae	*Pherosphaera hookeriana*	12	NT
Podocarpaceae	*Podocarpus acuminatus*	0	NT
Podocarpaceae	*Podocarpus acutifolius*	33	LC
Podocarpaceae	*Podocarpus affinis*	5	NT
Podocarpaceae	*Podocarpus angustifolius*	9	VU
Podocarpaceae	*Podocarpus aracensis*	0	LC
Podocarpaceae	*Podocarpus archboldii*	2	VU
Podocarpaceae	*Podocarpus atjehensis*	0	NT
Podocarpaceae	*Podocarpus borneensis*	0	LC
Podocarpaceae	*Podocarpus bracteatus*	0	LC
Podocarpaceae	*Podocarpus brasiliensis*	0	LC
Podocarpaceae	*Podocarpus brassii*	8	LC
Podocarpaceae	*Podocarpus brevifolius*	1	NT
Podocarpaceae	*Podocarpus buchii*	0	EN
Podocarpaceae	*Podocarpus capuronii*	0	EN
Podocarpaceae	*Podocarpus celatus*	1	LC
Podocarpaceae	*Podocarpus chingianus*	8	DD
Podocarpaceae	*Podocarpus confertus*	0	EN
Podocarpaceae	*Podocarpus coriaceus*	5	LC
Podocarpaceae	*Podocarpus costalis*	11	EN
Podocarpaceae	*Podocarpus costaricensis*	0	CR
Podocarpaceae	*Podocarpus crassigemma*	0	LC
Podocarpaceae	*Podocarpus cunninghamii*	41	LC
Podocarpaceae	*Podocarpus decumbens*	1	CR
Podocarpaceae	*Podocarpus deflexus*	0	NT
Podocarpaceae	*Podocarpus dispermus*	10	LC
Podocarpaceae	*Podocarpus drouynianus*	9	LC
Podocarpaceae	*Podocarpus ekmanii*	0	LC
Podocarpaceae	*Podocarpus elatus*	54	LC
Podocarpaceae	*Podocarpus elongatus*	19	LC
Podocarpaceae	*Podocarpus fasciculus*	4	VU
Podocarpaceae	*Podocarpus gibbsiae*	1	VU
Podocarpaceae	*Podocarpus glaucus*	0	LC
Podocarpaceae	*Podocarpus globulus*	0	EN
Podocarpaceae	*Podocarpus glomeratus*	1	NT
Podocarpaceae	*Podocarpus gnidioides*	9	NT
Podocarpaceae	*Podocarpus grayae*	11	LC
Podocarpaceae	*Podocarpus guatemalensis*	7	LC
Podocarpaceae	*Podocarpus henkelii*	43	EN
Podocarpaceae	*Podocarpus hispaniolensis*	0	EN
Podocarpaceae	*Podocarpus humbertii*	0	EN
Podocarpaceae	*Podocarpus insularis*	1	LC
Podocarpaceae	*Podocarpus lambertii*	13	NT
Podocarpaceae	*Podocarpus latifolius*	39	LC
Podocarpaceae	*Podocarpus laubenfelsii*	0	EN
Podocarpaceae	*Podocarpus lawrencei*	36	LC
Podocarpaceae	*Podocarpus ledermannii*	1	LC
Podocarpaceae	*Podocarpus levis*	0	LC
Podocarpaceae	*Podocarpus longefoliolatus*	5	EN
Podocarpaceae	*Podocarpus lophatus*	0	VU
Podocarpaceae	*Podocarpus lucienii*	4	LC
Podocarpaceae	*Podocarpus macrocarpus*	0	EN

Family	Taxon name	No. of *ex situ* collections	IUCN Red List status
Podocarpaceae	*Podocarpus macrophyllus*	118	LC
Podocarpaceae	*Podocarpus macrophyllus* var. *macrophyllus*	5	LC
Podocarpaceae	*Podocarpus macrophyllus* var. *maki*	43	NT
Podocarpaceae	*Podocarpus madagascariensis*	1	NT
Podocarpaceae	*Podocarpus madagascariensis* var. *procerus*	0	EN
Podocarpaceae	*Podocarpus madagascariensis* var. *rotundus*	0	DD
Podocarpaceae	*Podocarpus magnifolius*	0	LC
Podocarpaceae	*Podocarpus matudae*	23	VU
Podocarpaceae	*Podocarpus micropedunculatus*	0	NT
Podocarpaceae	*Podocarpus milanjianus*	7	LC
Podocarpaceae	*Podocarpus nakaii*	3	EN
Podocarpaceae	*Podocarpus neriifolius*	45	LC
Podocarpaceae	*Podocarpus neriifolius* var. *degeneri*	0	LC
Podocarpaceae	*Podocarpus neriifolius* var. *neriifolius*	5	LC
Podocarpaceae	*Podocarpus nivalis*	74	LC
Podocarpaceae	*Podocarpus novae-caledoniae*	10	LC
Podocarpaceae	*Podocarpus nubigenus*	20	NT
Podocarpaceae	*Podocarpus oleifolius*	8	LC
Podocarpaceae	*Podocarpus palawanensis*	0	CR
Podocarpaceae	*Podocarpus pallidus*	2	VU
Podocarpaceae	*Podocarpus parlatorei*	9	NT
Podocarpaceae	*Podocarpus pendulifolius*	0	EN
Podocarpaceae	*Podocarpus perrieri*	0	CR
Podocarpaceae	*Podocarpus pilgeri*	5	LC
Podocarpaceae	*Podocarpus polyspermus*	2	EN
Podocarpaceae	*Podocarpus polystachyus*	12	VU
Podocarpaceae	*Podocarpus pseudobracteatus*	3	LC
Podocarpaceae	*Podocarpus purdieanus*	3	EN
Podocarpaceae	*Podocarpus ramosii*	2	DD
Podocarpaceae	*Podocarpus ridleyi*	0	VU
Podocarpaceae	*Podocarpus roraimae*	0	LC
Podocarpaceae	*Podocarpus rostratus*	0	EN
Podocarpaceae	*Podocarpus rubens*	3	LC
Podocarpaceae	*Podocarpus rumphii*	15	NT
Podocarpaceae	*Podocarpus rusbyi*	0	VU
Podocarpaceae	*Podocarpus salicifolius*	0	LC
Podocarpaceae	*Podocarpus salignus*	62	VU
Podocarpaceae	*Podocarpus salomoniensis*	1	NT
Podocarpaceae	*Podocarpus sellowii*	4	EN
Podocarpaceae	*Podocarpus smithii*	8	LC
Podocarpaceae	*Podocarpus spathoides*	0	DD
Podocarpaceae	*Podocarpus spinulosus*	17	LC
Podocarpaceae	*Podocarpus sprucei*	1	EN
Podocarpaceae	*Podocarpus steyermarkii*	0	LC
Podocarpaceae	*Podocarpus subtropicalis*	5	DD
Podocarpaceae	*Podocarpus sylvestris*	3	LC
Podocarpaceae	*Podocarpus tepuiensis*	0	LC
Podocarpaceae	*Podocarpus teysmannii*	1	NT
Podocarpaceae	*Podocarpus totara*	65	LC
Podocarpaceae	*Podocarpus transiens*	0	EN
Podocarpaceae	*Podocarpus trinitensis*	4	NT

Family	Taxon name	No. of *ex situ* collections	IUCN Red List status
Podocarpaceae	Podocarpus urbanii	3	CR
Podocarpaceae	Prumnopitys andina	70	VU
Podocarpaceae	Prumnopitys exigua	0	NT
Podocarpaceae	*Prumnopitys ferruginea*	20	LC
Podocarpaceae	*Prumnopitys ferruginoides*	1	LC
Podocarpaceae	*Prumnopitys harmsiana*	1	NT
Podocarpaceae	*Prumnopitys ladei*	21	VU
Podocarpaceae	*Prumnopitys montana*	5	VU
Podocarpaceae	*Prumnopitys standleyi*	2	EN
Podocarpaceae	*Prumnopitys taxifolia*	26	LC
Podocarpaceae	*Retrophyllum comptonii*	8	LC
Podocarpaceae	*Retrophyllum piresii*	1	DD
Podocarpaceae	*Retrophyllum rospigliosii*	13	VU
Podocarpaceae	*Retrophyllum vitiense*	3	LC
Podocarpaceae	*Saxegothaea conspicua*	45	NT
Podocarpaceae	*Sundacarpus amarus*	9	LC
Sciadopityaceae	*Sciadopitys verticillata*	156	NT
Taxaceae	*Torreya fargesii* ssp. *fargesii*	0	EN
Taxaceae	*Torreya grandis* var. *jiulongshanensis*	0	DD
Taxaceae	*Amentotaxus argotaenia*	18	NT
Taxaceae	*Amentotaxus argotaenia* var. *argotaenia*	1	NT
Taxaceae	*Amentotaxus argotaenia* var. *brevifolia*	0	CR
Taxaceae	*Amentotaxus assamica*	0	EN
Taxaceae	*Amentotaxus formosana*	12	VU
Taxaceae	*Amentotaxus hatuyenensis*	0	EN

Family	Taxon name	No. of *ex situ* collections	IUCN Red List status
Taxaceae	*Amentotaxus poilanei*	0	VU
Taxaceae	*Amentotaxus yunnanensis*	6	VU
Taxaceae	*Austrotaxus spicata*	3	NT
Taxaceae	*Pseudotaxus chienii*	27	VU
Taxaceae	*Taxus baccata*	189	LC
Taxaceae	*Taxus brevifolia*	60	NT
Taxaceae	*Taxus canadensis*	64	LC
Taxaceae	*Taxus chinensis*	31	EN
Taxaceae	*Taxus contorta*	0	EN
Taxaceae	*Taxus cuspidata*	144	LC
Taxaceae	*Taxus cuspidata* var. *cuspidata*	3	LC
Taxaceae	*Taxus cuspidata* var. *nana*	17	DD
Taxaceae	*Taxus floridana*	20	CR
Taxaceae	*Taxus globosa*	17	EN
Taxaceae	*Taxus mairei*	19	VU
Taxaceae	*Taxus wallichiana*	59	EN
Taxaceae	*Torreya californica*	67	VU
Taxaceae	*Torreya fargesii*	2	VU
Taxaceae	*Torreya fargesii* var. *yunnanensis*	1	EN
Taxaceae	*Torreya grandis*	41	LC
Taxaceae	*Torreya grandis* var. *grandis*	2	LC
Taxaceae	*Torreya jackii*	11	EN
Taxaceae	*Torreya nucifera*	111	LC
Taxaceae	*Torreya taxifolia*	43	CR

Pinus pinea *at the Royal Botanic Gardens, Kew. Least Concern (LC), reported as held in 107* ex situ *collections worldwide.*

Annex II: Priority Critically Endangered (CR) and Endangered (EN) conifer taxa for increased *ex situ* conservation efforts.

Number of *ex situ* collections refers to PlantSearch records and records supplied by International Conifer Conservation Programme (ICCP) sites.

Critically Endangered (CR) taxa reported as absent from *ex situ* collections	
Cupressaceae	*Juniperus gracilior* var. *ekmanii*
Pinaceae	*Pinus squamata*
Podocarpaceae	*Podocarpus sellowii* var. *angustifolius*
Podocarpaceae	*Podocarpus costaricensis*
Podocarpaceae	*Podocarpus palawanensis*
Podocarpaceae	*Podocarpus perrieri*
Taxaceae	*Amentotaxus argotaenia* var. *brevifolia*

Critically Endangered (CR) taxa reported in a small number (1-5) of *ex situ* collections	
Cupressaceae	*Juniperus gracilior* var. *ekmanii*
Pinaceae	*Pinus squamata*
Podocarpaceae	*Podocarpus sellowii* var. *angustifolius*
Podocarpaceae	*Podocarpus costaricensis*
Podocarpaceae	*Podocarpus palawanensis*
Podocarpaceae	*Podocarpus perrieri*
Taxaceae	*Amentotaxus argotaenia* var. *brevifolia*
Cupressaceae	*Juniperus barbadensis* var. *barbadensis*
Cupressaceae	*Juniperus saxicola*
Pinaceae	*Abies yuanbaoshanensis*
Podocarpaceae	*Podocarpus decumbens*
Cupressaceae	*Cupressus chengiana* var. *jiangensis*
Cupressaceae	*Juniperus deppeana* var. *sperryi*
Cupressaceae	*Libocedrus chevalieri*
Pinaceae	*Abies beshanzuensis*
Pinaceae	*Abies delavayi* ssp. *fansipanensis*
Pinaceae	*Pinus massoniana* var. *hainanensis*
Podocarpaceae	*Dacrydium guillauminii*
Podocarpaceae	*Podocarpus urbanii*
Cupressaceae	*Widdringtonia whytei*

Endangered (EN) taxa reported as absent from *ex situ* collections	
Araucariaceae	*Agathis orbicular*
Cupressaceae	*Juniperus comitana*
Cupressaceae	*Juniperus deppeana* var. *zacatecensis*
Cupressaceae	*Juniperus gamboana*
Cupressaceae	*Juniperus gracilior* var. *gracilior*
Cupressaceae	*Juniperus gracilior* var. *urbaniana*
Cupressaceae	*Juniperus jaliscana*
Cupressaceae	*Juniperus saltillensis*
Pinaceae	*Abies hickelii* var. *hickelii*
Pinaceae	*Pinus amamiana*
Pinaceae	*Pinus greggii* var. *australis*
Pinaceae	*Pinus pinaster* ssp. *renoui*
Podocarpaceae	*Podocarpus sellowii* var. *sellowii*
Podocarpaceae	*Retrophyllum minus*
Podocarpaceae	*Dacrydium comosum*
Podocarpaceae	*Falcatifolium angustum*
Podocarpaceae	*Nageia maxima*
Podocarpaceae	*Podocarpus buchii*
Podocarpaceae	*Podocarpus capuronii*
Podocarpaceae	*Podocarpus confertus*
Podocarpaceae	*Podocarpus globules*
Podocarpaceae	*Podocarpus hispaniolensis*
Podocarpaceae	*Podocarpus humbertii*
Podocarpaceae	*Podocarpus laubenfelsii*
Podocarpaceae	*Podocarpus macrocarpus*
Podocarpaceae	*Podocarpus madagascariensis* var. *procerus*
Podocarpaceae	*Podocarpus pendulifolius*
Podocarpaceae	*Podocarpus rostratus*
Podocarpaceae	*Podocarpus transiens*
Taxaceae	*Torreya fargesii* ssp. *fargesii*
Taxaceae	*Amentotaxus assamica*
Taxaceae	*Amentotaxus hatuyenensis*
Taxaceae	*Taxus contorta*

Endangered (EN) taxa reported in a small number (1-5) of *ex situ* collections	
Pinaceae	*Pinus wangii*
Podocarpaceae	*Podocarpus sprucei*
Taxaceae	*Torreya fargesii* var. *yunnanensis*
Araucariaceae	*Agathis kinabaluensis*
Pinaceae	*Abies fanjingshanensis*
Pinaceae	*Picea aurantiaca*
Podocarpaceae	*Dacrydium pectinatum*
Podocarpaceae	*Podocarpus polyspermus*
Podocarpaceae	*Prumnopitys standleyi*
Cephalotaxaceae	*Cephalotaxus hainanensis*
Cupressaceae	*Cupressus guadalupensis* var. *guadalupensis*
Pinaceae	*Abies hickelii* var. *oaxacana*
Pinaceae	*Keteleeria davidiana* var. *formosana*
Pinaceae	*Pinus occidentalis*
Podocarpaceae	*Podocarpus nakaii*
Podocarpaceae	*Podocarpus purdieanus*
Cephalotaxaceae	*Cephalotaxus lanceolata*
Pinaceae	*Picea maximowiczii* var. *maximowiczii*
Pinaceae	*Pinus caribaea* var. *caribaea*
Podocarpaceae	*Dacrydium nausoriense*
Podocarpaceae	*Podocarpus sellowii*
Cupressaceae	*Libocedrus yateensis*
Pinaceae	*Picea likiangensis* var. *hirtella*
Pinaceae	*Pinus nelsonii*
Podocarpaceae	*Podocarpus longefoliolatus*

Annex III: Participating institutions

Participating institutions that provided information to PlantSearch are listed below (ordered alphabetically by country). International Conifer Conservation Programme (ICCP) sites also contributed information to the survey.

Jardín Botánico “Cascada Escondida”; Jardín Botánico “Lucien Hauman”; Sevan Botanical Garden; Vanadzor Botanical Garden; Yerevan Botanic Garden; Alexandra Gardens; Alice Springs Desert Park; Australian National Botanic Gardens; Bendigo Botanic Gardens, White Hills; Booderee Botanic Gardens; Botanic Gardens of Adelaide; Brisbane Botanic Gardens; Bundaberg Botanic Gardens; Burrendong Botanic Garden & Arboretum; Cooktown Botanic Gardens; Darwin Botanic Gardens; Fruit Spirit Botanical Garden; Geelong Botanic Gardens; Kings Park and Botanic Garden; Mackay Regional Botanic Gardens; National Arboretum Canberra; North Coast Regional Botanic Garden; Royal Botanic Gardens Sydney; Royal Botanic Gardens, Melbourne; Royal Tasmanian Botanical Gardens; St. Kilda Botanic Garden; Tasmanian Arboretum Inc; The Cairns Botanic Gardens; Townsville Botanic Gardens; University of Melbourne Grounds and Gardens; Alpengarten Villacher Alpe; Core Facility Botanical Garden; Botanical Garden Komarov, Herbarium & Baku Botanical Institute; Bangladesh Agricultural University Botanic Garden; Central Botanical Garden; The Belorussian Agricultural Academy; The Botanical Garden of the Technological Institute; Arboretum Groenendaal - Flemish Forest Department - Houtvesterij Groenendaal; Arboretum Waasland; Arboretum Wespelaar; Bokrijk Arboretum; Ghent University Botanic Garden; Hof ter Saksen Arboretum; Kalmthout Arboretum; Leuven Botanic Garden; National Botanic Garden of Belgium; The Bermuda Botanical Gardens; Royal Botanical Garden, Serbithang; Limbe Botanic Garden; Annapolis Royal Historic Gardens; Arboretum at the University of Guelph, The; Biodôme de Montréal - Botanical Garden; Calgary Zoo, Botanical Garden & Prehistoric Park; Cowichan Lake Research Station Arboretum; Devonian Botanic Garden; Dominion Arboretum and Central Experimental Farm; Dr. Sun Yat-Sen Classical Chinese Garden; Gardens of Fanshawe College and A.M. Cuddy Gardens; Great Lakes Forestry Centre Arboretum; Harriet Irving Botanical Gardens; Milner Gardens and Woodland; Montreal Botanical Garden / Jardin botanique de Montréal; Morden Arboretum Research Station; National Tree Seed Centre; New Brunswick Botanical Garden; Niagara Parks Botanical Gardens and School of Horticulture, The; Patterson Gardens; Riverview Horticultural Centre Society, The; Royal Botanical Gardens, Ontario; Royal Roads University Botanical Gardens; Sherwood Fox Arboretum; Toronto Botanical Garden; Toronto Zoo; University of British Columbia Botanical Garden; VanDusen Botanical Garden; Jardim Botanico Nacional ‘L. Grandvaux Barbosa’; Queen Elizabeth II Botanic Park; Arboretum (Institute of Silviculture, Forestry Faculty); Jardin Botanico (Instituto de Botanica); Jardin Botanico Nacional; Arboretum of Guizhou Institute of Forestry Science; Arboretum of Jiangxi Institute of Forestry Science; Arboretum of Nanjing Forestry University; Arboretum of Wuhan University; Baoji Botanical Garden (Shaanxi); Beijing Medicinal Garden; Changchun Forest Botanic Garden, Jilin; Dashushan Botanical Garden; Dinghushan National Nature Reserve; Dongfeng Forest Farm (Guizhou); Gannan Arboretum of Jiangxi; Guangxi Botanical Garden of Medicinal Plants; Guilin Botanical Garden; Guizhou Botanical Garden; Hangzhou Botanical Garden; Heilongjiang Forest Botanical Garden; Hohhot Arboretum; Hong Kong Zoological and Botanical Gardens; Hunan Forest Botanical Garden; Hunan Nanyue Arboretum; Jinyunshan Botanical Garden (Chongqing); Kadoorie Farm and Botanic Garden; Lushan Botanical Garden; Maijishan Arboretum (Gansu); Minqin Garden of Desert Plants; Nanjing Botanical Garden Mem. Sun Yat-sen; Nanjing Botanical Garden of Medicinal Plants; Research Institute of Subtropical Forestry (Zhejiang); Shanghai Botanical Garden; Shenzhen Fairy Lake Botanical Garden; Shing Mun Arboretum, AFCD; South China Botanical Garden, Chinese Academy of Sciences; Turpan Desert Botanic Garden; Wuhan Botanic Garden; Wutaishan Arboretum (Shanxi); Xi'an Botanical Garden; Xiashi Arboretum; Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences; Yanchi Arid Land Shrub Garden (Ningxia); Yinchuan Botanical Garden (Ningxia); Jardin Botanico Eloy Valenzuela; Jardín Botánico José Celestino Mutis; Arboretum ‘Trsteno’; Botanical Garden of the University of Zagreb; Jardin Botanico Sancti Spiritus; Arboretum St exední lesnické školy; Charles University Botanic Garden (Botanicka zahrada University Karlovy); Institute of Botany, Czech Academy of Sciences; Jardin Botanique de Kisantu; Københavns Universitets Botaniske Have; Royal Veterinary and Agricultural University Arboretum; The Greenland Arboretum; University of Aarhus Botanical Institute; Jardin Botanico Nacional “Dr. Rafael M. Moscoso”; Reserva Rio Guaycuyacu; El Saff Botanic Garden; Botanical Garden of Tartu University; Tallinn Botanic Garden; Gullele Botanic Garden; Botanical Gardens and Museum of Oulu University; Helsinki University Botanic Garden; University of Turku - Botanical Garden; Arboretum des Grands-Murcins; Arboretum Marcel Kroenlein; Bibliotheque Centrale; Conservatoire Botanique National de Porquerolles; Conservatoire Botanique National du Brest; Conservatoire et Jardins Botaniques de Nancy; Conservatoire Genetique des Arbres Forestiers USC ONF-INRA; Espace Pierres Folles; Harmas de Fabre; Jardin Botanique Alpin de la Jaysinia; Jardin Botanique de l'Université de Strasbourg;

Jardin Botanique de la Ville de Lyon; Jardin Botanique de la Ville de Nice; Jardin botanique de la Ville de Paris; Jardin Botanique de la Ville et de l'Universite de BESANCON; Jardin Botanique de le Villa Thuret; Jardin Botanique de Marnay sur Seine; Jardin Botanique des Plantes Medicinales et Aromatiques; Jardin Botanique et Arboretum Henri Gaussen; Jardin Botanique Exotique " Val Rahmeh "; Jardin des Plantes de Paris et Arboretum de Chevreloup; Jardin des Serres d' Auteuil; Jardins des Plantes de l'Université; Les Jardins Suspendus; Parc Zoologique et Botanique de la Ville de Mulhouse; Station Alpine du Lautaret; Universite Paris-Sud - Parc Botanique de Launay; Bakuriani Alpine Botanical Garden; Batumi Botanical Garden; National Botanical Garden of Georgia; Alpengarten auf dem Schachen; Arboretum Freiburg-Guenterstal im Staedtischen Forstamt Freiburg; Botanic Garden of Rostock University; Botanical Garden University of Duesseldorf; Botanische Gärten der Universität Bonn; Botanischer Garten; Botanischer Garten der Carl von Ossietzky-Universitat Oldenburg; Botanischer Garten der Friedrich-Schiller-Universitaet; Botanischer Garten der J.W. Goethe-Universitat; Botanischer Garten der Johannes Gutenberg-Universität Mainz; Botanischer Garten der Justus-Liebig Universität Giessen; Botanischer Garten der Martin-Luther-Universitat; Botanischer Garten der Philipps-Universität Marburg; Botanischer Garten der Ruhr-Universität Bochum; Botanischer Garten der Technischen Universitaet Darmstadt; Botanischer Garten der Technischen Universitaet Dresden; Botanischer Garten der Universitaet des Saarlandes; Botanischer Garten der Universität Freiburg; Botanischer Garten der Universitat Kiel; Botanischer Garten der Universitat Leipzig; Botanischer Garten der Universitat Osnabruck; Botanischer Garten der Universität Ulm; Botanischer Garten München-Nymphenburg; Botanischer Garten und Botanisches Museum Berlin-Dahlem; Botanischer Versuchs- und Lehrgarten; Forstbotanischer Garten der Technischen; Universitaet Dresden; Forstbotanischer Garten Eberswalde; Forstbotanischer Garten und Arboretum; Grugapark und Botanischer Garten der Stadt Essen; Kurpark Bad Bellingen; Neuer Botanischer Garten der Universität Göttingen; Oekologisch-Botanischer Garten Universitaet Bayreuth; Palmengarten der Stadt Frankfurt am Main; Aburi Botanic Gardens; Gibraltar Botanic Gardens; Park for the Preservation of Flora and Fauna; Philodassiki Botanic Garden; The Balkan Botanic Garden at Kroussia Mountains; Jardin Botanico Cecon; Eötvös Loránd University Botanic Garden; Nyugat-Magyarországi Egyetem, Botanikus Kert; Hortus Botanicus Reykjavikensis; Acharya Jagadish Chandra Bose Indian Botanic Garden; Punjabi University Botanic Garden; The Agri-Horticultural Society of India; Cabang Balai Kebun Raya Eka Karya Bali; Center for Plant Conservation - Bogor Botanic Gardens; Birr Castle Demesne; Mount Usher Gardens; National Botanic Gardens, Glasnevin; Talbot Botanic Garden; Trinity College Botanic Garden; Jerusalem Botanical Gardens; Arboreto di Arco - Parco Arciducale; Ente Giardini Botanici Villa Taranto; Giardino Botanico Alpino alle Viotte di M. Bondone; Giardino Botanico Friuli "Cormor"; il Giardino della Minerva; Istituto e Orto Botanico dell'Universita di Pavia; Istituto ed Orto Botanico della Universita; Orto Botanico "Carmela Cortini" - Università di Camerino; Orto Botanico "Giardino dei Semplici"; Orto Botanico - Università degli Studi di Catania; Orto Botanico delll'Università; Orto Botanico dell'Universita di Ferrara; Orto Botanico di Perugia; Orto Botanico Università degli Studi di Padova; Brackenhurst Botanic Garden; Friends of Nairobi Arboretum; National Museums of Kenya, Nairobi Botanic Garden; Gareev Botanical Garden of the National Academy of Sciences, Kyrgyzstan; Botanical Garden of the University of Latvia, The; National Botanic Garden of Latvia; Botanical Garden of Vilnius University; Kaunas Botanical Garden; Arboretum Kirchberg; National Herbarium & Botanic Gardens of Malawi; Rimba Ilmu Botanic Garden; Ecojardin del CIEco; FES Iztacala Banco de Semillas; Fundación Xochitla A.C.; Jardin Botanico - Dr. Alfredo Barrera Marin; Jardin Botanico - Efraim Hernandez Xolocotzi; Jardin Botanico - Ignacio Rodriguez Alconedo – BUAP; Jardin Botanico - Jerzy Rzedowski Rotter; Jardin Botanico - Louise Wardle de Camacho; Jardin Botanico - Rey Netzahualcoyotl; Jardin Botanico Benjamin F. Johnston; Jardin Botanico Culiacán; Jardín Botánico de Acapulco; Jardin Botanico de Hampolol; Jardin Botanico de la Facultad de Estudios Superiores; Jardin Botanico de la Universidad Autónoma de Guerrero; Jardin Botanico Dr. Faustino Miranda; Jardín Botánico Francisco Javier Clavijero; Jardin Botanico Tizatlan; Jardin Etnobotanico - Francisco Pelaez R.; Jardin Etnobotanico - Francisco Pelaez R. - Banco de Semillas; Jardin Etnobotanico y Museo de Medicina Tradicional y Herbolaria; Vallarta Botanical Gardens, A.C.; Jardin Exotique de Monaco; National Kandawgyi Botanical Gardens (Maymyo Botanical Garden); Arboretum Oudenbosch; Botanic Garden, Delft University of Technology; Botanical Gardens Wageningen UR; Botanische Tuin De Kruidhof; Botanische Tuin Groningen "Domies Toen"; Dutch Open Air Museum / Nederlands Openluchtmuseum; Historische Tuin Aalsmeer; Hortus Botanicus Amsterdam; Hortus Botanicus Vrije Universiteit; Pinetum Blijdenstein; Rotterdam Zoological and Botanical Gardens; Stichting Botanische Tuin Kerkrade; Stichting Botanische Tuin van Steyl Jochum-Hof; Trompenburg Gardens & Arboretum; Utrecht University Botanic Gardens; Auckland Botanic Gardens; Christchurch Botanic Gardens; Dunedin Botanic Garden; Gore Public Gardens; Otari Native Botanic Garden; Pukeiti Garden; Pukekura Park; Timaru Botanic Garden; Wellington Botanic Garden; Agodi Gardens; CPES Biological Garden of Federal University of Technology, Minna; Forestry Research Institute of Nigeria (FRIN) - Herbal Garden; IITA – Arboreta; NACGRAB Field Genebank; Nigeria Montane Forest Project; Sarius Palmetum and Botanical Garden; Shodex Botanic Garden; Arboretum and Botanic Garden, University of Bergen; Ringve Botanical Garden; University of Oslo Botanical Garden; Government College University Lahore, Botanic Garden (GCBG); Lipizauga Botanical Sanctuary; Makiling Botanic Gardens; Northwestern University Ecotourism Park and Botanic Gardens; Siit Arboretum Botanical Garden; Arboretum w Przelewicach; Kornik Arboretum; Ogród Botaniczny Uniwersytetu Wroclawskiego; Rogów Arboretum of Warsaw University of Life Sciences; Warsaw University Botanic Garden; Jardim Botanico da Ajuda; Jardim Botanico da Madeira; Jardim Botânico da Universidade de Coimbra; Jardim Botânico da Universidade de Lisboa; Jardim Botanico do Faial; Jardim Botânico Tropical; Parque Botânico da Tapada da Ajuda; Parques de Sintra - Monte da Lua S.A.; Conservatoire Botanique National de Mascarin; Gradina Botanica “Alexandru Borza” a Universitatii din Cluj-Napoca; Gradina Botanica a Universitatii din Bucuresti; Gradina Botanica a Universitatii din Craiova; Gradina Botanica Targu Mures; Botanic Garden of Tver State University; Botanical Garden - Center of Ecological Education of Moscow Palace for Children and Youth Creativity; Botanical Garden - Institute of the Volga State Technological University; Botanical Garden of Chelyabinsk State University; Botanical Garden of Pyatigorsk State Pharmaceutical Academy; Botanical Garden of St. Petersburg State University; Botanical Garden of the V.L. Komarov Botanical Institute; Botanical Garden-Institute, Ufa Research Center; Central Siberian Botanical Garden; Main Botanical Garden, Russian Academy of Science; Moscow State University Botanical Garden; Mountain Botanical Garden of the Dagestan Scientific Centre; Novosibirsk Dendropark; Siberian Botanical Garden of Tomsk State University; Stavropol Botanical Garden; The B.M. Kozo-Polyansky Botanical Garden of Voronezh State University; St Vincent and the Grenadines Botanic Gardens; Jardin d’Experimentation des Plantes Utiles (J.E.P.U.); Arboretum Radigojno; National Botanic Gardens Foundation; Singapore Botanic Gardens; Arboretum Mly any SAS; Juliana Alpine Botanical Garden; Ljubljana University Botanic Garden; Maribor University Botanic Garden; Kirstenbosch National Botanical Garden; KwaZulu-Natal National Botanical Garden; Lowveld National Botanical Garden; Pretoria National Botanical Garden; Walter Sisulu National Botanical Garden; Korean National Arboretum; Kwanak Arboretum of Seoul National University; Dr. P. Font i Quer Arboretum of Lleida Botanic Garden; Jardi Botanic de Barcelona; Jardí Botànic de la Universitat de València; Jardi Botanic de Soller; Jardí Botànic Marimurtra; Jardin Botanico “Viera y Clavijo”; Jardin Botanico de Cordoba; Jardin Botanico-Historico “La Concepcion” de Malaga; Jardin de Aclimatacion de la Orotava; Real Jardín Botánico Juan Carlos I; Real Jardin Botanico, CSIC; Bergius Botanic Garden; Göteborg Botanical Garden; University of Uppsala Botanic Garden; Botanischer Garten der Universitat Bern; Botanischer Garten der Universitat Zurich; Conservatoire et Jardin botaniques de la Ville de Genève; Jardin Botanique de l’Universite de Neuchatel; Musee et Jardins Botaniques Cantonaux; Sukkulenten-Sammlung Zurich; Amani Botanical Garden; Dokmai Botanical Garden; Huay Kaew Arboretum; Nong Nooch Tropical Botanical Garden; Entebbe Botanic Gardens; Tooro Botanical Gardens; Catalogue of Medicinal Plants of Ukrainian Botanic Gardens and Parks; Catalogue of Rare Plants of Ukrainian Botanic Gardens and Parks; Donetsk Botanical Garden; M.M. Gryshko National Botanical Garden; State Nikitsky Botanical Gardens; Anglesey Abbey; Batsford Arboretum; Benmore Botanic Garden; Bristol Zoological Gardens; Cambridge University Botanic Garden; City of Leeds Botanic Gardens; City of Liverpool Botanic Gardens; Dawyck Botanic Garden; Durham University Botanic Garden; Dyffryn Gardens; Eden Project, The; Glasgow Botanic Gardens; Hergest Croft Gardens; High Beeches Gardens Conservation Trust; Killerton; Knightshayes; Logan Botanic Garden; Lyme Park; Millennium Seed Bank; National Botanic Garden of Wales; Paignton Zoo Environmental Park; Penrhyn Castle; Pine Lodge Pinetum; Rowallane Garden; Royal Botanic Garden Edinburgh; Royal Botanic Gardens Kew (Wakehurst); Royal Botanic Gardens, Kew; Royal Horticultural Society’s Garden, Harlow Carr; Royal Horticultural Society’s Garden, Hyde Hall; Royal Horticultural Society's Garden, Rosemoor; Royal Horticultural Society's Garden, Wisley; Sheffield Botanical Gardens; Sissinghurst Castle Garden; St. Andrews Botanic Garden; Stourhead; Tatton Garden; Society/Quinta Arboretum; Tatton Park; The Harris Garden; The Living Rainforest; The National Pinetum Bedgebury; The Sir Harold Hillier Gardens; The Tree Register of the British Isles; Thwaite Gardens, University of Hull Botanic & Experimental Garden; Tregothnan Estate; Tresco Abbey Garden; University of Bristol Botanic Garden; University of Dundee Botanic Garden; University of Liverpool Botanic Gardens (at Ness); Wentworth Castle Gardens; Westonbirt, The National Arboretum; Adkins Arboretum; Alaska Botanical Garden; Ambler Arboretum of Temple University, The; Arboretum at Kutztown University; Arboretum at Penn State, The; Arboretum at the University of California, Santa Cruz; Arboretum of The Barnes Foundation; Arnold Arboretum of Harvard University, The; Atlanta Botanical Garden; Aullwood Garden MetroPark; Bamboo Brook Outdoor Education Center; Bartlett Tree Research Laboratories Arboretum; Bayard Cutting Arboretum; Berkshire Botanical Garden; Betty Ford Alpine Gardens; Bickelhaupt Arboretum; Bishop Museum - Checklist of Cultivated Plants of Hawai'i; Bok Tower Gardens Conservation Program - Living Plants; Boone County Arboretum; Botanic Garden of Smith College, The; Botanic Gardens at Kona Kai Resort, The; Botanic Gardens of the Heard Natural Science Museum; Bowman’s Hill Wildflower Preserve; Boyce Thompson Arboretum; Brenton Arboretum, The; Brooklyn Botanic Garden; Brookside Gardens; C. M. Goethe Arboretum; Cape Fear Botanical Garden; Center for Plant Conservation (USA); Chanticleer Foundation; Charles R. Keith Arboretum, The; Chester M. Alter Arboretum; Chicago Botanic Garden; Chicago Botanic Garden - Dixon National Tallgrass Prairie Seed Bank; Chihuahuan Desert Gardens at the Centennial Museum; Cincinnati Zoo and Botanical

Gardens; Cincinnati Zoo and Botanical Gardens – CryoBioBank; Cleveland Botanical Garden; Clovis Botanical Garden; Coastal Maine Botanical Gardens; Columbus Botanical Garden; Connecticut College Arboretum; Cornell Plantations; Cox Arboretum & Gardens; Crosby Arboretum, The; Dawes Arboretum, The; Denver Botanic Gardens; Desert Botanical Garden; Desert Botanical Garden - Seed Bank; Dixon Gallery and Gardens, The; Donald E. Davis Arboretum; Duke Biology Plant Teaching and Research Facility; Duke Farms; DuPage Forest: Forest Preserve District of DuPage County; Eddy Arboretum - Pacific Southwest Research Station; Edison and Ford Winter Estates; EEB Plant Growth Facilities; Elisabeth C. Miller Botanical Garden; Eloise Butler Wildflower Garden & Bird Sanctuary; Enid A. Haupt Glass Garden; Fairchild Tropical Botanic Garden; Fellows Riverside Gardens; Fernwood Botanical Garden and Nature Preserve; Florida Botanical Gardens; Foellinger-Freimann Botanical Conservatory; Forrest Deaner Native Plant Botanic Garden; Fort Worth Botanic Garden; Frederik Meijer Gardens & Sculpture Park; Frelinghuysen Arboretum; Ganna Walska Lotusland; Gardens at SIUE, The; Gardens of the Big Bend: Magnolia Garden; Garvan Woodland Gardens; Grapevine Botanical Gardens at Heritage Park; Green Bay Botanical Garden; Green Spring Gardens; Greenwood Gardens; Harold L. Lyon Arboretum; Harry P. Leu Gardens; Hawaii Tropical Botanical Garden; Henry Schmieder Arboretum; Hershey Gardens; Hidden Lake Gardens; Holden Arboretum, The; Honolulu Botanical Gardens System; Hoyt Arboretum; Huntington Botanical Gardens; Huntsville Botanical Garden; Jackson's Garden of Union College; Jensen-Olson Arboretum; John C. Gifford Arboretum; Key West Tropical Forest & Botanical Garden; Lady Bird Johnson Wildflower Center; Lady Bird Johnson Wildflower Center - seed bank; Lakes Park Botanic Garden; Landis Arboretum; Lauritzen Gardens; Lewis Ginter Botanical Garden; Lincoln Park Conservatory; Living Desert Zoo & Gardens State Park; Living Desert Zoo and Gardens; Longwood Gardens; Los Angeles County Arboretum and Botanic Garden; Marie Selby Botanical Gardens; Marjorie McNeely Conservatory at Como Park; Matthaei Botanical Gardens & Nichols Arboretum; Maymont Foundation; Mead Botanical Garden; Meadowlark Botanical Gardens; Memphis Botanic Garden; Mendocino Coast Botanical Gardens; Mercer Arboretum & Botanic Gardens; Minnesota Landscape Arboretum; Missouri Botanical Garden; Mitchell Park Horticultural Conservatory (The Domes); Montgomery Botanical Center; Morris Arboretum, The; Morton Arboretum, The; Mount Auburn Cemetery; Mountain Top Arboretum; Mt. Cuba Center; Naples Botanical Garden; Naples Zoo at Caribbean Gardens; National Plant Germplasm System - USDA-ARS-NGRL; National Tropical Botanical Garden; Nebraska Statewide Arboretum; New England Wild Flower Society - Garden in the Woods; New England Wild Flower Society - seed bank; New York Botanical Garden, The; Norfolk Botanical Garden; North Carolina Arboretum, The; North Carolina Botanical Garden; Northwest Trek Wildlife Park; Oak Park Conservatory; Oklahoma City Zoo and Botanical Gardens; Phoenix Zoo - Gardens; Polly Hill Arboretum, The; Quarryhill Botanical Garden; Queens Botanical Garden; Rancho Santa Ana Botanic Garden; Rancho Santa Ana Botanic Garden - Seed Bank; Reading Public Museum and Arboretum, The; Red Butte Garden and Arboretum; Reiman Gardens; Rio Grande Botanic Garden; San Diego Botanic Garden; San Diego Zoo Botanical Gardens; San Diego Zoo Safari Park; San Francisco Botanical Garden (formerly Strybing Arboretum); San Luis Obispo Botanical Garden; Santa Barbara Botanic Garden; Santa Fe Botanical Garden; Sarah P. Duke Gardens; Scott Arboretum of Swarthmore College, The; Sea World San Diego; Seeds of Success (SOS); Shaw Nature Reserve of the Missouri Botanical Garden; Sister Mary Grace Burns Arboretum; Smith-Gilbert Gardens; Spring Grove Cemetery and Arboretum; State Arboretum of Virginia (Orland E. White Arboretum); State Botanical Garden of Georgia, The; State of Missouri Arboretum; The Arboretum, State Botanical Garden of Kentucky; Toledo Botanical Garden; Trees Atlanta; Tyler Arboretum; UC Davis Arboretum; United States Botanic Garden; United States National Arboretum; University of California Botanical Garden at Berkeley; University of Delaware Botanic Gardens; University of Georgia Tifton Campus Conifer Evaluation and Breeding Project, The; University of Idaho Arboretum & Botanical Garden; University of Washington Botanic Gardens; Vanderbilt University Arboretum; Ventura County Community College District - Ventura College; W. J. Beal Botanical Garden; Waimea Valley Arboretum and Botanical Garden; Wallace Desert Gardens; Willowwood Arboretum; Wind River Canopy Crane Research Facility; Yew Dell Botanical Gardens; Scientific Plant Production Centre "Botanica" of Uzbek Academy of Sciences; Fundacion Jardin Botanico Unellez; Cuc Phuong Botanic Garden.

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