Conservation Gap Analysis of *Nothofagus*

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Global Conservation Consortium Nothofagus

Wakehurst Royal Botanic Gardens Kew

Forestry England

Botanic Gardens Conservation International

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December 2024

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Cover photos:
Front cover:
Nothofagus aequilateralis,
New Caledonia (Dan Crowley)
Back cover:
Nothofagus alessandrii,
Wakehurst, UK
(Olivia Steed-Mundin)

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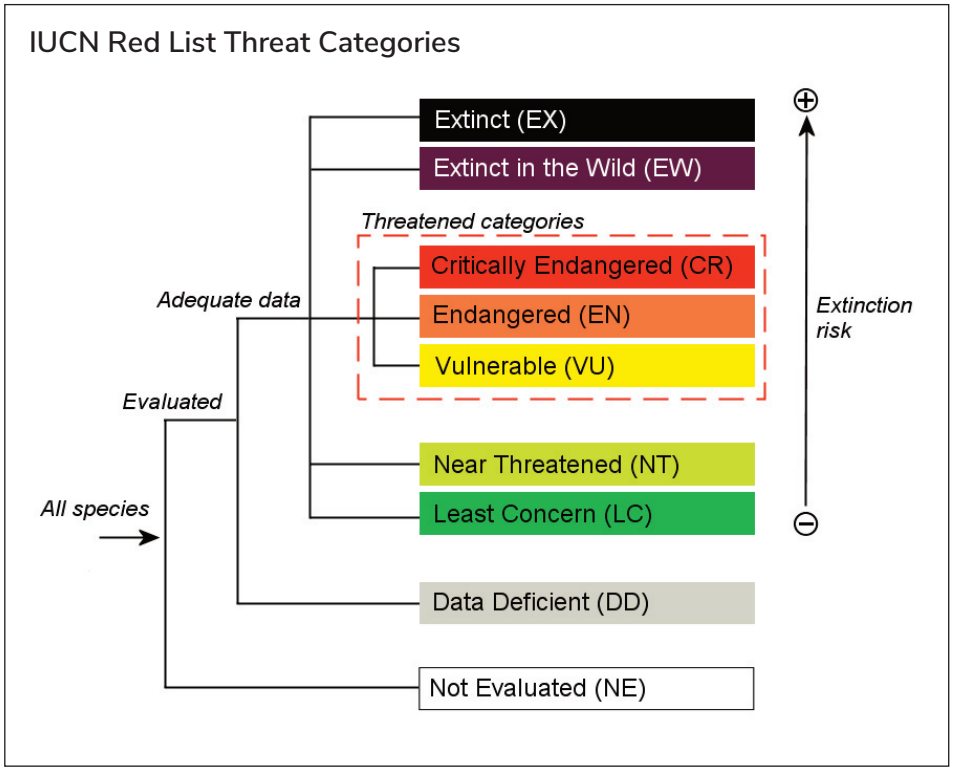

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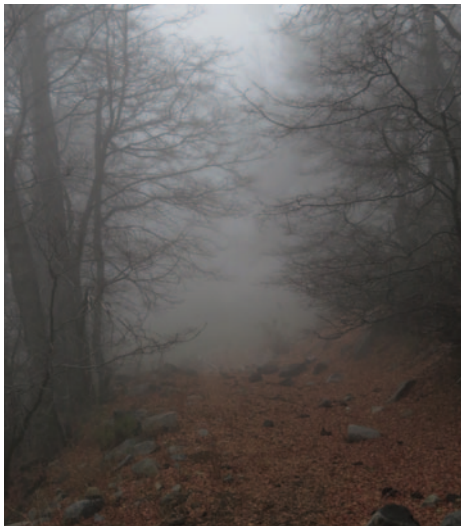

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Executive Summary

Nothofagus is a genus of 37 tree and shrub species, with a disjunct distribution across the Southern Hemisphere. *Nothofagus* often dominates the forests it inhabits; some species form large tracts of forest (particularly in parts of South America and Oceania); whilst all species play a critical role in the ecology, functioning, and health of the ecosystems in which they are found. Yet, individual species can have a relatively narrow distribution – more than 50% are single country endemics, some are known from just a handful of localities, and many occur within a narrow climatic envelope.

A significant number of *Nothofagus* species are at risk in the wild; the IUCN Red List of *Nothofagus* identified 11 species as threatened with extinction (i.e. Critically Endangered, Endangered or Vulnerable) and a further four as Near Threatened (Baldwin et al., 2018). With limited resources available for conservation, it is critical to identify gaps in conservation efforts especially in relation to threats, with a view to help prioritise the most urgent conservation needs moving forward.

To facilitate this, we carried out a comprehensive Conservation Gap Analysis for the threatened and Near Threatened *Nothofagus* (i.e. 15 'target species'). Adapting previous methodologies, including the *Conservation Gap Analysis of Native US* Oaks (Beckman et al., 2019) and the *Global Conservation Gap Analysis of* Magnolia (Linsky et al., 2022), our study included surveys, consultation, and literature reviews to assess the status of each target species, *in situ,* and in *ex situ* collections. It also enabled us to identify the conservation activities currently in place, and the conservation priorities moving forward.

To ascertain the representation of the target species in *ex situ* collections we carried out an accession-level survey to include both living and seed collections. A total of 48 organisations from nine countries provided data for the target species. Of the 15 species, seven species are represented in *ex situ* collections (six species in seed collections and seven in living collections). There is a clear collection-bias towards temperate species (i.e. species from Chile and Australia), with none of the species from tropical latitudes represented in seed collections and only one tropical species found in living collections (in this case, only a single plant). In total, there are 329,181 *Nothofagus* seeds in seed banks and 911 plants in *ex situ* living collections. Almost all seeds are of wild provenance (99.5%) as are the majority of plants (70%).

Nothofagus codonandra, Mt Koghi, New Caledonia (Dan Crowley)

Geolocated wild provenance data provided in the *ex situ* survey was used to assess the geographical and ecological coverage of *ex situ* collections, enabling the identification of populations that are geographically and/or ecologically underrepresented. For the target species, geographic coverage of *ex situ* living collections is under 60% for all temperate *Nothofagus* species except for *N. alessandrii* (87%). Ecological coverage provided by living collections is above 80% in all temperate species apart from *N. moorei* (56%). With regards to seed collections for the target species, only four temperate species have *ex situ* seed collections that represent at least half or almost half of their geographical range: *N. gunnii* (55%), *N. alessandrii* (50%), *N. cunninghamii* (49%), and *N. glauca* (46%). Whilst the ecological coverage of *ex situ* seed collections is more than 75% in all temperate species except for *N. moorei* (44%). With regards to tropical *Nothofagus*, apart from *N. codonandra*, no species are present in collections, so all remaining tropical species have 0% ecological coverage and 0% geographical coverage represented in *ex situ* living and seed collections.

To provide a clear picture of the threats facing wild populations, the current conservation activities in place, and the required conservation actions to protect the target species, we conducted a Conservation Activity Questionnaire. A total of 24 respondents from 22 organisations contributed to the questionnaire, representing a range of sectors including botanic gardens and arboreta, universities, government agencies and the private sector. We supplemented this research by consulting with regional experts and conducting a literature review. The threats identified differed regionally, but global trends included fire, climate change and anthropogenic development. The most common conservation activities currently being undertaken by respondents to the questionnaire were conservation horticulture, public awareness and education, and collection and distribution of germplasm. The only activities reported in the questionnaire related to temperate species. No responses were received in relation to tropical species. Additional regional consultation and literature reviews found that there is very limited activity associated with the conservation of tropical species and identified a number of challenges to conservation regionally. With regard to priority conservation actions moving forward, respondents to the questionnaire only identified actions for temperate species, the most common activities were public awareness and education, protect and/or manage habitat and implement protection policies or regulations.

Nothofagus gunnii, Cradle Mountain, Tasmania (Olivia Steed-Mundin)

We then synthesised the findings of the research to make key conservation recommendations for each species. These are provided in detail in the species profiles which are available for each of the 15 target species (Appendix A). Regional recommendations are also highlighted in the main report.

Finally, using a combination of the metrics provided within this report (IUCN Red List Category, *ex situ* representation, and spatial analysis of collections) we carried out an exercise to rank the species in order of conservation priority. Globally, the three species of the highest conservation concern are from Papua New Guinea, Indonesian New Guinea and New Caledonia because they are not represented *ex situ*, have limited conservation activities associated with them, and are in many cases more threatened in the wild. However, it is also paramount to consider species prioritisation at a regional scale, and these breakdowns are also presented in our report.

Many organisations are already carrying out important activities that are advancing the conservation of some of the most threatened *Nothofagus* both *in situ* and *ex situ*. However, there is almost a complete gap in conservation activities associated with tropical species, and some notable gaps and challenges in temperate regions, which this report highlights. We hope that these findings can not only help guide a conservation strategy for *Nothofagus*, but also help to coordinate conservation actions, so that resources can be used most effectively. We would like to thank everyone who has contributed to the report. We hope it can be used as a catalyst for future collaborations and look forward to working together to help conserve this important genus.

Introduction and Objectives

Figure 1. Distribution of the genus *Nothofagus*.

Nothofagus is a small genus of 37 trees and shrubs. It has a disjunct distribution across the Southern Hemisphere, with extant taxa found on the disparate land masses of South America (Chile and Argentina), Australia (southeast mainland and Tasmania), New Zealand, New Caledonia and New Guinea (Papua New Guinea and Indonesian New Guinea) (Figure 1). This modern day distribution is indicative of an ancient distribution across the land mass of Gondwana, from the late Cretaceous period.

Nothofagus species are today found in both temperate and tropical environments, inhabiting latitudes 0°- 56° S, from sea level to subalpine elevations (Veblen et al., 1996). They often dominate the forest canopy and/or act as keystone species (Veblen et al., 1996; Baldwin et al., 2018), thus playing a crucial role in supporting the ecology and biodiversity of the forests they inhabit and in sustaining important ecosystem services. In certain regions, particularly in parts of South America and Oceania, *Nothofagus* form large tracts of forest (Baldwin et al., 2018).

Nothofagus cunninghamii, epiphytic community, Cradle Mountain, Tasmania (Olivia Steed-Mundin)

A large proportion of *Nothofagus* species are under significant threat from anthropogenic activities which are changing the ecological dynamics of *Nothofagus* forests, preventing natural regeneration and putting many species at risk of extinction. *The Red List of* Nothofagus (Baldwin et al., 2018) found 11 of the 37 taxa to be threatened (i.e. Critically Endangered; Endangered; Vulnerable) and a further four to be Near Threatened. Major threats identified included deforestation and timber harvesting, modification of natural regimes (e.g. fire), agriculture and climate change.

No conservation gap analysis has ever been conducted for *Nothofagus*. This kind of analysis can provide a comprehensive assessment of the conservation achievements, gaps and needs both *in situ* (within native habitat) and *ex situ* (off-site, e.g. in botanic gardens/seed banks), to determine the state of conservation for each *Nothofagus* species individually and the genus as a whole. It can therefore be used to prioritise actions and guide a comprehensive conservation strategy, which supports the work of regional partners, promotes closer collaboration within the conservation community and helps coordinate efficient use of limited resources for conservation activities (Beckman et al., 2019).

It is important to note that there are a number of conservation challenges specifically associated with *Nothofagus*, which underpin the need to carry out a conservation gap analysis to help inform a conservation strategy.

Individual species usually have a relatively narrow distribution, with >50% being single country endemics. This is particularly evident in threatened and Near Threatened species, of which 87% are endemics, including some that are known from just one or a few localities (e.g. *N. baumanniae; N. nuda; N. stylosa; N. womersleyi*). The genus is known to have poor vagility (Veblen et al., 1996), with pollen (from wind-pollinated flowers) and large seeds reported to display limited dispersal capacity (Sola et al., 2020; Marchelli et al., 2012). In addition, many threatened species are found in habitats with poor or extreme soil conditions, often occurring at higher altitudes and/or occupying small climatic envelopes (Veblen et al., 1996; Baldwin et al., 2018). The combination of these factors mean it may be difficult for some *Nothofagus* species to respond to threats such as climate change (Baldwin et al., 2018). Moreover, since many of the threatened species are found in relatively small, often fragmented populations (Baldwin et al., 2018), gene flow between populations may be limited, which could reduce genetic diversity within populations and decrease their ability to adapt to environmental changes.

Nothofagus baumanniae, New Caledonia (Benoît Henry)

Although seed storage behaviour for temperate *Nothofagus* appears to be largely orthodox (León-Lobos & Ellis, 2005; Royal Botanic Gardens Kew, 2022a), seed characteristics of tropical species have not been studied. A study, which included other tropical evergreen rainforest species, found almost 50% of species were intolerant to drying and therefore not suitable for traditional seed banking (Tweddle et al., 2003). In addition, seed production in both tropical and temperate *Nothofagus* species is highly variable from year to year, with mast-seeding observed across the genus (Veblen et al., 1996). Studies on several species have found that in non-mast years both seed production and viability are much reduced (e.g. Alley et al., 1998; Fitzgerald et al., 2004), with germination rates recorded as low as 1%-2% (Read & Hope, 1996).

Lastly, some threatened and Near Threatened *Nothofagus* species, particularly those in tropical climates, occur in locations where there has been limited exploration, research and/or conservation activities. For example, some species are solely recorded from just two or three collection events made over 30 years ago.

With all these challenges in mind, we conducted a global conservation gap analysis of *Nothofagus*, focusing on species that were identified as threatened (11 species) or Near Threatened (4 species) in *The Red List of* Nothofagus (Baldwin et al., 2018). The aim of this focused approach was to provide richer insight into the conservation needs of the 15 *Nothofagus* species at risk of extinction. We hope that the results will provide not only a baseline, but also act as a roadmap to inform next steps for the community of conservationists, researchers and land managers looking to protect *Nothofagus* species.

We have based much of our approach on methodologies used in the *Conservation Gap Analysis of Native US* Oaks (Beckman et al., 2019) and the *Global Conservation Gap Analysis of* Magnolia (Linsky et al., 2022), addressing for each species:

- native distribution, protected area coverage and *ex situ* collection coverage
- threats in wild populations
- conservation value of existing *ex situ* collections in living collections and seed banks
- current *in situ* and *ex situ* conservation activities
- priority conservation actions moving forward

Nothofagus cunninghamii, Wakehurst, UK (Olivia Steed-Mundin)

Nothofagus alessandrii, Reserva Nacional Los Ruiles, Chile (Nicolás Lavandero)

Significant contributions from individuals and organisations within the global community of botanic gardens, conservation organisations and scientific institutions have been received, providing data and informing us of species-specific threats and conservation activities.

Results have been collated, analysed and presented via a genus-wide summary, while individual species profiles are also provided (Appendix A). This approach aims to allow for easy comparison between species, helping to identify the greatest and most urgent conservation needs. This report aims to provide a scientifically informed guide that can aid efficient and effective prioritisation of conservation efforts to protect those *Nothofagus* species which face the greatest threats and conservation challenges.

Methods

Global Distribution of Threatened and Near Threatened *Nothofagus*

This study includes *Nothofagus* species that were identified as threatened (i.e. Critically Endangered (CR), Endangered (EN), Vulnerable (VU)) or Near Threatened (NT) by *The Red List of* Nothofagus (Baldwin et al., 2018)). These 15 species will hereon be referred to as the 'target species' (Table 1). The methodology that follows refers to these target species.

Global distribution of the target species at country level was gathered from the IUCN Red List of Threatened Species (IUCN, 2022); Global Biodiversity Information Facility (GBIF) (GBIF.org, 2022); herbarium vouchers (Royal Botanic Gardens Kew, 2022b); *ex situ* collections; consultation with experts. Data was used for producing distribution maps at country level for each target species.

Table 1. *Nothofagus* target species and IUCN Red List Category.

Target species	IUCN Red List Category
Nothofagus aequilateralis (Baum.-Bod.) Steenis	NT
Nothofagus alessandrii Espinosa	EN
Nothofagus baumanniae (Baum.-Bod.) Steenis	EN
Nothofagus codonandra (Baill.) Steenis	NT
Nothofagus crenata Steenis	VU
Nothofagus cunninghamii (Hook.) Oerst.	VU
Nothofagus discoidea (Baum.-Bod.) Steenis	EN
Nothofagus glauca (Phil.) Krasser	VU
Nothofagus gunnii (Hook.f.) Oerst.	NT
Nothofagus macrocarpa (A.DC.) F.M.Vázquez & R.A.Rodr.	VU
Nothofagus moorei (F.Muell.) Krasser	VU
Nothofagus nuda Steenis	CR
Nothofagus pseudoresinosa Steenis	NT
Nothofagus stylosa Steenis	CR
Nothofagus womersleyi Steenis	CR

Nothofagus cunninghamii, Mt Field, Tasmania (Olivia Steed-Mundin)

Threats to Wild Populations

Threats to wild populations were identified by reviewing the *The Red List of* Nothofagus (Baldwin et al., 2018), expert consultation, a broader literature review, and a Conservation Activity Questionnaire. Threat categories included in the Conservation Activity Questionnaire were based on those used for the *Conservation Gap Analysis of Native U.S* Oaks (Beckman et al., 2019). Questionnaires were sent out 2021-2022 to the same communities targeted for *ex situ* collections (see section: '*Ex situ* collections reported 2021-2022', p 12) plus a further 12 contacts at conservation agencies. A total of 82 organisations were contacted directly. The questionnaire was also cascaded further by contacts in centres of diversity.

The results from the Conservation Activity Questionnaire were merged with information gleaned from the other sources under the following 12 threat categories:

- Land use change - agriculture and/or silviculture
- Development, mining and/or roads
- Logging and/or wild harvesting
- Disturbance regime modification including fire
- Climate change
- Extremely restricted populations and/or genetic diversity loss
- Invasive species
- Pests and/or pathogens
- Natural regeneration issues
- Tourism and/or recreation
- Unknown
- Other

The identification of these threats can contribute to developing the most appropriate priority conservation actions for each species and to identify regional trends to inform conservation strategies (Linsky et al., 2022).

Nothofagus cunninghamii, Wakehurst, UK
(Olivia Steed-Mundin)

Conservation Activities

We investigated on-going and required conservation activities for each target species. Data was gathered from an *ex situ* collections survey, a Conservation Activity Questionnaire, literature review and expert consultation. In addition, spatial analyses were carried out to estimate the representation of wild populations held in *ex situ* collections, and protected area coverage.

Ex situ collections reported 2021-2022

We identified organisations with *ex situ Nothofagus* collections and sent out a request for accession-level data for the target species. As defined in BGCI's *Manual on Planning, Developing and Managing Botanic Gardens* (in Gratzfeld, 2016), an accession is:
plant material (individual or group) of a single taxon and propagule type with identical or closely similar parentage acquired from one source at the same time. An accession is catalogued and assigned a unique identifier (number or code) associated with additional information.

Organisations with *ex situ* collections were identified by:

- Institutions who reported target *Nothofagus* species to BGCI's PlantSearch database (BGCI, 2022)
- Organisations who hold National Collections of *Nothofagus*
- Arboreta/botanic institutions with renowned woody plant collections and/or *Nothofagus* collections
- Experts/conservation organisations in target species countries of origin
- Seed banks in target species countries of origin and/or those with known *Nothofagus* collections.

More than 70 organisations were contacted directly. The request was also cascaded to additional organisations via collaborators and contacts.

Accession data, including associated provenance details, was requested in a standardised format. Once received, these data were cleaned and standardised. When distribution coordinates were not provided, it was manually geolocated using locality and source data or via cross-referencing with another accession with the same locality description. When the provenance type was not provided it was assigned 'unknown'.

Nothofagus baumanniae, New Caledonia (Benoît Henry)

Since a number of *Nothofagus* species are known to be present in seed banks, *ex situ* records were differentiated by living plant collections and seed collections — these data are largely reported separately. Organisations were asked to include the number of individuals and/or seeds in each accession. Where the number of individual plants was not given, it was assumed the accession was one individual. Where 'mass planting' was indicated as the number of individuals, it was recorded as two individual plants. Numbers of plants held in *ex situ* collections should therefore be considered as an estimate. Where seed quantity was provided in grams, it was converted to number of seeds by using the average recorded seed weight for the species using Royal Botanic Gardens, Kew's Millennium Seed Bank data.

Estimated representation of *ex situ* collections

Spatial analysis of *ex situ* records was performed to assess the potential geographic and ecological coverage of *ex situ* collections globally, in comparison to the known range of each species. Geographic and ecological coverage is used here as a proxy for representation of the genetic diversity of the species in *ex situ* collections (Linsky et al., 2022; Beckman et al., 2019). With this method, populations and ecological zones that are under-represented in collections can be identified. Adapting methods used by Beckman et al. (2019), Beckman et al. (2021) and Linsky et al. (2022), we used *in situ* occurrence point datasets for each target species in combination with the geolocated wild provenance source locality information (gathered in the *ex situ* collections surveys of 2021 and 2022), to estimate how well current *ex situ* collections represent the geographical and ecological breadth of wild populations. For the ecological coverage estimation, ecoregions used were the Terrestrial Ecoregions of the World (Olson et al., 2001).

To perform spatial analysis, a robust set of data points representing the known native range of each target species was compiled. *In situ* occurrence points for each target species were taken from the most recent IUCN Red List assessments and downloaded from the IUCN website (IUCN, 2022). Where relevant, point data was modified based on information that has come to light since assessments were published. Additional sources used were: data uploaded to GBIF (GBIF.org, 2022); locality information associated with verified specimens at Royal Botanic Gardens, Kew's herbarium (Royal Botanic Gardens Kew, 2022b); geographic origin of *ex situ* collections; in-country expert consultation. For *Nothofagus gunnii*, additional occurrence points were also downloaded from the Natural Values Atlas (Department of Natural Resources and Environment Tasmania, 2023).

Geographic and ecological coverage were calculated by comparing known *in situ* occurrences and *ex situ* collection source localities. Circular buffers of 40, 60 and 80 km around each *in situ* and *ex situ* point were used to approximate the habitat, populations and gene flow. These buffer sizes were chosen because it has been reported for wind-pollinated tree species that distances of effective pollen dispersal range between 10 to 100 km (Kremer et al., 2012), and Duncan et al. (2016) found that *Nothofagus cunninghamii* trees show a significant gene flow across at least 60 km. When the buffers of the *in situ* and *ex situ* points overlap, that area is considered conserved by the *ex situ* collection. The geographic and ecological coverage of *ex situ* collections were estimated using the following formulas:

CAE (Combined Area *Ex situ*) = Combined total area of 40, 60 and 80 km circular buffers, respectively, around *ex situ* collection points of wild provenance.

CAI (Combined Area *In situ*) = Combined total area of 40, 60 and 80 km circular buffers, respectively, around all documented *in situ* occurrence points.

Geographical coverage = CAE / CAI

Ecological coverage = # of Ecoregions in CAE / # of Ecoregions in CAI

Nothofagus aequilateralis, Parc Provincial Rivière Bleue, New Caledonia (Fabian Carriconde)

The calculations were carried out for living plant and seed collections independently as well as for the combined data.

Data processing was performed in R (R Core Team, 2022). Maps were produced using ArcGIS Pro (Esri Inc., 2022).

It should be noted that creating buffers around *in situ* points might result in an overestimation of both *in situ* occurrence and *ex situ* representation. This is due to fragmented distribution of many *Nothofagus* species and because the buffers might include areas containing unsuitable environmental conditions for the target species. However, there is no comprehensive analysis for all *Nothofagus* species which estimates the potential distribution of our target species. Therefore, the use of buffers around *in situ* points is useful to illustrate immediate habitat representation and facilitates comparisons between the target species.

Estimated land protection

To assess the habitat security of each target species, we also estimated the proportion of the inferred native range (CAI) for each buffer size that occurs within protected areas. Protected area coverage was calculated by finding the spatial intersection of the native ranges of each species, using the same buffer sizes as for estimating geographical and ecological coverage (40, 60 and 80 km respectively), and terrestrial protected areas from the World Database on Protected Areas (WDPA) (UNEP-WCMC & IUCN, 2022). Protected area maps for each target species were created, using WDPA data as the standardised source of protected areas.

Protected area coverage = CAI within protected areas / CAI

Data processing was performed in R (R Core Team, 2022). Maps were produced using ArcGIS Pro (Esri Inc., 2022).

As mentioned in the previous section, creating buffers around *in situ* points might result in an overestimation of the inferred native range for target species. Therefore, values given for protected area coverage should be treated as estimates.

Current conservation activities

Information regarding current conservation activities was gathered through literature review, expert consultation and via the Conservation Activity Questionnaire. Questionnaires were sent out 2021-2022 to the same communities targeted for the *ex situ* collections (see section: '*Ex situ* collections reported 2021-2022', p 12) with 12 additional contacts from conservation agencies. A total of 82 organisations were contacted directly and the request was cascaded further by contacts in centres of diversity. The categories for the Conservation Activity Questionnaire follow those used in the *Conservation Gap Analysis of* Magnolia (Linsky et al., 2022):

- Collect and distribute germplasm
- Pollen and/or seed banking
- Conservation horticulture
- Cryopreservation and/or micropropagation
- Implement protection policies or regulations
- Occurrence surveys or population monitoring
- Population reinforcement or introduction
- Habitat restoration
- Protect and/or manage habitat
- Public awareness or education
- Research: genetics
- Research: taxonomy
- Research: climate change
- Research: pests and pathogens

Because the number of responses received was limited, the research in this area was heavily reliant on additional expert consultation and a literature review.

The results from the Conservation Activity Questionnaire were merged with results from expert consultation and the literature review, and reported in detail in the species profiles (Appendix A) under nine conservation activities categories following the *Conservation Gap analysis of U.S* Oaks (Beckman et al., 2019).

Priority Conservation Actions

Results of the Conservation Activity Questionnaire

Priority conservation actions were identified for each species through the Conservation Activity Questionnaire (sent out to 82 organisations as detailed in section '*Ex situ* collections reported 2021-2022', p 12). Conservation action categories follow those used in the *Conservation Gap Analysis of* Magnolia (Linsky et al., 2022), (see section: 'Current conservation activities', p14).

Recommendations

The data, information and analysis compiled within the report was synthesised for each species to formulate recommendations. Conservation actions which should be continued, strengthened and/or initiated were identified. These recommendations are discussed separately for each species in the species profiles (Appendix A), with a review at a regional level in the results section (p29-32).

Finally, regional experts were invited to review species profiles for accuracy and to ensure that recommendations for conservation actions are appropriate.

Prioritising Target Species

Prioritising target species helps to create more effective conservation strategies (Linsky et al., 2022). To prioritise *Nothofagus* species for conservation, the following metrics were applied to our target species (adapted from Linsky et al., 2022):

- IUCN Red List category
- Number of organisations with *ex situ* collections (including plants and/or seeds)
- Number of individual plants in *ex situ* living collections
- Number of wild origin seedlings in nurseries
- Number of seeds in *ex situ* collections
- Percentage of geographic range captured by *ex situ* collections (plants and/or seed)
- Percentage of ecological range captured by *ex situ* collections (plants and/or seed)
- Percentage of protected area coverage.

Each species was assigned scores based on the level of severity for each metric (Table 2) and a total score was calculated for each species.

Table 2. Prioritisation scoring matrix identifying *in situ* and *ex situ* metrics measuring conservation of the target *Nothofagus* species globally.

Criterion	5 points	4 points	3 points	2 points	1 points	0 points
IUCN Red List category	CR	EN	VU	NT	DD	LC
# organisations with *ex situ* collections (inc. plants and/or seeds)			0	1-5	6-19	>19
# of individual plants in *ex situ* living collections		0-5	6-25	26-50	51-100	>100
# wild origin seedlings in nurseries				0-1,000	1,001 - 10,000	>10,000
# of seeds in *ex situ* collections		0-100	101-1000	1001-3000	3000-30,000	>30,000
% of geographic range captured by *ex situ* collections (plant and/or seed)			0-25	26-50	51-75	>75
% of ecological range captured by collections (plant and/or seed)			0-25	26-50	51-75	>75
% of protected area coverage			0-10	11-25	26-50	51-100

Results and Analysis

Global Distribution of Threatened and Near Threatened *Nothofagus*

There are 15 *Nothofagus* species included in this study (Table 1). These are the species that are listed as threatened with extinction (i.e. Critically Endangered, Endangered or Vulnerable) or Near Threatened in *The Red List of* Nothofagus (Baldwin et al., 2018). Five of these species are endemic to the island of New Guinea (Figure 2): one species that occurs only in Indonesian New Guinea, two species in Papua New Guinea, and two species that occur in both. New Caledonia has four target species, all of which are endemic; while Chile and Australia each have three target species, which are also endemic (Figure 2; Table 3).

Nothofagus macrocarpa, Altos de Cantillana, Chile (Nicolás Lavandero)

Figure 2. Number of threatened or Near Threatened *Nothofagus* species per country (threatened *Nothofagus* species are those assessed as globally CR, EN or VU by the IUCN Red List).

Table 3. Summary of the number of threatened and Near Threatened *Nothofagus* species per country/territory. *New Guinea refers to the species that occur in both Papua New Guinea and Indonesian New Guinea (excluding those species that are endemic to Papua New Guinea only or Indonesian New Guinea only).

Country/Territory	Number of threatened species	Number Near Threatened species	Total
Australia	2	1	3
Chile	3	0	3
New Caledonia	2	2	4
New Guinea*	2	0	2
Papua New Guinea	1	1	2
Indonesian New Guinea	1	0	1

Threats to Wild Populations

A total of 23 respondents from 21 organisations (see Appendix B for the list of participating organisations) provided threat information for six of the threatened or Near Threatened species in the Conservation Activity Questionnaire. This included information for Chilean and Australian target species only. Threat information was also gathered from *The Red List of* Nothofagus (Baldwin et al., 2018), broader literature review, and expert consultation. The results were merged as appropriate under the categories presented in Figure 3.

The most common threats to the target species are disturbance regime modification including fire, with all 15 species impacted, followed by development, mining and/or roads (12 species), and climate change (12 species). Although invasive species competition, and tourism and recreation were not widely reported threats from a global perspective, both are common threats reported for Chile, where all three species are affected by these threats. Unknown threats were also reported for a high number of species (seven species). This may reflect the lack of clarity surrounding the threats or lack of specific knowledge by the respondents, although for two species from New Caledonia, it refers to a dieback phenomena for which the cause has not yet been investigated.

Nothofagus codonandra, dieback, Mt Koghi, New Caledonia (Dan Crowley)

More detailed results from this research are presented at species level in each species profile (Appendix A), whilst a regional breakdown is provided in Appendix C.

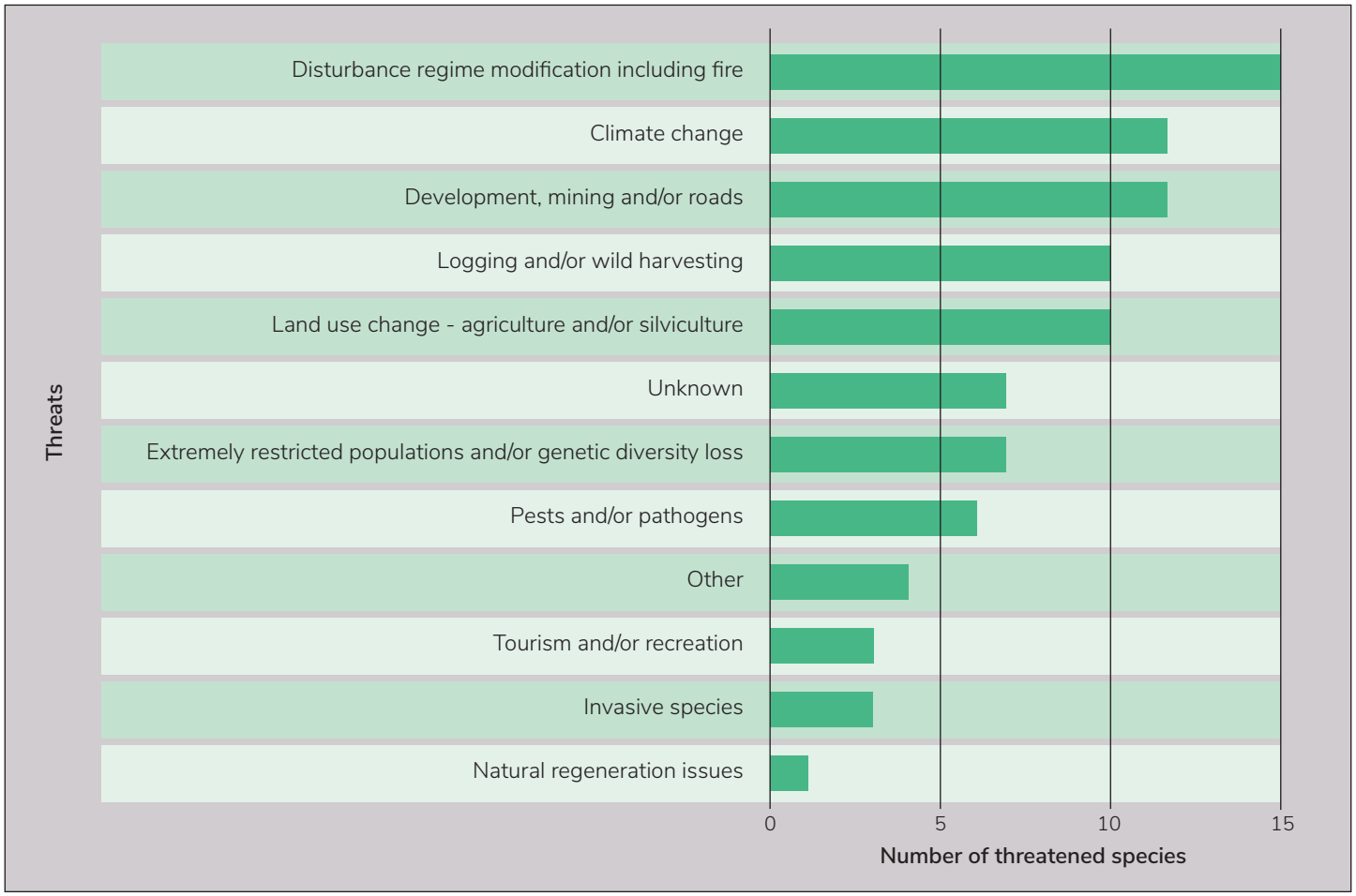

Figure 3. Major threats to the 15 target *Nothofagus species* based on the Conservation Activity Questionnaire results and IUCN Red List Assessments, literature review and expert consultation.

Conservation Activities

Ex situ collections reported 2021- 2022

A total of 48 organisations from nine countries provided accession level data for the target species in response to our ex *situ* collections survey of *Nothofagus* species (see Appendix D for a list of participating organisations). Organisations included botanic gardens, arboreta, conservation organisations, seed banks, and forestry institutes in five European countries, Chile, USA, Australia and New Zealand (Figure 4). The majority of organisations reporting *Nothofagus* collections are located in the UK (42%), followed by Australia (25%) and Chile (15%).

Of the 15 *Nothofagus* target species, only seven are known to be held in ex *situ* collections (Figure 5). This includes all three species from both Chile and Australia and one from New Caledonia (*N. codonandra*) Figure 5). The remaining species from New Caledonia and all five species from the island of New Guinea are not present in ex *situ* collections. *Nothofagus* species present in ex *situ* collections differ greatly in the number of accessions held (Figure 6), and the number of individuals present (Figure 7). See Appendix E for an overview of ex *situ* collections listed by species.

a) Living collections: plants

The species with the highest number of plant accessions in ex *situ* living collections is *N. cunninghamii* (201), followed by *N. moorei* (91). All other species have less than 70 accessions (Figure 6A). Accessions of Australian species are largely held within Australia. Conversely, accessions of the Chilean species are largely held outside of Chile and the one accession from New Caledonia (*N. codonandra*) is in Australia (Figure 6A).

Nothofagus glauca, Wakehurst, UK (Olivia Steed-Mundin)

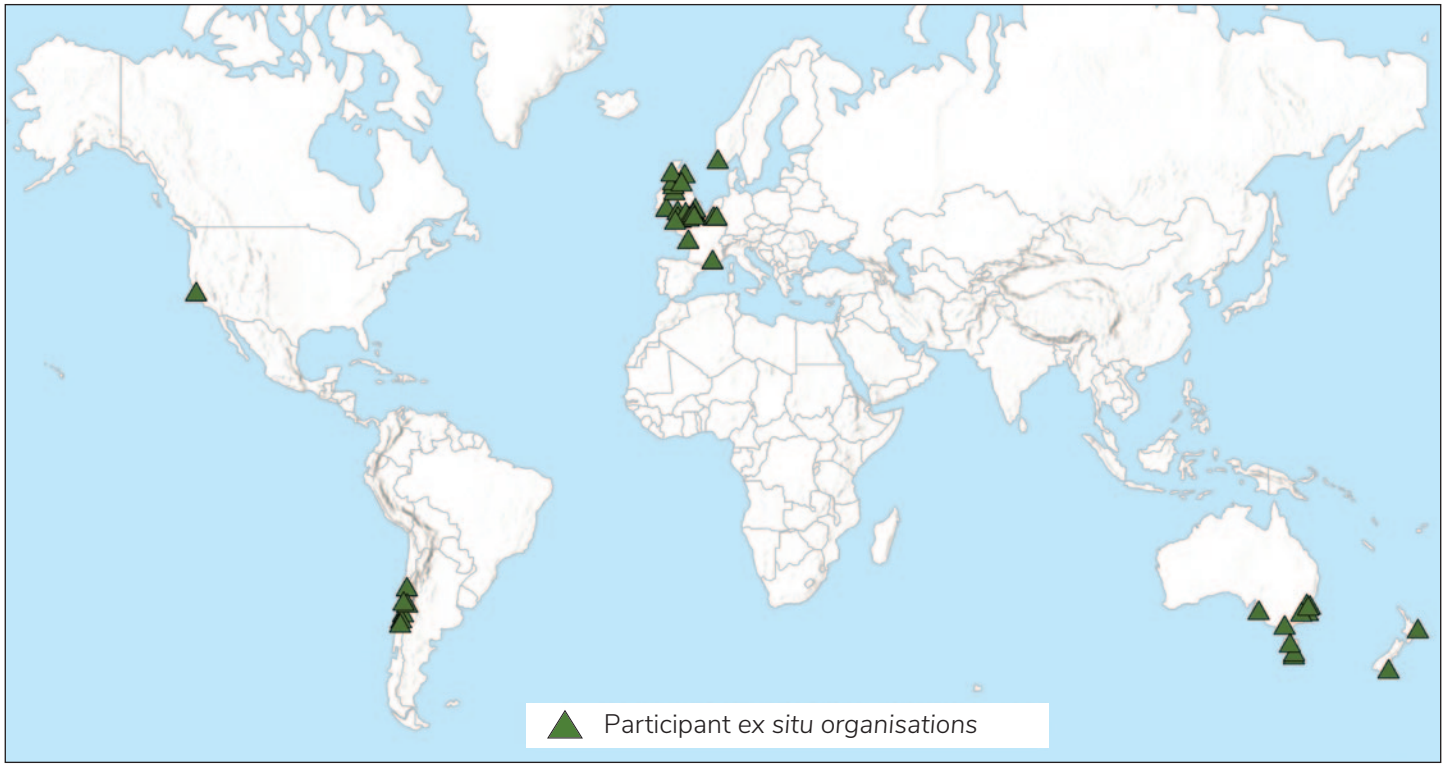

Figure 4. Location of the 48 organisations that responded to the ex *situ Nothofagus* collections survey and provided accession-level data.

Figure 5. Number of organisations that reported *ex situ* collections of *Nothofagus*, displayed by species. Five species are not reported in any *ex situ* collections.

In terms of individual plants in collections, *N. cunninghamii* has more than 400, and all other species each have less than 200 (Figure 7A). Species with the lowest number of individual plants are *N. codonandra*, represented by just a single plant, *N. macrocarpa* with 23 and *N. gunnii* with 27 (Figure 7A). The majority of plants for all species are of wild provenance (Figure 7A).

b) Living collections: seedlings

The six species from temperate regions have seedlings in living collections. All have five or less accessions (Figure 6B). The number of seedling individuals varies considerably, with >15,000 seedlings of *N. glauca* and >4,000 seedlings of *N. alessandrii* (Figure 7B). In both cases, these seedlings are likely to be used for conservation research or reintroductions. All other species are represented by <10 seedling individuals in *ex situ* collections (Figure 7B).

c) Seed banks: seeds

Only the six species from temperate regions have seed accessions in seed banks. *N. cunninghamii* has the largest number of seed accessions (10), followed by *N. glauca* (8) and *N. gunnii* (7) (Figure 6C). The number of individual seeds in collections varies considerably, *N. cunninghamii* has over 250,000, whereas all the others each have <27,000 (Figure 7C). The species with the lowest number of individual seeds is *N. moorei*, with only 706, followed by *N. alessandrii* with 2,115 (Figure 7C). Almost all seeds are of known wild provenance (Figure 7C).

Nothofagus moorei hedge, Blue Mountains Botanic Gardens, Mt Tomah, Australia (Olivia Steed-Mundin)

Nothofagus glauca seeds, Wakehurst, UK (Olivia Steed-Mundin)

Figure 6. Number of ex *situ* accessions in A) living collections: plants (i.e. excluding seedlings) B) living collections: seedlings and C) seed banks per *Nothofagus* species, categorised by whether the accession is held in an organisation inside or outside of the species' native range. Information was obtained from the ex *situ Nothofagus* collections survey.

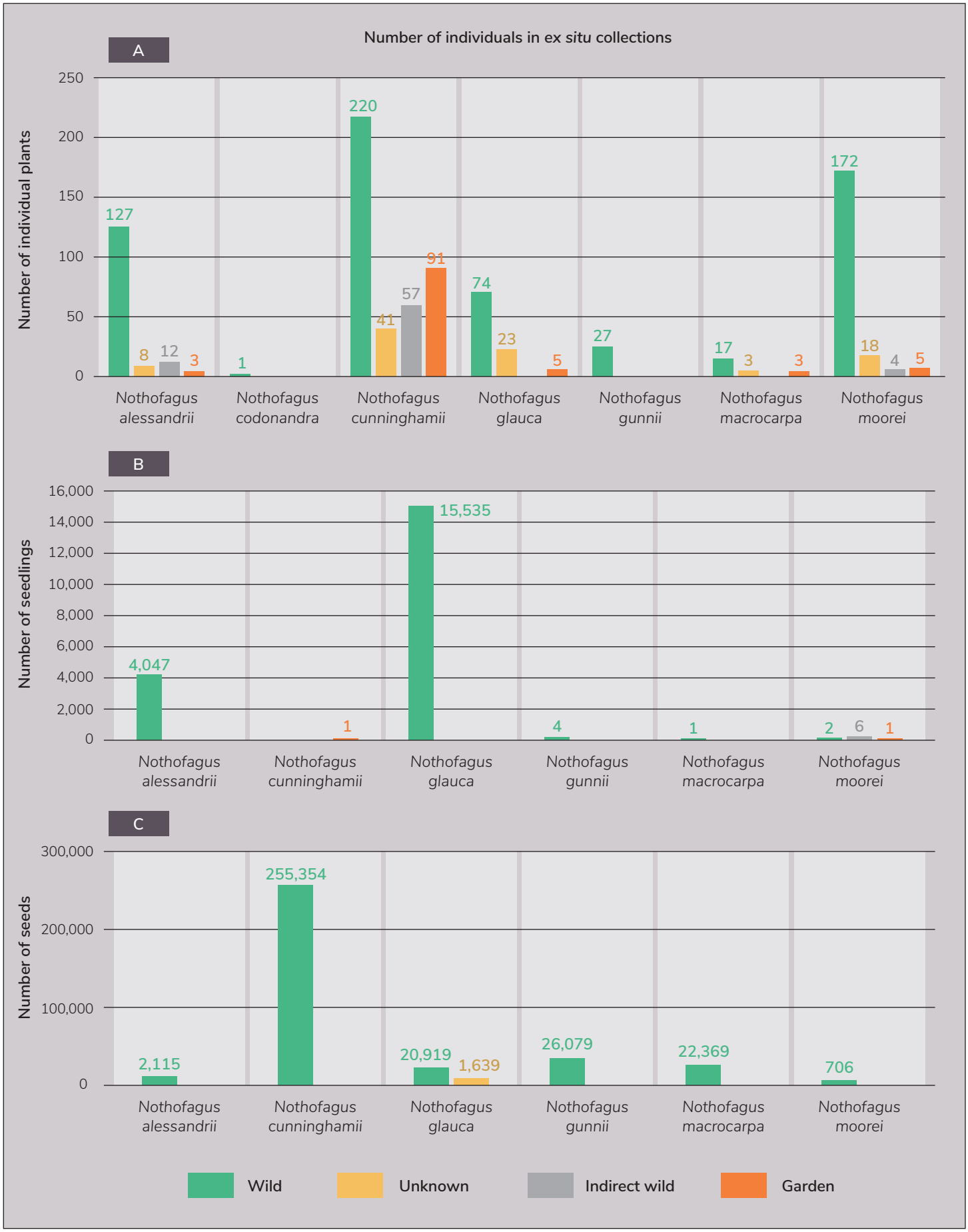

Figure 7. Number of individuals of A) plants, B) seedlings and C) seeds per *Nothofagus* species in *ex situ* collections, categorised by provenance type. Information was obtained from the *ex situ Nothofagus* collections survey.

Estimated representation of *ex situ* collections

As described by Beckman et al. (2019) and Linsky et al. (2022) the conservation quality of *ex situ* collections for a given species depends on the degree to which they represent the genetic diversity found in the wild. Because molecular genetic studies are not available for many *Nothofagus* species, we used two proxies for estimating the genetic diversity represented within *ex situ* collections: geographic and ecological coverage. These proxies are based on the assumption that sampling across a species' full native distribution and all ecological zones it inhabits is the best way to ensure that the full spectrum of genetic diversity, including the suite of adaptive and potentially adaptive traits, is captured in *ex situ* collections (CPC, 2019). As stated by Linsky et al. (2022), the calculations of geographical and ecological coverage are based on estimations of the species' range and should be considered approximate estimations of the coverage of *ex situ* collections. Additionally, this analysis may show a single plant as adequately representing the genetic diversity, however, in practice a minimal collection of 50 plants from each population is usually needed to sufficiently capture genetic diversity *ex situ* (CPC, 2019).

With these assumptions and caveats in mind, these spatial analyses, and the maps within the individual species profiles (Appendix A), can be used to prioritise populations for future wild collecting efforts.

Nothofagus codonandra, dieback and regrowth, Mt Koghi, New Caledonia (Olivia Steed-Mundin)

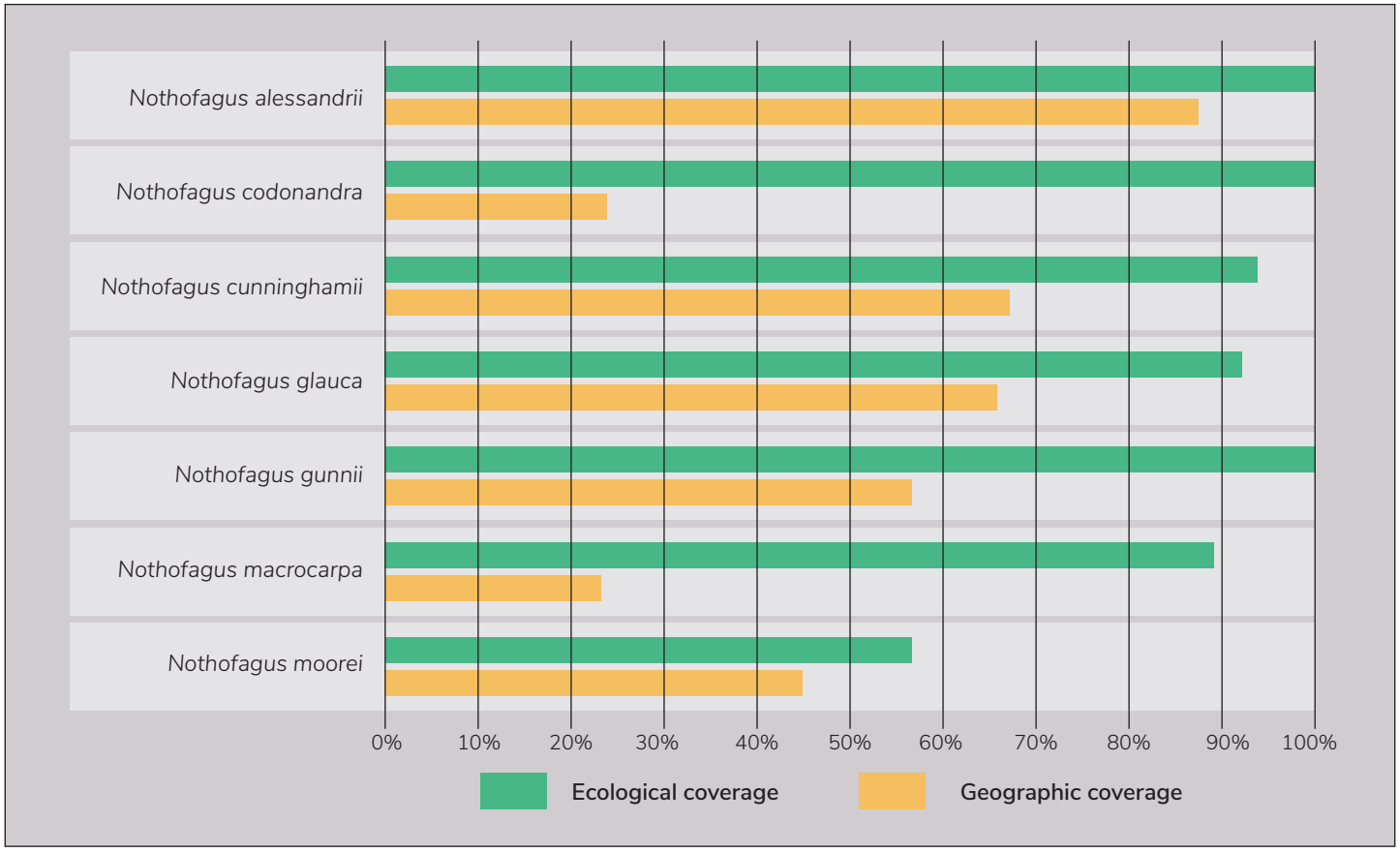

Figure 8. Estimated geographic and ecological coverage of *ex situ* collections (including living plants and seed collections). The average coverage of the three buffer sizes (40, 60 and 80 km) is shown. Only *Nothofagus* species with *ex situ* collections are shown.

The following results refer to the seven *Nothofagus* species with known *ex situ* collections.

a) *Ex situ* collections (living and seed combined)

Only four species are estimated to have *ex situ* collections (living and seed combined) that represent 50% or more of their geographical range (Figure 8). These are *N. alessandrii* (88%) and *N. glauca* (66%), from Chile, and *N. cunninghamii* (67%) and *N. gunnii* (56%) from Australia. Overall, the ecological coverage for living and seed collections combined is 89% or more for all species, except for *N. moorei* from south eastern Australia, which has less than 60% (Figure 8).

b) *Ex situ* living collections

Geographic coverage of *ex situ* living collections is under 60% for all species except for *N. alessandrii* (87%) (Figure 9A). Only three other species have *ex situ* living collections that represent more than half of their geographical range: *N. glauca* (54%), *N. gunnii* (54%) and *N. cunninghamii* (53%) (Figure 9A). Ecological coverage of living collections is greater than 80% in all species apart from *N. moorei*, with only 56% of ecological coverage (Figure 9B).

Nothofagus alessandrii, Wakehurst, UK (Olivia Steed-Mundin)

Nothofagus macrocarpa, Cerro El Roble, Chile (Nicolás Lavandero)

c) *Ex situ* seed collections

Two species from Australia and two species from Chile have *ex situ* seed collections that represent half or almost half of their geographical range (Figure 9A): *N. gunnii* (55%), *N. cunninghamii* (49%), *N. alessandrii* (50%) and *N. glauca* (46%). Two species have *ex situ* seed collections that represent less than 20% of their geographical range: *N. macrocarpa* (19%) and *N. moorei* (18%) (Figure 9A). The ecological coverage of *ex situ* seed collections is more than 75% in all species except for *N. moorei* (44%) (Figure 9B). *N. codonandra* has no seed collections (Figure 9).

Estimated land protection

We estimated the percentage of each species' inferred native range within protected areas to characterise the degree of habitat security for each *Nothofagus* target species. The calculations of protected area coverage rely on estimations of the species' range, as buffers around *in situ* points are likely to overestimate the distribution range of the target species. Furthermore, the buffers might include non-protected habitat where the target species are unlikely to occur. Thus, when interpreting these results, the protected area coverage should be considered approximate estimations. Additionally, we should keep in mind that protected area coverage is not always representative of land protection, as in some cases mining and/or logging can still take place. For example, in New Caledonia, not all of the protected areas are protected from mining (Jaffré et al., 1996). Within the individual species profiles (Appendix A), specific analyses for New Caledonian species have been carried out to consider this.

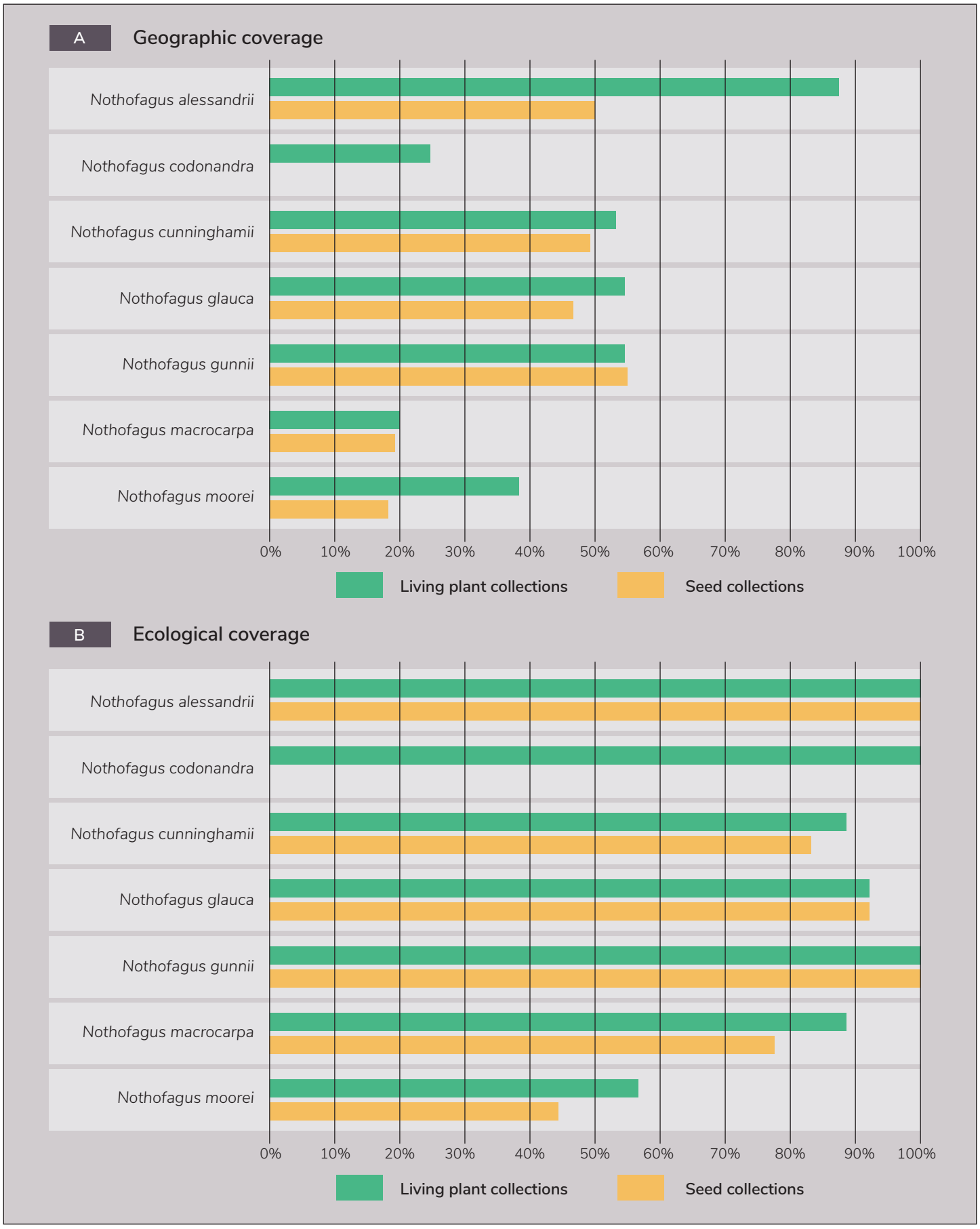

Figure 9. Estimated A) geographic coverage and B) ecological coverage of *ex situ* collections for seven of the target *Nothofagus* species. *Ex situ* collections are separated by seed and living collections. The average coverage of the three buffer sizes (40, 60 and 80 km) is shown. Only *Nothofagus* species with *ex situ* collections are shown.

Overall, most of the distribution of *Nothofagus* target species lies outside protected areas (Figure 10). The lowest proportion of protected area coverage is for *N. nuda*, where 0% of the native range in Papua New Guinea is found within protected areas, whilst only 0.2% of *N. alessandrii*, from Chile, is inside protected areas (Figure 10). The majority of species have between 1 to 20% of their range within protected areas (Figure 10). Only three species have more than 30% of the native range within protected areas (Figure 10): *N. cunninghamii* (31%) occurring in Tasmania and Victoria, south Australia, *N. gunnii* (59%) in west of Tasmania, where protected areas cover a relatively large proportion of land, and *N. stylosa* (56%) known from a single occurrence point from Mt Trikora which sits within Lorentz National Park, Indonesian New Guinea.

Nothofagus alessandrii, Huelón, Chile (Paulina Hechenleitner)

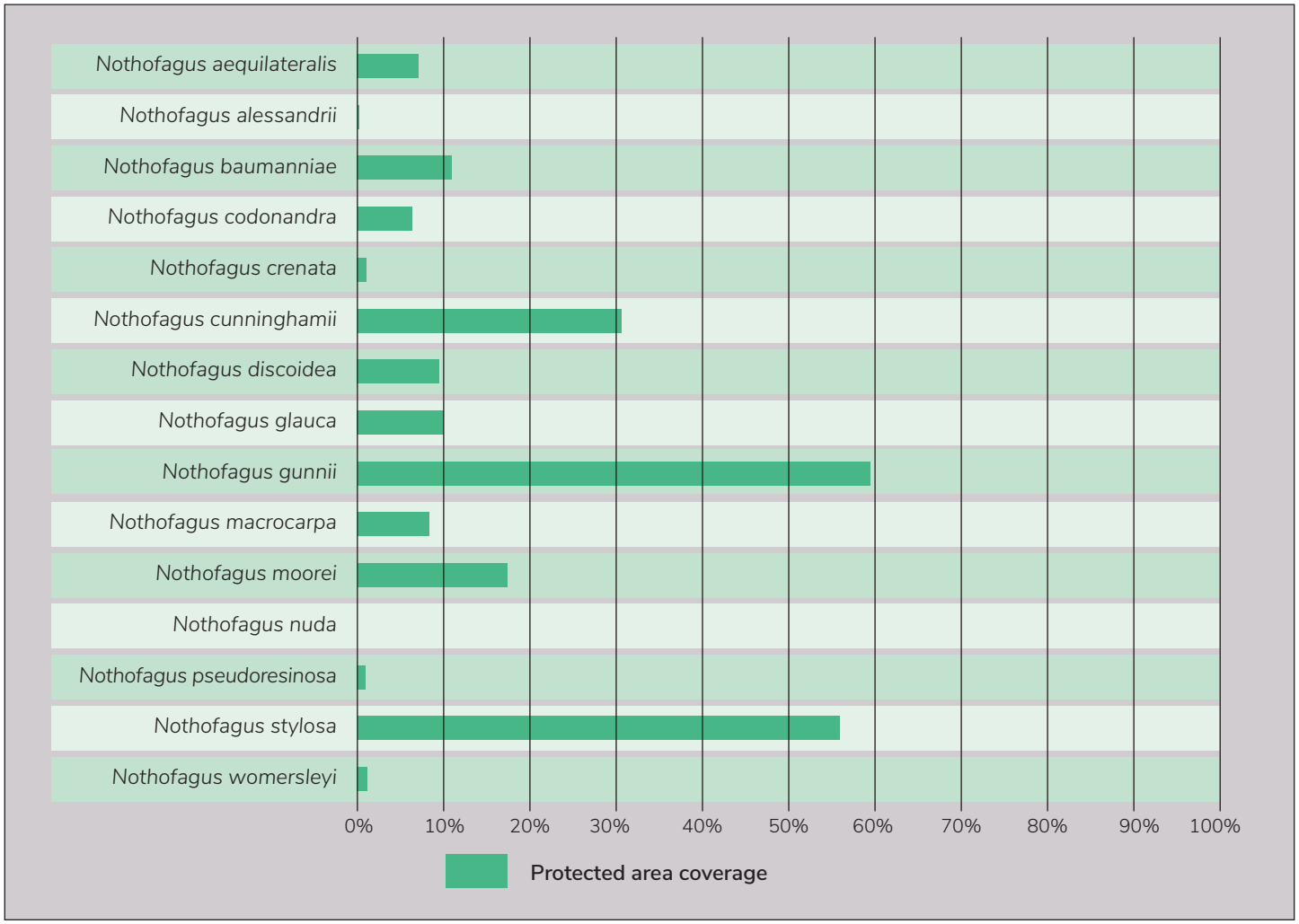

Figure 10. Estimated proportion of *Nothofagus* target species' inferred native range occurring within protected areas. The average coverage of the three buffer sizes (40, 60 and 80 km) is shown.

Current conservation activities

A total of 24 respondents from 22 organisations provided information on current conservation activities in the *Nothofagus* Conservation Activity Questionnaire (see Appendix B for the list of participating organisations). Fifteen of the organisations that responded to the Questionnaire are in centres of diversity for *Nothofagus*, such as Chile and Australia (Figure 11).

From the 15 target species, organisations only provided data for six species, all of which occur in Chile and Australia. Respondents were from four types of organisations, most commonly from arboreta or botanic gardens, followed by universities or colleges and private sector or industry (Figure 12).

The most commonly reported conservation activities were conservation horticulture by 38 organisations, public awareness and education (33), and collect and distribute germplasm (20) (Figure 13). The species with most conservation activities reported were *N. glauca* (VU) and *N. alessandrii* (EN), both of which are from Chile. The species with the least conservation activities reported were *N. gunnii* (NT) from Australia, and *N. macrocarpa* (VU) from Chile (Figure 13). None of the species from New Caledonia, Indonesian New Guinea or Papua New Guinea had any reported conservation activities in the Conservation Activity Questionnaire.

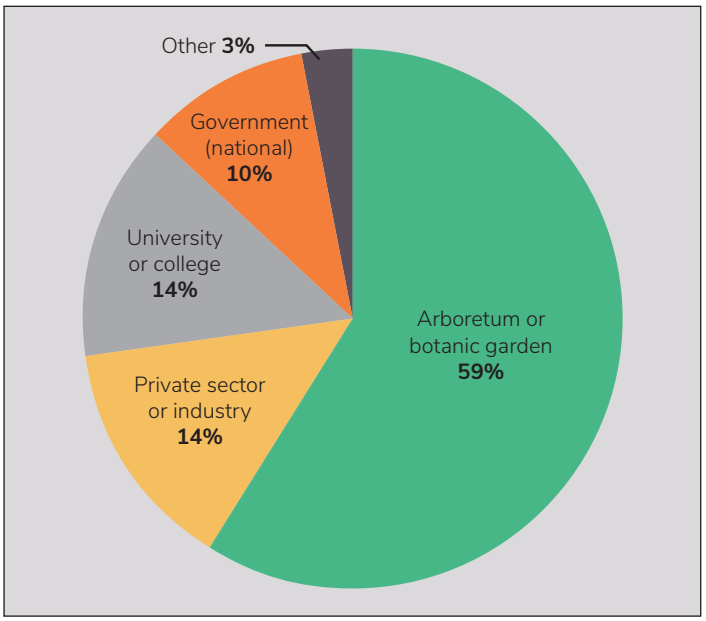

Figure 12. The proportion of respondents to the Conservation Activity Questionnaire by organisation type that provided information about current conservation activities. A total of 24 respondents from 22 organisations provided data.

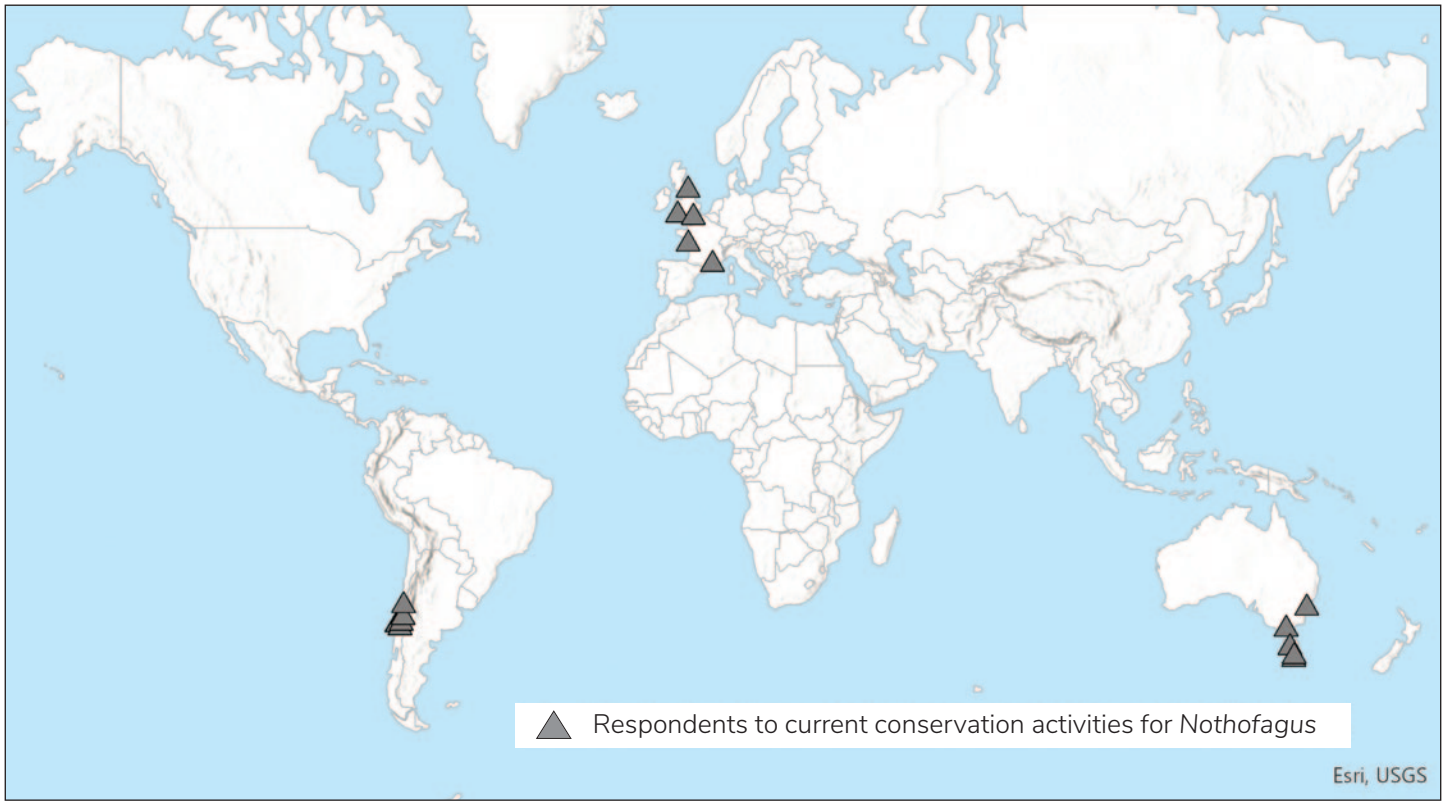

Figure 11. Location of 18 of the 22 organisations that provided information on current conservation activities in the *Nothofagus* Conservation Activity Questionnaire (four organisations opted to be anonymous).

Further research into conservation activities was conducted by literature review and expert consultation. This provided more details to the questionnaire and uncovered some additional conservation activities, particularly in regions which were not reported on by the respondents to the questionnaire. The following summaries present regional trends from this research. Further details for each species is reported in the species profiles (Appendix A).

Chile

Chile has a well-developed programme of *in situ* and *ex situ* conservation for *Nothofagus* and a broad range of conservation activities were reported for the three target species both in the Conservation Activity Questionnaire and through further research. In many cases, activities are being carried out by multiple Chilean organisations, often collaboratively.

Common activities reported for all three target species in the Conservation Activity Questionnaire include: conservation horticulture, public awareness and education, collect and distribute germplasm, habitat restoration, protect and manage habitat, population reinforcement or introduction, occurrence surveys or population monitoring, and research (Figure 13). Other conservation activities reported for *N. glauca* and *N. alessandrii*, (but not for *N. macrocarpa)*, in the questionnaire included: implementation of protection policies or regulations, and pollen or seed banking (Figure 13). There was less breadth of activities and fewer organisations reported to be carrying out conservation activities for *N. macrocarpa* than the other two target species from Chile.

In 2022, a conservation project funded by Fondation Franklinia was initiated to target the conservation, ecological restoration and capacity building to benefit the three threatened *Nothofagus* species native to South America. The project is led by Universidad de Concepción, working with Chilean institutions Universidad de Chile, Instituto Forestal (INFOR), Universidad Católica del Maule, Universidad de Talca, INIA and Club del Árbol de Talca, with support from BGCI.

Despite this, a common theme which arose for all three target species through expert consultation was the need for more resources to implement species protection policies and for sustainable land management, particularly related to control of invasive species. It should also be noted that <10% of the inferred range of each species falls within formal protected areas.

Australia

A fairly broad range of conservation activities were reported for all species in Australia via the Conservation Activity Questionnaire, expert consultation and literature review.

The most reported conservation activity in the Conservation Activity Questionnaire for *N. moorei*, *N. gunnii* and *N. cunninghamii* is conservation horticulture, followed by public awareness or education, pollen or seed banking and cryopreservation and/or micropropagation (Figure 13). Habitat restoration was only reported to be taking place for *N. cunninghamii*, and there were no reported activities for any of the Australian species relating to implementing protection policies or regulations; occurrence surveys; population monitoring; population reinforcement or introductions; protect and/or manage habitat (Figure 13). However, it should be noted that Australia has a well managed network of protected areas and when species occur in these areas, ongoing management is undertaken to protect native biodiversity and vegetation.

There are also a number of research programmes currently underway which will offer useful insights for conservation of the individual Australian species moving forward. This includes a population genomics study of *N. moorei*, the results of which can inform collecting strategies for *ex situ* collections. A monitoring programme of myrtle wilt on Bruny Island is also in place, which will offer some insight into the current status of the disease and the threat to *N. cunninghamii* populations locally. More research is needed to understand the current threat from this disease to *N. cunninghamii* more widely.

There were less conservation activities associated with *N. gunnii* than the other two species, and expert consultation identified that any potential conservation activities associated with propagation and breeding for *N. gunnii* (e.g. reintroductions, conservation horticulture etc.) are limited by difficulties with establishing seedlings *ex situ*.

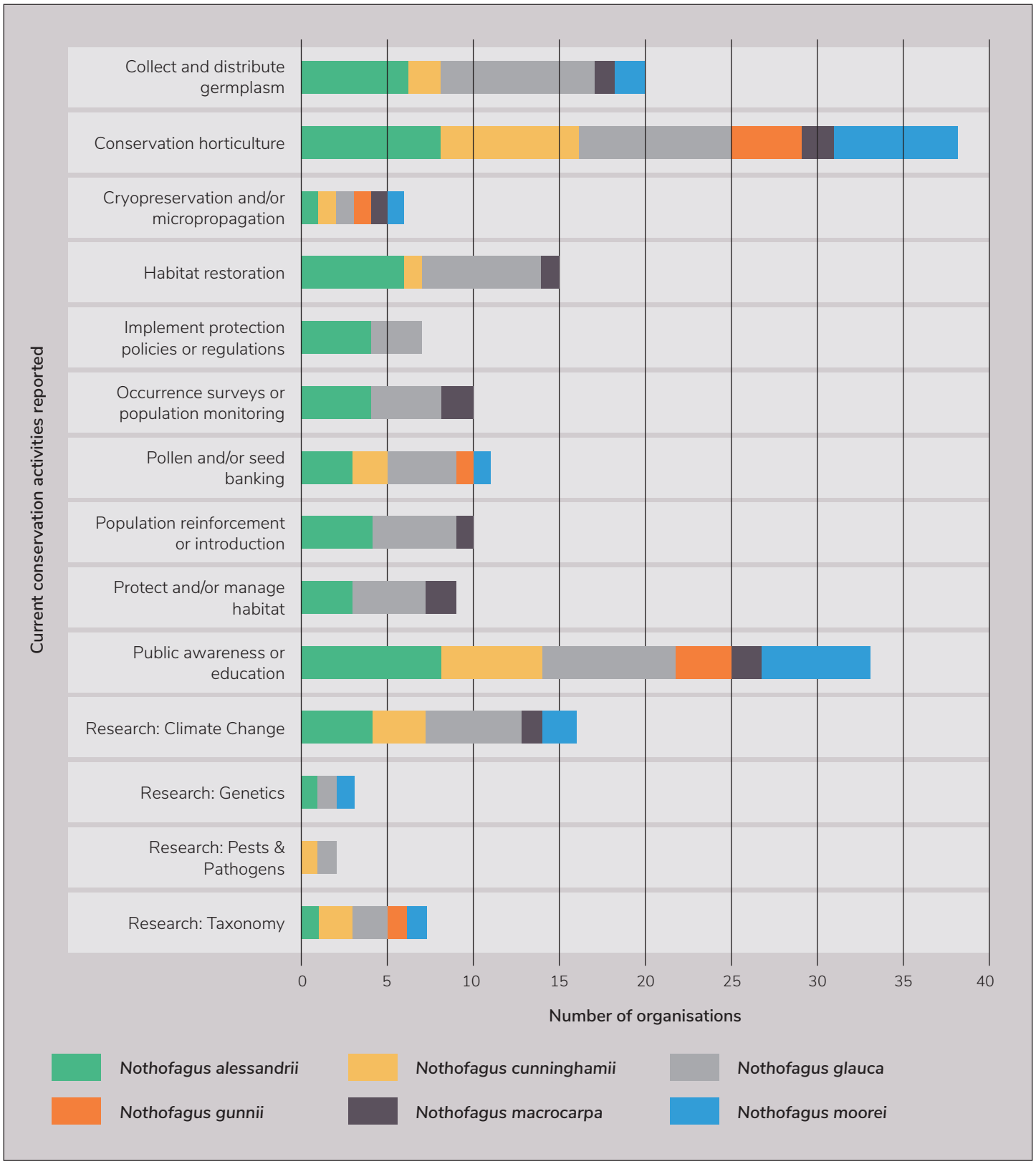

Figure 13. Number of organisations reporting each conservation activity in the Conservation Activity Questionnaire by species. A total of 22 organisations provided data for target *Nothofagus* species. Where two respondents from the same organisation provided data, the data was merged.

New Caledonia

No conservation activities were reported in the Conservation Activity Questionnaire for target species from New Caledonia. Further consultation found that conservation activities which depend on seed collecting (e.g. collecting and distributing germplasm, seed banking and population reinforcement or reintroduction) are limited because of challenges including: erratic seed production; seed phenology which is poorly understood; physical difficulty with collecting seeds in the forest stands (S. McCoy pers. comm., 2022). In addition, breeding and reintroduction programmes are inhibited by seedling establishment issues, which, at least in some species, appear to be linked to the need for a mycorrhizal association (S. McCoy & F. Carriconde pers. comm., 2022). Some protection is afforded to *Nothofagus* populations by species and habitat-level legislation. However, some protected areas in New Caledonia are not protected from mining activity (Jaffré et al., 1996), which poses a continued threat.

There has been some research into the population dynamics of *Nothofagus* forests (Demenois et al., 2016; Read & Jaffré, 2013; Read et al., 2018) and some on the mycorrhizal communities in *N. aequilateralis* forests (Carriconde et al., 2019; Gourmelon et al., 2016), which provide useful insights for conservation.

New Guinea (Papua New Guinea and Indonesian New Guinea)

No conservation activities were reported in the Conservation Activity Questionnaire and our additional research found that conservation activities are almost entirely lacking for all target species from Papua New Guinea and Indonesian New Guinea. Seed production appears to be erratic and phenology is poorly understood and there have been no seed collecting or seed banking initiatives, and therefore, no population breeding or reintroduction programmes. Legislation provides some habitat protection for most species in theory, but a lack of resources limits activities associated with protecting and managing habitat for most species. There appears to be no published research for any species apart from for *N. pseudoresinosa*, which was included in a population dynamics study (Read et al., 1990). However, there is some ongoing research into a dieback phenomena observed in *Nothofagus* forests in the Lorentz National Park (R. Saputra pers. comm., 2022).

Priority Conservation Actions

Results from the Conservation Activity Questionnaire

A total of 24 respondents from 21 organisations provided insights into the most important conservation actions needed for the target species (see Appendix B for the list of participating organisations). The responses only provided information for six of the 15 target species and only those that occur in Australia and Chile, hence these results are limited (Figure 14). Commonly identified priorities for all these six species include: public awareness or education; protect and/or manage habitat; implement protection policies or regulations; occurrence surveys or population monitoring; conservation horticulture; pollen and/or seed banking; collect and distribute germplasm; research on climate change; and research on genetics (Figure 14).

Nothofagus macrocarpa, Cerro El Roble, Chile (Nicolás Lavandero)

Nothofagus discoidea fruit cupules, New Caledonia (Dan Crowley)

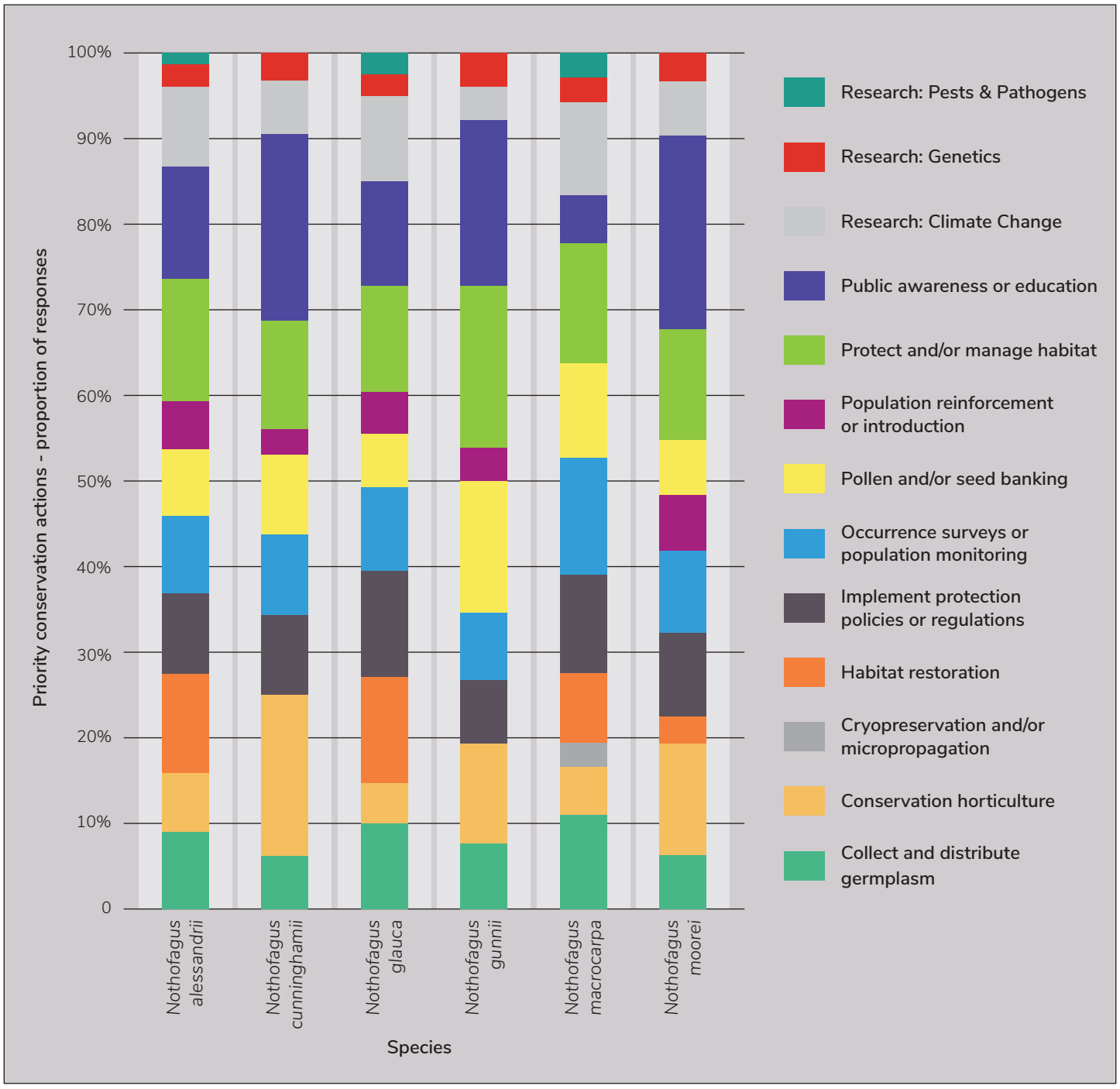

Figure 14. Priority conservation actions identified in the Conservation Activity Questionnaire reported as a proportion of responses by species. A total of 24 respondents provided information from 21 organisations. Only *Nothofagus* species with priority actions reported are shown.

Recommendations

We synthesised the findings from our research and consulted with regional experts to make recommendations for the most important conservation actions for each of the target *Nothofagus* species. These are presented in detail for each species in the individual species profiles (Appendix A). These recommendations have been collated and major recommendations at a regional level are presented below in order of priority for each region.

Chile

1. **Assess and update current distribution and status of wild populations:** given recent fires and issues with natural regeneration/invasive species, it is important to carry out this research to help inform and prioritise conservation activities. Results will inform updated IUCN Red List assessments.

2. **Habitat protection and restoration:** populations of the target species are commonly small, fragmented and/or occur in a matrix of exotic species plantations. More resources are required to implement species protection plans, invasive species management, to support natural regeneration and to reinforce populations.

Nothofagus moorei juvenile leaves, Barrington Tops, New South Wales, Australia (Dan Crowley)

Nothofagus moorei fruit, Wakehurst, UK (Olivia Steed-Mundin)

3. **Establish genetically representative *ex situ* collections:** it is important to establish more representative *ex situ* collections for all three species, with a focus particularly on those populations most at risk from fire and climate change, and those which have not been collected previously. *N. macrocarpa* is very poorly represented in *ex situ* collections and should be a priority.

4. **Research:** for *N. macrocarpa*, research is required to investigate what is preventing natural regeneration; for *N. alessandrii* research is required into the effects of climate change in relation to dynamics of phenology, seed production, regeneration and establishment.

Australia

1. **Establish genetically representative *ex situ* collections:** it is recommended that more representative *ex situ* collections are established for all three species, with a focus on those populations which have not been collected previously and those most at threat. This is perhaps most pressing for *N. gunnii* and *N. moorei*, with increasing threats from climate change and fire. In addition, *N. moorei* is particularly poorly represented in both seed and living collections and data provided by the population genomics study, currently underway at Botanic Gardens of Sydney, could enable a very targeted collection strategy for this species.

2. **Research:** for *N. cunninghamii*, further research is required to understand the current threat from myrtle wilt especially in Tasmania; for *N. gunnii* research is required to understand the issues with establishing seedlings *ex situ*, with a view to develop a propagation protocol for this species; for all species, further research is required into long-term viability of seed *ex situ* as well as climate change modelling.

3. **Monitoring:** it would be useful to provide further insights into the impact of recent fires of *N. moorei* populations (and possible regrowth); effects of climate change on *N. gunnii* and *N. moorei* populations; and current prevalence of myrtle wilt for *N. cunninghamii*, in comparison with historic monitoring plots.

New Caledonia

1. **Address the challenges preventing seed collecting:** this includes: research into seed phenology, developing a methodology for collecting seed, and training local seed collectors.

2. **Overcome seedling establishment issues:** research is recommended into microbial communities associated with *Nothofagus* seedlings and potentially the development of an inoculant to aid seedling establishment. Once established, propagation protocols can be written.

3. **Establish genetically representative ex *situ* collections:** given there is only one plant in ex *situ* collections, this is particularly important to initiate. However it is largely dependent on the above initiatives being implemented first. In addition, research into seed storage traits of tropical *Nothofagus* is required before ex *situ* seed collections can be established.

4. **Population reinforcement or reintroductions:** it would be beneficial to work with local mining companies to include *Nothofagus* into work programmes for reintroduction and/or reinforcement.

Nothofagus macrocarpa, Altos de Cantillana, Chile (Nicolás Lavandero)

Nothofagus alessandrii, immature fruit, Wakehurst, UK (Olivia Steed-Mundin)

New Guinea
(Papua New Guinea and Indonesian New Guinea)

1. **Population surveying:** most populations of threatened species on the island of New Guinea have not been recorded for some time, so there is an urgent need to refind them and carry out population surveys to determine if there is recruitment and/or any additional threats, so that more focused recommendations for conservation actions can be made. This is particularly pressing for *N. stylosa* and *N. nuda*, which are Critically Endangered (CR) in the wild and both are only known from a single population, neither of which have been recorded for more than 40 years.

2. **Seed collecting to establish ex *situ* collections:** there are currently no species in ex *situ* collections globally so this is important to initiate for all species. It is most pressing for the three CR species from New Guinea (*N. stylosa*, *N. womersleyi*, and *N. nuda*), so it is recommended that seed collecting is attempted at the same time as population surveying.

3. **Research:** is required into phenology, seed storage traits, and germination requirements for all species. In addition, further research is required into the dieback that is affecting populations in Lorentz National Park. It would also be useful to carry out climate change modelling, especially for the species occurring at high altitudes.

4. **Potential updates to IUCN Red List assessment:** once population surveys have been completed and more is understood about the current status of and threats to extant populations, it is recommended that the Red List assessments are updated for each species.

Prioritising Target Species

The *Nothofagus* species of the greatest conservation concern, based on the prioritisation matrix (Table 4), are *N. nuda* and *N. womersleyi* from the island of New Guinea (Figure 15). Both are Critically Endangered (CR), have no representation in *ex situ* collections and have none to very little protected area coverage (Table 4). The next species in order of priority, are the remaining species from tropical latitudes: *N. discoidea; N. baumanniae; N. crenata; N.aequilateralis; N. pseudoresinosa; N. stylosa;* and *N. codonandra* (Figure 15; Table 4). Temperate species are considerably better represented in *ex situ* collections (Table 4) and hence all score lower in terms of priority than tropical species. The species of greatest conservation concern in the temperate regions are: *N. macrocarpa* from Chile, and *N. moorei* from Australia. (Figure 15; Table 4).

Table 4. Prioritisation matrix identifying conservation concern score for *Nothofagus* target species.

Prioritisation matrix	Concern Score (max score = 27)	IUCN Red list category	# organisations with ex situ collections (plants and/or seeds)	# of individual plants in ex situ living collections	# wild origin seedlings in nurseries	# of seeds in ex situ collections	% of geographic range captured by ex situ collections (plant and/or seed)	% of ecological range captured by ex situ collections (plant and/or seed)	% of protected area coverage
Nothofagus nuda	27	CR	0	0	0	0	0	0	0%
Nothofagus womersleyi	27	CR	0	0	0	0	0	0	2%
Nothofagus discoidea	26	EN	0	0	0	0	0	0	9%
Nothofagus baumanniae	25	EN	0	0	0	0	0	0	11%
Nothofagus crenata	25	VU	0	0	0	0	0	0	2%
Nothofagus aequilateralis	24	NT	0	0	0	0	0	0	7%
Nothofagus pseudoresinosa	24	NT	0	0	0	0	0	0	2%
Nothofagus stylosa	24	CR	0	0	0	0	0	0	56%
Nothofagus codonandra	20	NT	1	1	0	0	24%	100%	6%
Nothofagus macrocarpa	16	VU	9	23	1	22369	23%	89%	8%
Nothofagus moorei	13	VU	20	199	9	706	45%	56%	17%
Nothofagus alessandrii	10	EN	21	150	4047	2115	88%	100%	0%
Nothofagus gunnii	9	NT	6	27	0	26079	56%	100%	59%
Nothofagus glauca	8	VU	24	102	15535	22558	66%	92%	10%
Nothofagus cunninghamii	7	VU	30	409	0	255354	67%	94%	31%

5 points | 4 points | 3 points | 2 points | 1 point | 0 points

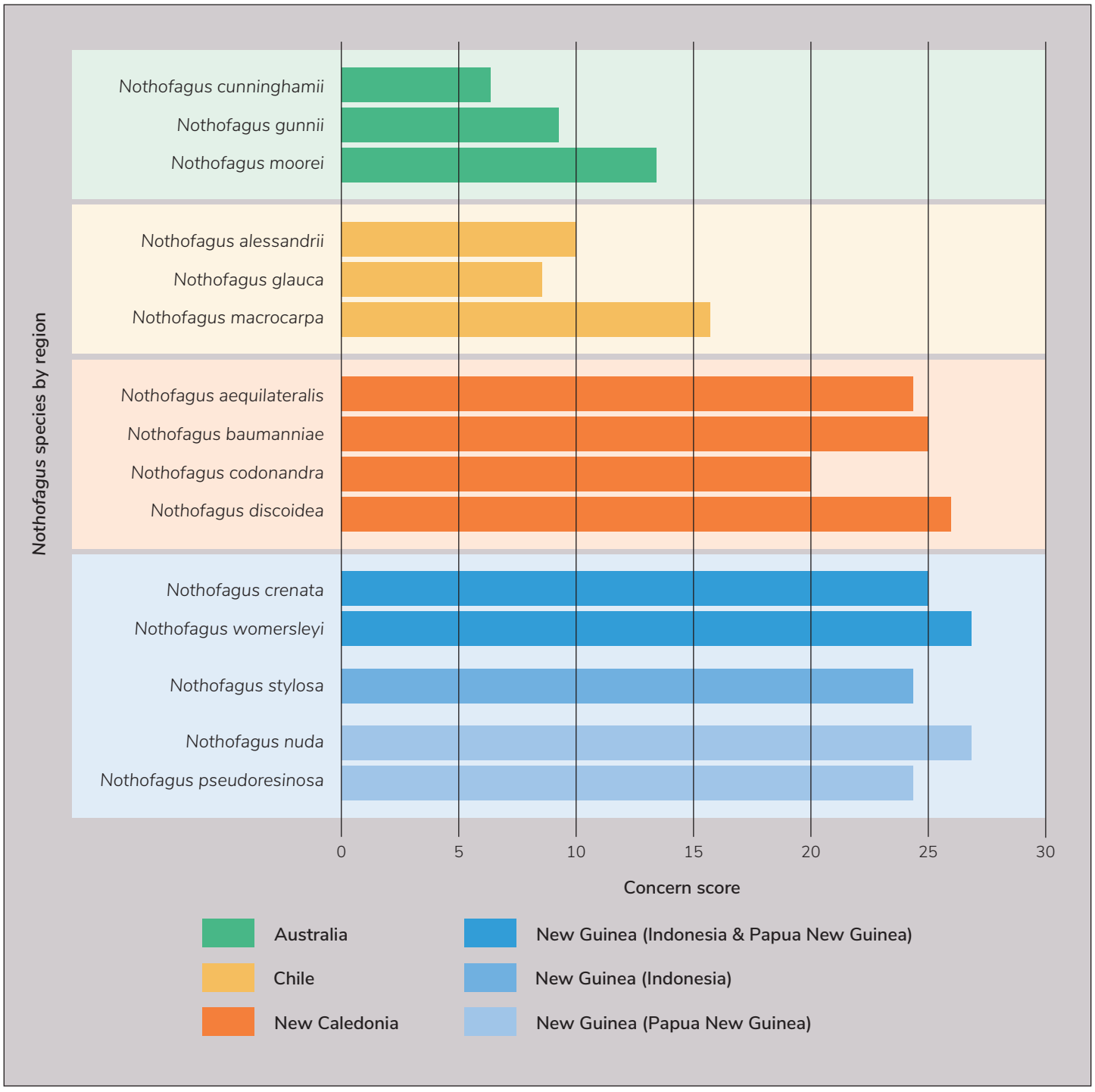

Figure 15. Conservation concern score by species (results taken from the Prioritisation Matrix), represented by country/region

A more comprehensive conservation gap analysis for each target species, including detailed priority conservation actions and recommendations at the species level is provided in the species profiles (Appendix A). Each profile includes the following:

- Distribution and Ecology
- Threats to wild populations
- Maps of occurrence
- Protected areas and source localities of *ex situ* collections
- Results of the spatial analysis
- Ongoing conservation activities
- Recommended conservation actions.

The profiles provide valuable information to help guide and develop conservation strategies for each *Nothofagus* species.

Conclusions

This Conservation Gap Analysis of *Nothofagus* has built on the work of the *IUCN Red List of* Nothofagus (Baldwin et al., 2018) to provide a genus-wide analysis of the current state of conservation for all species that were identified as threatened (CR, EN, VU) or Near Threatened in the Red List (i.e. target species). Our study involved a survey of *ex situ* collections globally, spatial data analysis, a Conservation Activity Questionnaire, expert consultation, and an extensive literature review. Results have been synthesised and presented here to identify gaps and priorities for conservation globally and regionally. This report, including its appendices, is intended for a wide-range of stakeholders including botanic gardens, non governmental organisations, conservation agencies, government agencies, policy makers and land managers.

A key theme highlighted by this report across all *Nothofagus* target species is the need for more research to better inform effective and targeted conservation strategies. A focus on climate change modelling is particularly important. The majority of target species occur in relatively small fragmented populations, often at high altitude and/or in extreme conditions, and there is a need to understand how these populations may cope as the climate changes. In addition, research into the phenology of seed production would help understand (and potentially predict) mast seeding events, which would facilitate effective wild collecting – this is particularly pertinent in the tropics where erratic seed production severely hinders seed collecting. Other key areas of research should be focused on fire relations (i.e. the threats from fire to specific populations and regeneration potential post-fire); seedling establishment trials (especially for species from New Caledonia and *N. gunnii*); seed storage traits; pest and pathogen extent and control (particularly for *N. cunninghamii* and for species displaying dieback in New Guinea and New Caledonia); population surveying; and population genetics studies.

Nothofagus cunninghamii, Tasmania (Dan Crowley)

Our analysis also highlighted a fundamental need to increase representation in *ex situ* collections for all species. This is particularly applicable to tropical species which have no representation in *ex situ* seed collections and almost none in *ex situ* living collections. But there are also significant geographical gaps in temperate species representation in *ex situ* living collections, with even greater deficiencies observed in seed collections. This report highlights for the first time which populations are lacking for each species, with a view to facilitate a more targeted approach to wild collecting. Creating genetically representative *ex situ* collections for each target species would underpin efforts to ensure these species do not go extinct in the wild. It is recommended that a metacollection approach to *ex situ* conservation is followed, creating a network of *Nothofagus* collections, sharing data and material between organisations, and encouraging global collaboration (Griffith et al., 2019). This would also help to coordinate and prioritise future *ex situ* conservation efforts.

Nothofagus cunninghamii, Tasmania (Dan Crowley)

Our results also showed that all but three species have less than 30% of their inferred native range occurring within protected areas. Protecting habitat from threats such as mining, logging and/or invasive species is crucial and would be highly beneficial. Additionally, increased resources to support the implementation of associated conservation actions are greatly needed.

One of the most marked findings of this report is the regional variation in both *in situ* and *ex situ* conservation activities, with a notable bias of conservation work focused on temperate species, versus an almost complete lack of conservation activities for any of the tropical species. Given that many of the most threatened species occur in the tropics, particular focus is required in these regions to help build capacity and resources to facilitate conservation in the country of origin. Particularly pressing is the need to locate and survey populations of the Critically Endangered species on the island of New Guinea. Two species *N. nuda* and *N. stylosa* are both only known from single populations that have not been recorded for more than 40 years.

It is worth noting that despite the gaps, there are some significant conservation efforts in place and some hope for future actions. In Chile, for example, a collaborative project, funded by Fondation Franklinia and led by Universidad de Concepción was initiated in 2022 to target the conservation, ecological restoration, and capacity building to benefit the three threatened *Nothofagus* species native to South America. In Australia, the results from a population genomics study which included *N. moorei*, led by Research Centre for Ecosystem Resilience, Botanic Gardens of Sydney, will be used to inform targeted wild collection initiatives by the Blue Mountains Botanic Garden who are aiming to create representative *ex situ* collections. Learnings from both these projects could also help inform other conservation efforts globally.

It is hoped this study provides stakeholders a useful resource in prioritising the conservation activities required at both a global and regional scale as well as providing evidence to help support funding applications and resource allocation. It has been invaluable to collaborate with experts across the globe and to draw on their knowledge and insights to develop this report. It will be vital moving forward to support communication and connections among stakeholders engaged in *Nothofagus* conservation globally and regionally. This will help the community to collectively address the global scale of threats, coordinate conservation efforts most needed, and advance the conservation of *Nothofagus* most effectively.

Nothofagus glauca fruit, Wakehurst, UK
(Olivia Steed-Mundin)

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(Olivia Steed-Mundin)

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Nothofagus macrocarpa, Altos de Cantillan, Chile (Nicolás Lavandero)

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Appendices

Appendix A: Species Profiles

Individual species profiles are included for all of the target species. Page numbers within the full-length PDF are listed below.

Species Profile	Country / territory	Pages
Nothofagus aequilateralis	New Caledonia	41-46
Nothofagus alessandrii	Chile	47-58
Nothofagus baumanniae	New Caledonia	59-64
Nothofagus codonandra	New Caledonia	65-72
Nothofagus crenata	Indonesian New Guinea and Papua New Guinea	73-77
Nothofagus cunninghamii	Australia	78-89
Nothofagus discoidea	New Caledonia	90-96
Nothofagus glauca	Chile	97-108
Nothofagus gunnii	Australia	109-118
Nothofagus macrocarpa	Chile	119-130
Nothofagus moorei	Australia	131-141
Nothofagus nuda	Papua New Guinea	142-145
Nothofagus pseudoresinosa	Papua New Guinea	146-150
Nothofagus stylosa	Indonesian New Guinea	151-155
Nothofagus womersleyi	Indonesian New Guinea and Papua New Guinea	156-160

Nothofagus aequilateralis (Baum.-Bod.) Steenis

Synonym(s): *Trisyngyne aequilateralis* Baum.-Bod. **Common name(s):** unknown

IUCN Red List Category and Criteria: Near Threatened (NT) B1ab(v)

Species profiles authors: Olivia Steed-Mundin, Wakehurst, Royal Botanic Gardens, Kew, UK; Dan Crowley, Westonbirt, The National Arboretum, UK, BGCI; Itxaso Quintana, BGCI; Stephane McCoy, Prony Resources, New Caledonia; Fabian Carriconde, New Caledonian Agronomic Institute (IAC).

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Distribution and Ecology

Endemic to New Caledonia, *Nothofagus aequilateralis* is the most widely distributed of all *Nothofagus* species in this territory (Figure 1; Baldwin, 2018). It has an extent of occurrence of 6843 km², with many, somewhat fractured populations in the south of Grande Terre and a few scattered populations towards the centre of the island (Baldwin, 2018). It usually occurs below 700 m a.s.l., although one herbarium collection made in 1967 was taken at 1150 m a.s.l (Bijmoer et al., 2022).

N. aequilateralis is an evergreen tree, 8-20 m tall (Van Steenis, 1971). It predominantly occurs on ultramafic soils but has also been occasionally recorded on volcano-sedimentary soils (Read & Hope, 1996; J. Read pers. comm., 2022). Similarly to other tropical *Nothofagus*, *N. aequilateralis* often dominates the upper canopy of the forests in which it occurs. It forms monodominant stands, considered to be an early successional stage, which establish following disturbance (Demenois et al., 2016; Read & Jaffré, 2013). These stands, frequently located within or adjacent to mixed rainforest (Read & Hope, 1996), support a rich diversity of host-specific ectomycorrhizal fungi communities which are likely playing an important part in the ecological functioning of *N. aequilateralis* in ultramafic soils, and potentially helping them to establish rapidly following disturbance (Carriconde et al., 2019).

The species composition and diversity in monodominant *N. aequilateralis* forests (below the upper canopy) is similar to adjacent mixed-canopy rainforests (Demenois et al., 2016; Read et al., 2000), containing several genera in families including Podocarpaceae, Araliaceae, Cunoniaceae, Lauraceae, Myrtaceae, Sapindaceae, Euphorbiaceae and Apocynaceae (Read & Hope, 1996).

N. aequilateralis, New Caledonia (Dan Crowley)

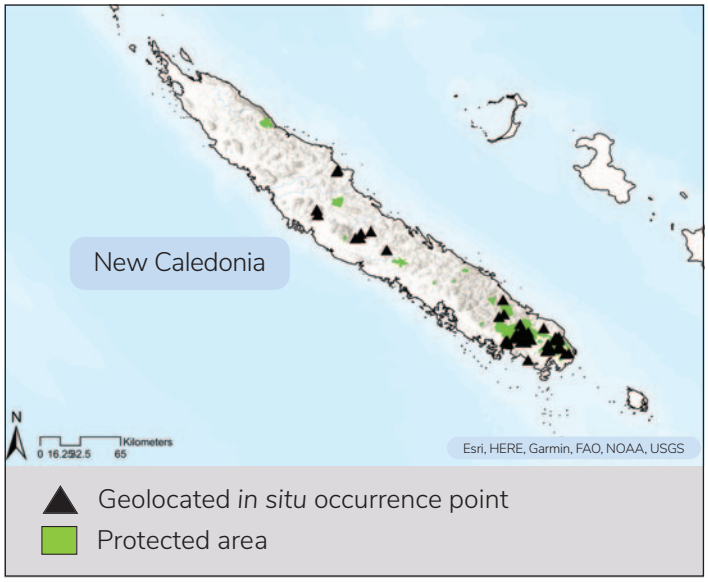

Figure 1. Documented *in situ* occurrence points for *Nothofagus aequilateralis* and Terrestrial Protected Areas in New Caledonia (Terrestrial Protected Areas are from UNEP-WCMC & IUCN 2022, Protected Planet).

Threats to Wild Populations

Threats to wild populations were identified by reviewing *The Red List of* Nothofagus (Baldwin et al., 2018), expert consultation and literature review. Because there is limited published research on threats to *N. aequilateralis* specifically, the information below largely refers to *Nothofagus* species in New Caledonia in general. No threats for *N. aequilateralis* were reported via the Conservation Activity Questionnaire.

The threats explored below are considered the current most significant threats, categorised into medium and low impact. This categorisation has been informed by the sources listed above and has been reviewed by regional experts.

Medium Impact Threats

Development, mining, and/or roads: Mining poses a general threat to New Caledonian *Nothofagus* species, contributing to species fragmentation and localised population loss (Baldwin, 2018). This threat has increased over the last 20 years, with the development of techniques enabling extraction from low-grade deposits that were previously unexploited (Baldwin, 2018; Jaffré et al., 2010).

Ecological restoration opportunities for *Nothofagus* in New Caledonia that could help mitigate against the threat from mining are complicated by irregular seed availability (S. McCoy pers. comm., 2022). In addition, there may be a need to consider ectomycorrhizal association for seedling establishment (S. McCoy & F. Carriconde pers. comm., 2022).

Disturbance regime modification including fire: Fire frequency has increased in New Caledonia with human settlement (Stevenson, 2004). Higher temperatures and sporadic rainfall are also making fires more common in some parts of the territory (Baldwin, 2018). *Nothofagus* forests often occur adjacent to maquis vegetation, which is frequently exposed to fire (Read & Jaffré, 2013). Indeed, the boundaries of some *Nothofagus* forests have already been affected by fire and once low altitude forest is lost following intense or frequent fires, regeneration becomes less likely (Baldwin, 2018). However, there does not currently appear to be any published information on how fire is affecting *N. aequilateralis* specifically.

Low Impact Threats

Climate change: There appears to be no specific research for this species regarding climate change. However, *Nothofagus* species in general have poorly dispersed seeds and specialist soil requirements which limits their ability to migrate to higher altitude in response to climate change (Read & Hope, 1996; Baldwin, 2018).

Nothofagus aequilateralis forest, Kopéto New Caledonia (Fabian Carriconde)

Conservation Activities

In 2021 and 2022, accession data were requested from *ex situ* collections for *Nothofagus* species that were identified as threatened or Near Threatened in *The Red List of* Nothofagus (i.e. 'target species') (Baldwin et al., 2018). There were no *ex situ* accessions of *N. aequilateralis* reported.

In addition, past, present and planned conservation activities for these species were examined through literature review, expert consultation and via a questionnaire. A Conservation Activity Questionnaire was sent out during 2021 and 2022. For *N. aequilateralis*, as with all *Nothofagus* species from New Caledonia, no conservation activities were reported. Information on conservation activities for this species has therefore been provided by expert consultation, research papers and other published sources.

Ex situ collections reported 2021–2022

No *ex situ* collections were reported.

Estimated *ex situ* representation

No *ex situ* collections were reported.

Wild collecting and/or *ex situ* curation

There are currently no known initiatives focused on wild collecting. Seed collecting initiatives for reintroduction purposes have been attempted by the mining company Prony Resources but they were limited by the irregularity of fruiting, with mast years (e.g. 1996) followed by years of limited fruiting, in a phenological sequence which is not well understood (S. McCoy pers. comm., 2022). In addition, fallen seeds are relatively small and difficult to find on the forest floor. A focus on alternative seed collecting methods could aid future collection from remote sites which are logistically complex (S. McCoy pers. comm., 2022). It should also be noted that there appears to be no published research focused on the seed storage characteristics of tropical *Nothofagus* species.

Propagation and/or breeding programmes

Breeding programmes are limited by the difficulties with seed collection (see section "Wild collecting and/or *ex situ* curation"). Prony Resources Nursery, a native plant nursery in New Caledonia, has only managed to propagate *N. aequilateralis* twice since 1996. Seedling survival without mycorrhizal associations was low (S. McCoy pers. comm., 2022).

Reintroduction, reinforcement and/or translocation

The roots of *N. aequilateralis* seedlings (0-1 years) have been observed to be strongly mycorrhizal, which may reflect a need for ectomycorrhizal association for successful reintroduction/reinforcement programmes (S. McCoy & F. Carriconde pers. comm., 2022). There have been some limited reintroductions by Prony Resources focused in areas of high importance which have been successful only in locations where juvenile *Nothofagus* are already occurring (S. McCoy pers. comm., 2022). Research into a mycorrhizal inoculation to aid seedling establishment could be beneficial for future reintroduction/reinforcement programmes (S. McCoy & F. Carriconde pers. comm., 2022). Alternative methods could also be considered, including seedling translocation following mast seeding.

Land protection

A spatial analysis was conducted to estimate the protected area coverage within the species' range. Forty, 60 and 80-kilometre buffers were placed around each *in situ* occurrence point. Collectively the *in situ* buffer area serves as the inferred native range of the species or "combined area *in situ*" (CAI40, CAI60, CAI80 respectively). By finding the spatial intersection of CAI within protected areas, protected area coverage was estimated. Results are presented in km^2 and percentage of area covered for 40, 60 and 80-kilometre buffers. The mean average percentage of coverage of all three buffer sizes is also presented (Table 1). The protected area coverage should be considered an estimation, as buffers around *in situ* points are likely to overestimate the distribution range of the target species. Additionally, these buffers might include non-protected habitat where the target species are unlikely to occur.

Table 1. Estimated protected area coverage for *Nothofagus aequilateralis*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Protected area coverage	861 / 11,410 **(8%)**	868 / 13,325 **(7%)**	923 / 14,421 **(6%)**	**(7%)**

Table 2. Estimated area coverage where mining is prohibited for *Nothofagus aequilateralis*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Prohibited mining area coverage	570 / 11,410 **(5%)**	574 / 13,325 **(4%)**	628 / 14,421 **(4%)**	**(5%)**

Within the inferred native range of *N. aequilateralis*, 7% of the land is covered by protected areas (Table 1). *N. aequilateralis* is found in five protected areas (Figure 1): Rivière Bleue Provincial Park, Pic du Pin Botanical Reserve, Montagne des Sources National Park, Yaté Barrage Botanical Reserve and Thy Custom Reserve (Baldwin, 2018).

Sustainable management of land

It should be noted that not all protected areas in New Caledonia are protected from mining activities. Mining appears to be prohibited in Rivière Bleue, Pic du Pin, Montagne des Sources, Yaté Barrage, but not Thy forest, which is a Custom Reserve in proximity to St Louis, which has undergone historical mining and suffered from recent fires (Jaffré et al., 1996; S. McCoy pers. comm., 2022). Figure 2 shows known *in situ* occurrence points of *N. aequilateralis* in relation to areas where mining is prohibited.

Given the specific threat from mining activities in New Caledonia, a second spatial analysis was carried out to estimate the coverage of areas where mining is prohibited, by finding the spatial intersection of CAI within mining prohibited areas. Results are presented in km^2 and percentage of area covered for 40, 60 and 80-kilometre buffers, the mean average percentage of coverage of all three buffer sizes is also presented (Table 2).

Within the inferred native range of *N. aequilateralis*, only 5% of the land is covered by areas where mining is prohibited (Table 2). This is lower than the estimated protected area coverage.

No other sustainable land management initiatives have been found where *N. aequilateralis* occurs.

Population monitoring and/or occurrences surveys

Five permanent plots of *N. aequilateralis* were established between 1991-1996 (Read & Jaffré, 2013) facilitating research focused on the population dynamics of *Nothofagus* forests. Analysis of population size structures suggests the *Nothofagus*-dominated forests are secondary forests that have established after large-scale disturbances, and that moderate to severe disturbance may be necessary to maintain these forests at low-to-mid-elevations in the long term. In the absence of such disturbance, the abundance of *Nothofagus* is likely to decline, with the forest canopy becoming mixed in composition. However, the type (i.e. fire vs cyclone), frequency and intensity of disturbance are likely to be critical in their effect on forest composition and need further investigation.

Research

Published research with a direct conservation-focus is somewhat limited. However, there are a number of important studies that could offer insights into the conservation and restoration of *N. aequilateralis* on the ultramafic soils in New Caledonia. These include research on the population dynamics of *Nothofagus* forests and monodominance (Demenois et al., 2016; Read & Jaffré, 2013; Read et al., 2018), ectomycorrhizal associations (Carriconde et al., 2019), soil microbial diversity in *N. aequilateralis* dominated forests (Gourmelon et al., 2016), and fungal inoculations for improving soil aggregate stability in ultramafic soils in New Caledonia (Demenois et al., 2017).

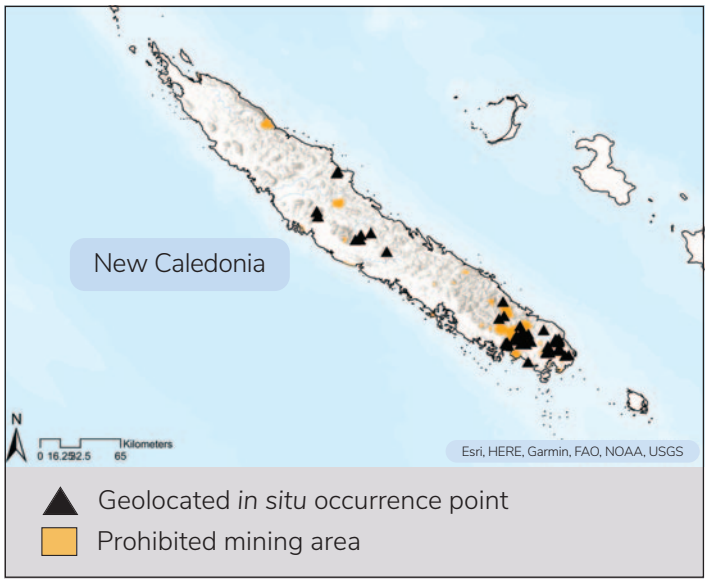

Figure 2. Documented *in situ* occurrence points for *Nothofagus aequilateralis* and prohibited mining areas in New Caledonia (Prohibited mining areas are from Plateforme de Téléchargment, Government of New Caledonia (GOUV.NC, 2021).

Education, outreach and/or training

There are no known initiatives in place for *N. aequilateralis*.

Species protection policies

There are species protection policies in place for all *Nothofagus* species in the Northern Province of New Caledonia. In the Southern Province, *Nothofagus* forest habitat is protected by the Southern Province Environmental Code by its rainforest heritage habitat status (Délibération n° 25-2009/APS, 2009), providing fire management prioritisation and controls against logging.

Priority Conservation Actions

Results of the Conservation Activity Questionnaire

There were no responses related to *N. aequilateralis* in the Conservation Activity Questionnaire.

Conclusion and Recommendations

The following conclusion and recommendations have been compiled by synthesising the research, data and analysis collated in this report, as well as via expert consultation.

This species is listed as Near Threatened on the IUCN Red List (Baldwin et al., 2018). The major threat is mining and the majority of this species' range does not fall within protected areas. There are also threats from fire and climate change. There are no ex *situ* collections of *N. aequilateralis* and no known *in situ* conservation activities.

In situ and ex *situ* conservation efforts for all *Nothofagus* species from New Caledonia are constrained by practical issues with collecting seeds and seedling establishment. Research and observations suggest *N. aequilateralis* seedlings are strongly mycorrhizal, which may reflect a need for ectomycorrhizal association for successful breeding programmes. An initial focus on facilitating seed collection of wild populations is therefore recommended followed by research into seedling establishment (potentially with ectomycorrhizal inoculations) to help facilitate potential breeding programmes.

Priority areas of research should focus on the phenological sequence of seed production, and fungal inoculations required for seedling establishment (for the latter, see related work focusing on some other endemic taxa from ultramafic substrates in New Caledonia with known ectomycorrhizal associations (e.g. Demenois et al., 2017)).

Practical initiatives could include developing seed collecting methodologies, training, and programmes to facilitate collecting of wild populations. Prony Resources Nursery has a well-established breeding and reintroduction programme in place for other native taxa from New Caledonia - these conservation initiatives would aim to facilitate similar programmes for *N. aequilateralis*.

Establishing genetically comprehensive ex *situ* collections of the species is also recommended. This could potentially be via seed banking, though there have been no studies to date on tropical *Nothofagus* species seed storage characteristics, hence seed collection would need to be supported by research into this. The creation of ex *situ* living collections would therefore be recommended in the interim, once constraints with seedling establishment are overcome and propagation protocols developed.

Finally, it is recommended for research into the potential threat of fire to specific populations to be undertaken, with a view to prioritising seed collecting in populations at highest risk.

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Nothofagus alessandrii Espinosa

Synonym(s): *Fuscospora alessandrii* (Espinosa) Heenan & Smissen. **Common name(s):** Ruil

IUCN Red List Category and Criteria: Endangered (EN) B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v)

Species profiles authors: Paula Moraga Stefanini, University of Concepción, Chile; Olivia Steed-Mundin, Wakehurst, Royal Botanic Gardens, Kew, UK; Dan Crowley, Westonbirt, The National Arboretum, UK, BGCI; Itxaso Quintana, BGCI; Cristian Echeverria, University of Concepción.

Suggested citation: Moraga Stefanini, P., Steed-Mundin, O., Crowley, D., Quintana I., Echeverria, C. (2024). *Nothofagus alessandrii* Espinosa. In Steed-Mundin, O., Crowley, D., Quintana, I., & Wenham, J. *Conservation Gap Analysis of* Nothofagus. Wakehurst, UK: Royal Botanic Gardens, Kew.

Distribution and Ecology

Endemic to the Chilean coastal mountain range in the Maule Region from Curepto (35° 04'S) to Pelluhue (35° 50'S) (Figure 1), *Nothofagus alessandrii* has a fragmented and restricted distribution with a latitudinal range of 100 km (Echeverría et al., 2022). It occurs from 150 to 500 m a.s.l. on south, south west, and south east exposures (Barstow et al., 2020; Olivares et al., 2005). It occupies an area of 314 ha in 305 forest stands, with a mean average size of 1.03 ha. These are distributed across 15 localities in the municipalities of Curepto, Constitución, Empedrado and Chanco (Santelices et al., 2012).

N. alessandrii is a shade-intolerant deciduous tree that grows to 30 m tall, occupying the upper and lower canopy in forests. It often forms nearly pure stands, though can occur in mixed forests following fire (González et al., 2022). It commonly inhabits ravines, micro-watersheds and intermontane valleys, in a microclimate that is more humid and temperate than the characteristic Mediterranean climate of the Central Zone of Chile (Olivares et al., 2005; San Martín, 2022). Co-occurring species include *Nothofagus glauca* (forming coastal maulino forest), *Cryptocarya alba*, *Aextoxicon punctatum* and *Gevuina avellana* (San Martín, 2022).

Nothofagus alessandrii, Chile (Pedro Garrido)

Nothofagus alessandrii, Chile (Pedro Garrido)

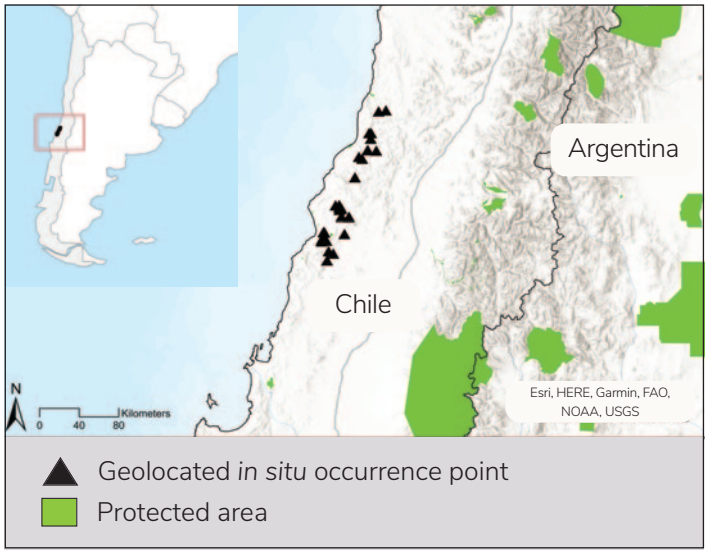

Figure 1. Documented *in situ* occurrence points for *Nothofagus alessandrii* and Terrestrial Protected Areas in Chile (Terrestrial Protected Areas are from UNEP-WCMC & IUCN 2022, Protected Planet).

Threats to Wild Populations

Threats to wild populations were identified by reviewing *The Red List of* Nothofagus (Baldwin et al., 2018), expert consultation, literature review, and via the Conservation Activity Questionnaire. A comprehensive list of all threats identified for *N. alessandrii* is available in Appendix C. From the questionnaire, 13 respondents from a total of 12 organisations provided threat data for *N. alessandrii* (Figure 2).

The threats explored below are considered the current most significant threats, categorised into high and medium impact. This categorisation has been informed by the sources listed above and has been reviewed by regional experts.

High Impact Threats

Invasive species: Invasive species competition was the second most common threat recorded by respondents to the Conservation Activity Questionnaire (Figure 2). *N. alessandrii* populations now only occur within a matrix of *Pinus radiata* plantations, and this exotic species has also invaded the remnant forests of *N. alessandrii* themselves (Gómez & Bustamante, 2022; Ministerio del Medio Ambiente, 2018). The establishment of *P. radiata* in the remnant forests is enabled by a combination of anthropogenic disturbances such as tree cutting and cattle activity, the small and irregular patches of forests exposed to border interactions with the plantations, and seed availability of the neighbouring exotic plants (Bustamante & Castor, 1998). Large-scale forest fires in 2017 led to a massive invasion of *P. radiata* seedlings in *N. alessandrii* remnants (Gómez & Garrido, 2018; Gómez & Bustamante, 2022). Other invasive species such as *Eucalyptus globulus* and *Acacia dealbata* are also colonising the remnant populations of *N. alessandrii* (Ministerio del Medio Ambiente, 2018).

Disturbance regime modification including fire: Disturbance regime modification was the third most common threat reported in the Conservation Activity Questionnaire (Figure 2). Increased frequency and intensity of fire is creating a direct and significant threat to the fragmented populations of *N. alessandrii*, particularly during summer as a result of the high temperatures and low humidity within its range (Barstow et al., 2020; Ministerio del Medio Ambiente, 2018). One of the largest forest fires that occurred in the central-southern zone of Chile in 2017 affected more than 50% of the area in which *N. alessandrii* occurs (i.e. 172 hectares of the 314 hectares remaining in 2008) (Ministerio del Medio Ambiente, 2018; Valencia et al., 2018).

Land use change - agriculture and/or silviculture: Agriculture, silviculture and/or ranching was the fourth most common threat to the species identified by respondents to the Conservation Activity Questionnaire (Figure 2). *N. alessandrii* is severely threatened by habitat loss as a consequence of forest clearance for agriculture and silviculture (Barstow et al., 2020). Forest plantations have led to a progressive loss and fragmentation of the remaining populations of *N. alessandrii* in the last five decades, and these fragments are now surrounded by a matrix of forestry plantations (Echeverria et al., 2022).

Extremely restricted population and/or genetic diversity loss: Populations of the species are highly fragmented. From 1981 to 1991, 57% of the remaining forest disappeared at a rate of 8% per year (Bustamante & Castor, 1998). In the following years, from 1991 to 2008, 12% of the remaining forest fragments were lost, with an annual deforestation rate of 0.74% (Santelices et al., 2012). The fragility of the populations makes the species one of those most at risk of extinction if current trends continue (Echeverría et al., 2022). Fragmentation also has the potential to strongly decrease gene flow between populations (Mora & Torres, 2022). Consistent with this, introgression and inbreeding was one of the threats identified by respondents to the Conservation Activity Questionnaire (Figure 2).

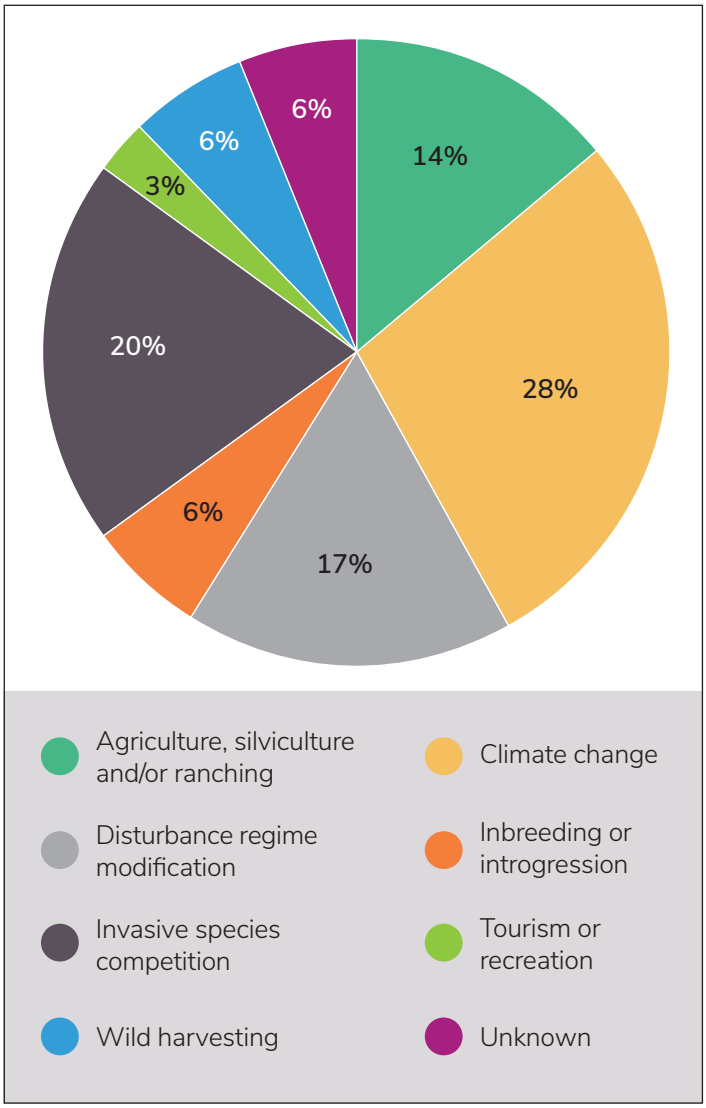

Figure 2. Threats to *Nothofagus alessandrii* reported by respondents to the Conservation Activity Questionnaire. The chart shows the proportion of responses relating to each threat. The total number of respondents was 13, from 12 organisations. Only threat categories that were reported are shown.

Medium Impact Threats

Climate change: Climate change was the most commonly identified threat to the species in the Conservation Activity Questionnaire (Figure 2). Changes in environmental conditions with increases in temperature and longer periods of drought may negatively impact this species, as it does not have its origins in the Mediterranean zone (Santibáñez & Santibáñez, 2022). Furthermore, climate change is associated with a higher frequency and intensity of forest fires across the distribution of *N. alessandrii* (Echeverría et al., 2022; Santelices et al., 2018).

Conservation Activities

In 2021 and 2022 accession data were requested from *ex situ* collections for all *Nothofagus* species that were identified as threatened or Near Threatened in *The Red List of* Nothofagus (i.e. 'target species') (Baldwin et al., 2018). A total of 21 organisations reported having *ex situ* collections of *N. alessandrii* (Table 1).

In addition, past, present and planned conservation activities for these species were also examined through literature review, expert consultation, and conduction of a questionnaire. Conservation Activity Questionnaires were sent out between 2021 and 2022. Twelve organisations reported being actively involved in several conservation activities relating to *N. alessandrii* (Figure 5).

Ex situ collections reported 2021–2022

There are 53 *ex situ* accessions including living plants and seeds held at 21 organisations (Table 1). These include 150 plants in living collections (Figure 3), 2115 seeds belonging to three seed accessions (Table 2) and more than 4000 plants in nurseries to be used in reintroduction programmes (Table 1). Of the 21 organisations holding *ex situ* collections, seven of them are in the country of origin.

Nothofagus alessandrii, Heulón, Chile (Paulina Hechenleitner)

Table 1. Results from the 2021-2022 *ex situ* survey for *Nothofagus alessandrii*.

Total	Number of organisations reporting *ex situ* collections	21
	Number of accessions in *ex situ* collections	53
Living collections	Number of accessions in *ex situ* living collections	50
	Number of plants in *ex situ* collections	150 in living collections 4047 in nurseries
	Percentage of *ex situ* plants of wild origin	85%
	Percentage of wild origin plants with known locality	98%
Seed collections	Number of accessions in *ex situ* seed collections	3
	Number of seeds in *ex situ* seed collections	2115
	Percentage of *ex situ* seed accessions of wild origin	100%
	Percentage of wild origin *ex situ* seed accessions with known locality	100%

Table 2. Quantity and origin of *Nothofagus alessandrii* seeds in *ex situ* collections.

Ex situ seed accession	Quantity of seed	Provenance	Locality data
1	555	Wild	Coordinates provided
2	560	Wild	Coordinates provided
3	1000	Wild	Coordinates provided

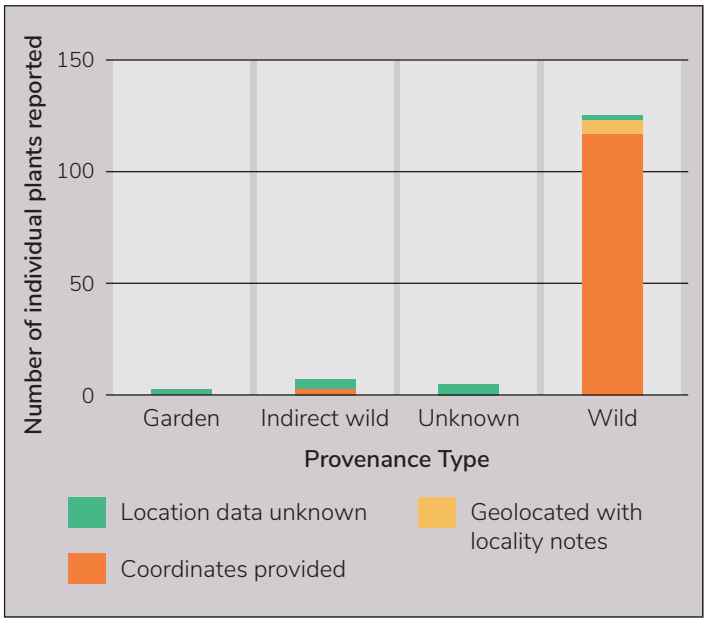

Figure 3. Quantity and origin of *Nothofagus alessandrii* plants in *ex situ* living collections.

Estimated *ex situ* representation

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* living and seed collections. Forty, 60 and 80-kilometre buffers were placed around each *in situ* occurrence point and the source locality of each *ex situ* accession (Figure 4). Collectively the *in situ* buffer area serves as the inferred native range of the species, or "combined area *in situ*" (CAI40, CAI60, CAI80 respectively). The *ex situ* buffer areas represent the native range "captured" in *ex situ* collections or "combined area *ex situ*" (CAE40, CAE60, CAE80 respectively). Geographic coverage of *ex situ* collections was estimated by dividing CAE by CAI, and ecological coverage was estimated by dividing the number of terrestrial ecoregions present in CAE by the number of ecoregions in CAI. Results are presented in Tables 3 & 4 in km^2 and as a percentage of area covered. The mean average percentage of coverage of all three buffer sizes is also presented. It should be noted these results should be considered an estimation.

Table 3. Estimated *ex situ* representation of living plant collections for *Nothofagus alessandrii*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Geographical coverage	10,786 / 12,754 **(85%)**	17,216 / 19,569 **(88%)**	24,845 / 27,643 **(90%)**	**87%**
Ecological coverage	2 / 2 **(100%)**	2 / 2 **(100%)**	2 / 2 **(100%)**	**100%**

Table 4. Estimated *ex situ* representation of seed collections for *Nothofagus alessandrii*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Geographical coverage	5,568 / 12,754 **(44%)**	9,945 / 19,569 **(51%)**	15,357 / 27,643 **(56%)**	**50%**
Ecological coverage	2 / 2 **(100%)**	2 / 2 **(100%)**	2 / 2 **(100%)**	**100%**

Due to the restricted and fragmented distribution of *Nothofagus* species in Chile, particularly for *N. macrocarpa* and *N. alessandrii*, the size of the buffers might lead to an overestimation of both *in situ* occurrence and *ex situ* representation. Even though a coarse spatial scale aids the identification of gaps in *ex situ* collections, studies at a finer spatial scale are recommended for more specific results.

The results showed 150 *N. alessandrii* plants in living collections, representing 87% geographic coverage and 100% ecological coverage (Table 3; Figure 4A). Many of the young plants in cultivation are traceable to the conservation collections made by Royal Botanic Garden, Edinburgh's International Conifer Conservation Programme (Christian, 2020), who collected material from two of the wild localities and distributed 142 plants to *ex situ* 'safe sites' (Baldwin et al., 2018). Given these collections were made from two localities, it is likely that many plants in collections are closely related.

This study also found three seed collections for this species, representing 50% geographic coverage and 100% ecological coverage (Table 4). The southern populations of the species are the only populations represented in seed collections (Figure 4B).

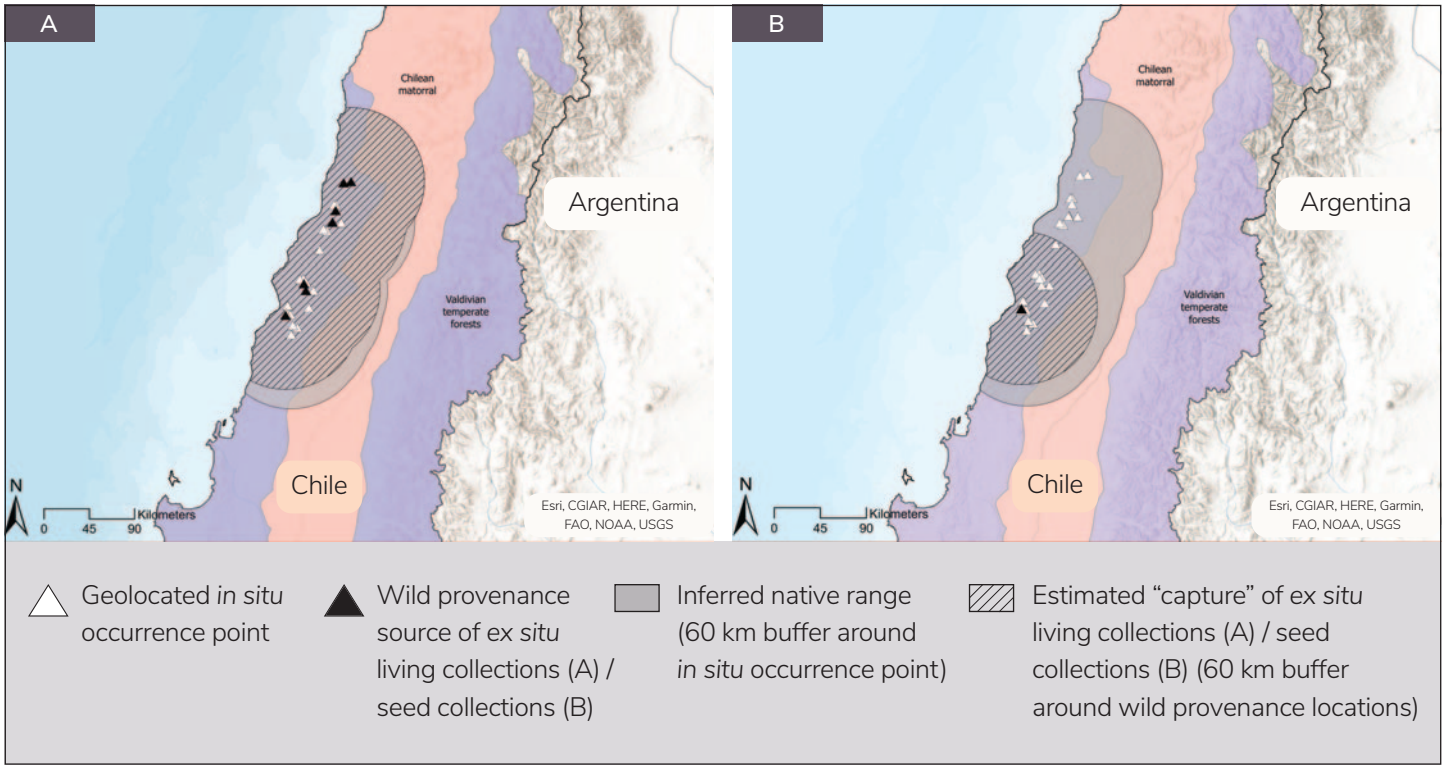

Figure 4. *Nothofagus alessandrii in situ* occurrence points and *ex situ* source localities for A) living collections and B) seed collections. Terrestrial Ecoregions of the World for Chile (Olson et al., 2001) are coloured and labelled. A 60km buffer has been placed around *in situ* occurrence points to infer the native range of *N. alessandrii*. A 60km buffer has been placed around the *ex situ* source location to infer the native range captured in *ex situ* collections.

Wild collecting and/or *ex situ* curation

In the Conservation Activities Questionnaire, three organisations reported seed banking activities, whilst six organisations reported that they were collecting and distributing germplasm of *N. alessandrii*, and eight organisations reported they were carrying out conservation horticulture (Figure 5). Organisations in Chile including The National Forestry Corporation (CONAF) and The Chilean Forestry Institute (INFOR) as well as private forestry companies, collect and distribute germplasm of this species. This provides the seeds necessary to supply conservation activities such as restoration and reforestation. However, it is important to note that most of the seeds collected from such projects come from a few localities. There is a known lack of ecological representation in *ex situ* collections. A project led by Universidad de Concepción is currently being undertaken to collect seeds from each genetic group to improve *ex situ* representation. Laguna Torca National Reserve also has an *ex situ* collection of 150 individuals of *N. alessandrii* of unknown provenance (Members of Maule region´s National Forestry Corporation pers. comm., 2022).

Propagation and/or breeding programmes

Medium scale propagation of *N. alessandrii* has been carried out by INFOR, CONAF and some forest companies, with the goal of contributing to restoration plantings in areas including Los Ruiles National Reserve (CONAF, 2014) and other degraded sites. Also, researchers from the University of Concepción, University of Talca, University Católica del Maule, University of Chile, Fundación El Arbol and INFOR, have recently initiated a conservation project that includes the propagation of *N. alessandrii* for restoration actions on private properties where this species occurs (C. Echeverria pers. comm., 2022). Forestry companies collect seeds to reproduce and propagate this species for use in ecological restoration actions (P. Garrido pers. comm., 2022).

Reintroduction, reinforcement and/or translocation

Four organisations reported carrying out population reinforcement or reintroductions in the Conservation Activities Questionnaire (Figure 5). Enrichment and reintroduction actions have been carried out on small plots on land owned by private landowners with the support of Fondation Franklinia, the Global Trees Campaign and BGCI, with plants produced for reintroduction on these plots (P. Gómez pers. comm., 2022). Also, INFOR propagates plants of this species to reintroduce them in the sites where the seeds were collected. In addition, reinforcement plantings are taking place between isolated stands of *N. alessandrii* in Los Ruiles National Reserve in the Maule region (Members of Maule region´s National Forestry Corporation pers. comm., 2022).

Nothofagus alessandrii, immature fruit, Wakehurst (Olivia Steed-Mundin)

Table 5. Estimated protected area coverage for *Nothofagus alessandrii*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Protected area coverage	29 / 12,754 **(0.2%)**	29 / 19,569 **(0.2%)**	34 / 27,643 **(0.1%)**	**0.2%**

Land protection

A second spatial analysis was conducted to estimate the protected area coverage within the species' range, by finding the spatial intersection of CAI within protected areas. Results are presented in km^2 and percentage of area covered for 40, 60 and 80-kilometre buffers. The mean average percentage of coverage of all three buffer sizes is also presented (Table 5). The protected area coverage should be considered an estimation, as buffers around *in situ* points are likely to overestimate the distribution range of the target species. Additionally, these buffers might include unprotected habitat where the target species are unlikely to occur.

Within the inferred native range of *N. alessandrii*, only 0.2% of the land is covered by protected areas (Table 5). The species occurs in Los Ruiles National Reserve in the Maule Region (Figure 1). This state reserve is the only area within the National System of State Protected Areas (SNASPE) that protects *N. alessandrii* and includes two main properties, one called El Fin in the municipality of Empedrado, and Los Ruiles located in the municipality of Chanco. The remaining distribution of the species is found in unprotected fragments on south-facing slopes owned by private landowners and forestry companies (Torres et al., 2007).

Sustainable management of land

In the Conservation Activities Questionnaire six organisations reported carrying out habitat restoration and three reported protecting and/or managing habitat (Figure 5).

In Los Ruiles National Reserve for example, which is surrounded by a matrix of forest plantations of exotic species such as *P. radiata* and *Eucalyptus* species (CONAF, 2014), the invasion of *P. radiata* from the borders is managed on a very small scale by mechanical and chemical methods. In addition, in private properties El Desprecio, Porvenir and La Montaña, the invasion of *P. radiata* in *N. alessandrii* stands is being managed on a small scale (due to the lack of resources), to control the regeneration of invasive species at high densities (P. Garrido & P. Gómez pers. comm., 2022). Furthermore, forestry companies are carrying out restoration initiatives, entitled Los Hualos de Loanco and Ruiles de Empedrado, located in the Maule region (CMPC, 2018).

Population monitoring and/or occurrence surveys

This activity was reported by four organisations in the Conservation Activity Questionnaire (Figure 5). There are approximately 11 monitoring plots currently operating in private properties in the locations of Curepto, Constitución and Empedrado, aimed at assessing the regeneration and establishment of this species (P. Gómez pers. comm., 2022). The regeneration and establishment of *N. alessandrii* post-fire and the invasion of *P. radiata* are also being monitored in permanent plots located in properties owned by forestry companies in the Maule region (CMPC, 2018). INFOR is developing a programme to monitor seedlings of *N. alessandrii* within Los Ruiles National Reserve to obtain data on the viability of the seeds (M. González pers. comm., 2022). Additionally, monitoring of the species' regeneration is being carried out by CONAF in Los Ruiles National Reserve (Members of Maule region's National Forestry Corporation pers. comm., 2022).

Research

In the Conservation Activity Questionnaire six organisations reported that they are currently carrying out research activities associated with *N. alessandrii* (Figure 5). Furthermore, a variety of research has been conducted into this species over the last three decades, including a number of studies associated with restoration actions such as:

- plant production and establishment techniques for effective restoration (Acevedo et al., 2020)
- seed supply of *N. alessandrii* with genetic considerations (Santelices et al., 2019)
- propagation and seedling cultivation (Santelices et al., 2009)
- analysis of current and potential distribution areas for the species (Santelices et al., 2012)
- impacts of land use change on spatial patterns of fragmentation of forests (Echeverría et al., 2022)
- post-fire regeneration from seed (Gómez et al., 2022).

Education, outreach, and/or training

The Recovery, Conservation and Management Plan of *N. alessandrii* mandated by the Ministry of Environment (Ministerio del Medio Ambiente, 2018) includes a series of activities linked to education. These include workshops with small landowners who own individuals of *N. alessandrii* to promote the conservation of the species. One of the activities already carried out is the construction of an interpretative trail inside a *N. alessandrii* forest owned by small landowners in the community of Empedrado. The purpose of this trail is to raise awareness of the species' value (Ministerio del Medio Ambiente, 2020; P. Gómez pers. comm., 2022). In Los Ruiles National Reserve, talks and guided walks are provided, where professionals highlight the importance of this protected area in conserving the Maulino Forest ecosystem and its species (Members of Maule region's National Forestry Corporation pers. comm., 2022).

Under the Ministry of Environment funded project, 'Recovery of coastal Maulino forest with presence of Ruil in the municipality of Empedrado', educational activities were carried out in schools, including workshops and talks on the biodiversity of *N. alessandrii* forests, field trips, reforestation actions and photographic exhibitions (P. Garrido pers. comm., 2022).

It should also be noted that public awareness or education was one of the most common activities reported in the Conservation Activity Questionnaire for this species, with eight organisations carrying out initiatives associated with it (Figure 5).

Species protection policies

Four organisations reported implementing protection policies or regulations for this species in the Conservation Activities Questionnaire (Figure 5).

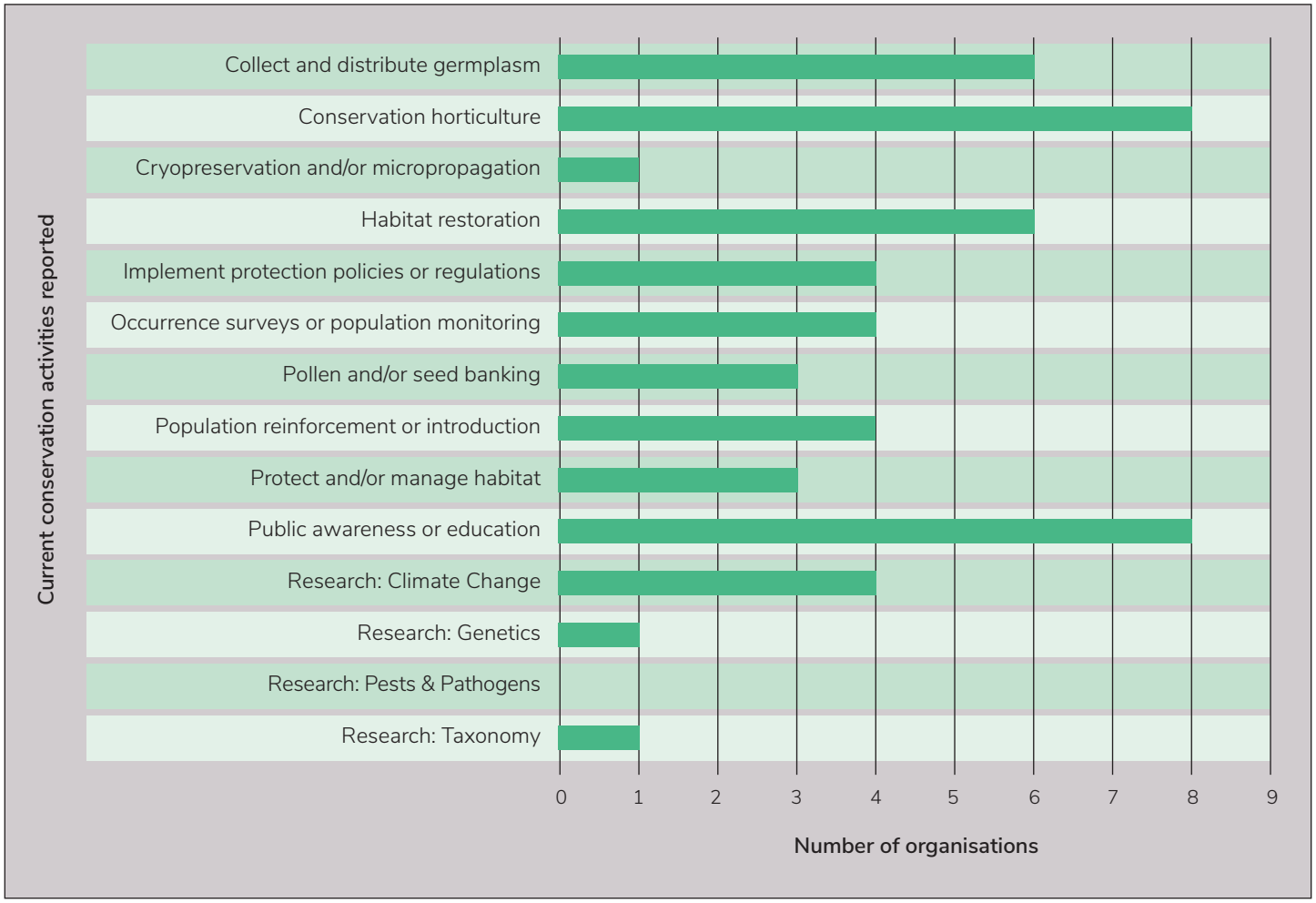

Figure 5. Number of organisations reporting specific conservation activities for *Nothofagus alessandrii* in the Conservation Activity Questionnaire. Total number of organisations who reported conservation activities for *N. alessandrii* was 12.

In 1995, the Ministry of Agriculture enacted the Decree Law No. 13 which declares species including *N. alessandrii* as Natural Monuments (Ministerio de Agricultura, 1995). This legal instrument declares that cutting or exploitation of the species is only authorised for scientific purposes, to build public works or for national defence, and states the need to develop management plans containing actions to conserve and improve the conservation status of these species (Ministerio de Agricultura, 1995).

Under Chile's Regulations for the Classification of Wild Species (RCE), *N. alessandrii* was categorised as Endangered and Rare (Ministerio Secretaría General de la Presidencia, 2007).

In 2018, the Recovery, Conservation and Management Plan of *N. alessandrii* was developed, which represents an administrative instrument of Law 19.300 on General Bases of the Ministry of Environment that contains actions, measures and procedures to better recover and conserve this endangered species (Ministerio del Medio Ambiente, 2018). Although this is a normative instrument (i.e. actions within must be carried out), there is little funding available to implement all the actions. Consequently, only some of them have been actioned (R. Santelices & P. Gómez pers. comm., 2022).

Nothofagus alessandrii, Reserva Nacional Los Ruiles, Chile (Nicolás Lavandero)

Priority Conservation Actions

Results of the Conservation Activity Questionnaire

A Conservation Activity Questionnaire was sent to identify priority conservation actions that should be undertaken for the future conservation of *N. alessandrii*. There were 14 respondents from 13 organisations. Protection and/or management of habitat, public awareness or education and habitat restoration were highlighted most frequently as priority actions that are needed for the future conservation of the species (Figure 6).

Conclusion and Recommendations

The following conclusion and recommendations have been compiled using the research, data and analysis collated in this report, as well as through expert consultation.

N. alessandrii is an Endangered species (Baldwin et al., 2018), distributed in extremely small and fragmented populations which are significantly threatened in the wild by invasive species, fire, and climate change. In addition, extant populations largely fall outside of the National System of State Protected Areas. There are important conservation activities already associated with this species, which are helping to conserve it both *in situ* and *ex situ*. Considering the continued fragility of the populations and the risk of extinction to this species, it is paramount that these continue, with supplementary focus in the following areas.

Given the impact from 2017 fires, it is particularly important to assess and update the current distribution and status of wild populations of *N. alessandrii*, which will help inform future conservation actions and updates to the species' IUCN Red List assessment. In addition, since large extents of *N. alessandrii* forest have been invaded by *P. radiata* post-fire, it is also recommended that significant focus and resources be assigned to implement large-scale control, habitat protection and support of natural regeneration of *N. alessandrii* (P. Garrido pers. comm., 2022). Considering the highly fragmented populations of this species, it is recommended to apply recent studies on population genetics to inform collection strategies for any potential restoration projects and check for inbreeding (Mora & Torres, 2022).

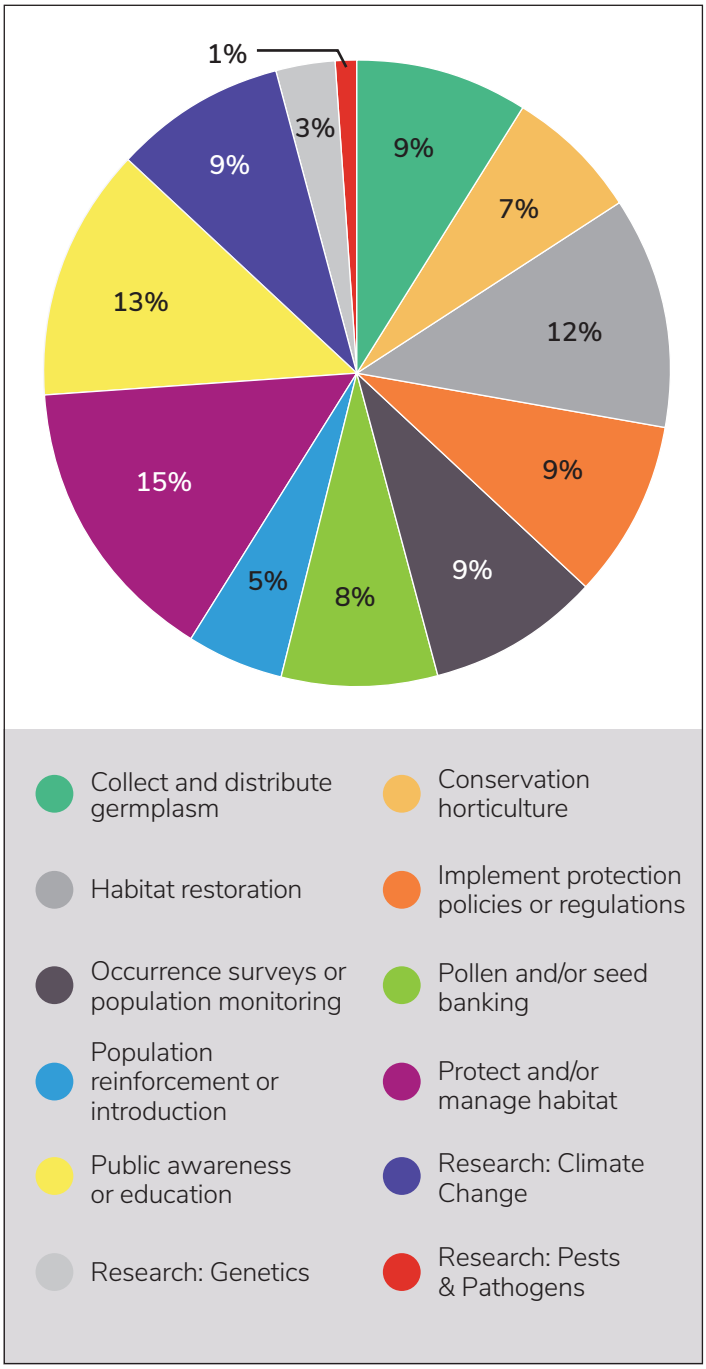

Figure 6. Priority conservation actions needed for the future conservation of *Nothofagus alessandrii* reported by respondents to the Conservation Activity Questionnaire. The chart shows the proportion of responses identifying conservation actions as a priority. Only action categories that were identified are shown. The total number of respondents was 14, from 13 organisations.

Given climate change is affecting seed production and seedling establishment, there is also a need to research the impacts of climate change on the dynamics of phenology, seed production, regeneration and establishment of the species (P. Garrido & R. Santelices pers. comm., 2022).

In situ conservation and research should be supported by genetically representative *ex situ* collections, especially given the threat to extant wild populations. The analysis presented in this report highlighted a number of localities that are not represented at all in seed collections so these should be prioritised.

Finally, it should be noted that in 2022 a conservation project funded by Fondation Franklinia was initiated to target the conservation, ecological restoration and capacity building to benefit the three threatened *Nothofagus* species native to South America, including *N. alessandrii*. The project is led by Universidad de Concepción, working with Chilean institutions Universidad de Chile, Instituto Forestal (INFOR), Universidad Católica del Maule, Universidad de Talca, INIA and Club del Árbol de Talca, with support from BGCI. Some of the recommendations noted here will be actioned as a result of this initiative.

Nothofagus alessandrii, Heulón, Chile (Paulina Hechenleitner)

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Nothofagus baumanniae (Baum.-Bod.) Steenis

Synonym(s): *Trisyngyne baumanniae* Baum.-Bod. **Common name(s):** unknown

IUCN Red List Category and Criteria: Endangered (EN) B1ab(i,ii,iii,v)+2ab(i,ii,iii,v)

Species profiles authors: Olivia Steed-Mundin, Wakehurst, Royal Botanic Gardens, Kew, UK; Dan Crowley, Westonbirt, The National Arboretum, UK, BGCI; Itxaso Quintana, BGCI; Stephane McCoy, Prony Resources, New Caledonia; Fabian Carriconde, New Caledonian Agronomic Institute (IAC).

Suggested citation: Steed-Mundin, O., Crowley, D., Quintana, I., McCoy, S., & Carriconde, F. (2024). *Nothofagus baumanniae* (Baum.-Bod.) Steenis. In Steed-Mundin, O., Crowley, D., Quintana, I., & Wenham, J. *Conservation Gap Analysis of* Nothofagus. Wakehurst, UK: Royal Botanic Gardens, Kew.

Distribution and Ecology

Endemic to New Caledonia, *Nothofagus baumanniae* has a very restricted distribution, found at three localities above 800 m a.s.l. towards the South of Grand Terre: Mont Mou, Mont Sindoa and Massif du Kouakoué (Figure 1; Read et al., 2005; Baldwin, 2018).

N. baumanniae is a small evergreen tree, growing to 5-10 m tall at the highest altitudes (Read & Hope, 1996). It occurs on ultramafic soils overlying peridotite, in stunted cloud forest on moss-humus accumulations (Read et al., 1995; Read & Hope, 1996; S. McCoy pers. comm., 2022).

Nothofagus baumanniae, New Caledonia (Benôit Henry)

Figure 1. Documented *in situ* occurrence points for *Nothofagus baumanniae* and Terrestrial Protected Areas in New Caledonia (Terrestrial Protected Areas are from UNEP-WCMC & IUCN 2022, Protected Planet).

As with other tropical *Nothofagus*, it can form small, monodominant stands (Read et al., 1995), and may require large-scale disturbance to enable regeneration (Baldwin, 2018). However, it is not clear whether high-elevation forests are dependent on disturbance to the same degree as are *Nothofagus*-dominated forests at lower altitudes (J. Read pers. comm., 2022). *N. baumanniae* forests are usually rich in bryophytes and filmy ferns, whilst co-occurring woody species include *Metrosideros porphyrea* and *Strasburgeria robusta* (Veillon, 1993).

Threats to Wild Populations

Threats to wild populations were identified by reviewing *The Red List of* Nothofagus (Baldwin et al., 2018), expert consultation and literature review. Because there is limited published research on threats to *N. baumanniae* specifically, the information below largely refers to *Nothofagus* species in New Caledonia in general. No threats for *N. baumanniae* were reported via the Conservation Activity Questionnaire.

The threats explored below are considered the current most significant threats, categorised into high and medium impact. This categorisation has been informed by the sources listed above and have been reviewed by regional experts.

High Impact Threats

Disturbance regime modification including fire: The IUCN Red list identified fire as the greatest threat to *N. baumanniae* (Baldwin, 2018). Higher temperatures and sporadic rainfall are making fires more frequent at higher altitudes in New Caledonia (Baldwin, 2018; S. McCoy pers. comm., 2022), including on the ultramafic massifs (Gomez et al., 2015; Jaffré et al., 2010), where *Nothofagus* species are generally found. Populations of *N. baumanniae* are particularly vulnerable to fire because of their very limited distribution. However, there does not appear to be any published information on how fire is affecting *N. baumanniae* specifically.

Medium Impact Threats

Climate change: *Nothofagus* species in general have poorly dispersed seeds and specialist soil requirements which limits their ability to migrate to higher altitude in response to climate change (Read & Hope, 1996; Baldwin et al., 2018). *N. baumanniae* is particularly threatened because it is already confined to the uppermost altitudes in New Caledonia, which limits its migratory capacity further (Read & Hope, 1996).

Development, mining, and/or roads: For plant species which occur on the metal-rich, ultramafic soils of New Caledonia, nickel mining poses a generalised threat. This threat has increased over the last 20 years, with the development of techniques enabling extraction from low-grade deposits that were previously unexploited (Baldwin et al., 2018; Jaffré et al., 2010).

Nothofagus baumanniae, New Caledonia (Benôit Henry)

Conservation Activities

In 2021 and 2022, accession data were requested from *ex situ* collections for all *Nothofagus* species that were identified as threatened or Near Threatened in *The Red List of* Nothofagus (i.e. 'target species') (Baldwin et al., 2018). There were no *ex situ* accessions of *N. baumanniae* reported.

In addition, past, present and planned conservation activities for these species were examined through literature review, expert consultation and via a questionnaire. A Conservation Activity Questionnaire was sent out in 2021 and 2022. For *N. baumanniae*, as with all *Nothofagus* species from New Caledonia, no conservation activities were reported. Information on conservation activities for this species has therefore been provided by expert consultation, research papers and other published sources.

Ex situ collections reported 2021–2022

No *ex situ* collections were reported.

Estimated *ex situ* representation

No *ex situ* collections were reported.

Wild collecting and/or *ex situ* curation

There are currently no known wild collecting activities associated with *N. baumanniae*. Opportunities for wild collecting are limited by the irregularity of fruiting, with mast years (e.g. 1996) followed by years of limited fruiting in a phenological sequence which is not well understood (S. McCoy pers. comm., 2022). In addition, *N. baumanniae* is only found in remote sites at high altitude which makes access for monitoring and collecting challenging. It should also be noted that no research appears to have been carried out on the seed storage characteristics of tropical *Nothofagus* species.

Propagation and/or breeding programmes

Breeding programmes are severely limited by the difficulties with seed collection (see previous section). There are no known breeding programmes.

Reintroduction, reinforcement and/or translocation

There does not appear to have been any attempted reintroductions of *N. baumanniae* in New Caledonia. It is possible that, like *Nothofagus aequilateralis* (which also occurs on ultramafic soils), it may require ectomycorrhizal associations for successful seedling establishment.

Land protection

A spatial analysis was conducted to estimate the protected area coverage within the species' range. Forty, 60 and 80-kilometre buffers were placed around each *in situ* occurrence point. Collectively the *in situ* buffer area serves as the inferred native range of the species or "combined area *in situ*" (CAI40, CAI60, CAI80 respectively). By finding the spatial intersection of CAI within protected areas, protected area coverage was estimated. Results are presented in km^2 and percentage of area covered for 40, 60 and 80-kilometre buffers. The mean average percentage of coverage of all three buffer sizes is also presented (Table 1). The protected area coverage should be considered an estimation, as buffers around *in situ* points are likely to overestimate the distribution range of the target species. Additionally, these buffers might include non-protected habitat where the target species are unlikely to occur.

Within the inferred native range of *N. baumanniae*, 11% of the land is covered by protected areas (Table 1). This includes Mont Mou and Kouakoué (Figure 1).

Table 1. Estimated protected area coverage for *Nothofagus baumanniae*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Protected area coverage	565 / 5,016 **(11%)**	803 / 6,576 **(12%)**	803 / 7,620 **(11%)**	**11%**

Table 2. Estimated area coverage where mining is prohibited for *Nothofagus baumanniae*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Prohibited mining area coverage	437 / 5,016 **(9%)**	470 / 6,576 **(7%)**	477 / 7,620 **(6%)**	**7%**

Figure 2. Documented *in situ* occurrence points for *Nothofagus baumanniae* and prohibited mining areas in New Caledonia (Prohibited mining areas are from Plateforme de Téléchargment, Government of New Caledonia (GOUV.NC, 2021).

Sustainable management of land

It should be noted that despite falling within protected areas, two of the three localities where this species occurs are not protected from mining activities i.e. Mont Mou or Kouakoué (Jaffré et al., 1996; Jaffré et al., 2010). Figure 2 shows known occurrence points of *N. baumanniae* in relation to areas where mining is prohibited.

Given the specific threat from mining activities in New Caledonia, a second spatial analysis was carried out to estimate the coverage of areas where mining is prohibited, by finding the spatial intersection of CAI within areas where mining is prohibited. Results are presented in km^2 and percentage of area covered for 40, 60 and 80-kilometre buffers. The mean average percentage of coverage of all three buffer sizes is also presented (Table 2).

Within the inferred native range of *N. baumanniae*, just 7% of the land is covered by areas where mining is prohibited (Table 2). This is notably lower than the estimated protected area coverage.

No other sustainable land management initiatives have been found where *N. baumanniae* occurs.

Population monitoring and/or occurrences surveys

There are no known monitoring programmes.

Research

Published research focusing on *N. baumanniae* is particularly limited. However, there are some broader studies, mostly relating to the other *Nothofagus* species in New Caledonia, that can add some potential insights for future conservation and/or reintroduction programmes of *N. baumanniae*. These include studies on: population dynamics of *Nothofagus* forests and monodominance (Read et al., 1995; Read & Jaffré, 2013; Demenois et al., 2016; Read et al., 2018), ectomycorrhizal associations which appear to have a role in the ecological functioning of *Nothofagus* species in ultramafic soils (Jourand et al., 2014), and fungal inoculations for improving soil aggregate stability in ultramafic soils in New Caledonia (Demenois et al., 2017).

Education, outreach and/ or training

There are no known initiatives in place for *N. baumanniae*.

Species protection policies

There are species protection policies for all *Nothofagus* species in the Northern Province. In addition, *Nothofagus* forest habitat in the Southern Province is protected by the Southern Province Environmental Code by its rainforest heritage habitat status (Délibération n° 25-2009/APS, 2009).

Priority Conservation Actions

Results of the Conservation Activity Questionnaire

There were no responses related to *N. baumanniae* in the Conservation Activity Questionnaire.

Conclusion and Recommendations

The following conclusion and recommendations have been compiled by synthesising the research, data and analysis collated in this report, as well as via expert consultation.

This species occurs in only three localities in New Caledonia and is listed as Endangered on the IUCN Red List (Baldwin et al., 2018). The major threats are from fire, mining and climate change. There are no *ex situ* collections and no known conservation activities associated with *N. baumanniae*, whilst the vast majority of this species' range does not fall within protected areas, nor areas where mining is prohibited.

In situ and *ex situ* conservation efforts for all *Nothofagus* species from New Caledonia are constrained by practical issues with collecting seeds and seedling establishment. An initial focus on facilitating seed collection of wild populations is therefore recommended followed by research into seedling establishment (potentially with ectomycorrhizal inoculations) to help facilitate potential breeding programmes.

Priority areas of research should focus on the phenological sequence of seed production and propagation and seedling establishment requirements (including whether fungal inoculations are required for seedling establishment). Given the extremely restricted range of this species (three localities), it would also be beneficial to carry out occurrence surveys and population monitoring to determine the extent of the remaining populations and whether they are declining, lacking recruitment and/or facing other specific threats.

Practical initiatives could include seed-collecting methodologies, training, and programmes to facilitate collecting from wild populations. It should be noted that the relatively small ultimate size of *N. baumanniae* individuals (5 - 10 m tall) makes ground collecting techniques more practical than for other *Nothofagus* species in New Caledonia, however the remote localities of extant populations, will present a challenge.

Establishing genetically comprehensive *ex situ* collections is also recommended. This could potentially be via seed banking, though there have been no studies to date on whether tropical *Nothofagus* species have orthodox seed storage characteristics, hence seed collection would need to be supported by research into this. The creation of *ex situ* living collections would therefore be recommended in the interim, once constraints with seedling establishment are overcome and propagation protocols are developed.

Finally, it is recommended for research into the potential threat of fire to specific populations, with a view to prioritise seed collection in populations at highest risk.

Given that *N. baumanniae* is listed as Endangered and has no conservation activities associated with it, it is recommended that highest priority is given to conservation of this species (and *Nothofagus discoidea*) in New Caledonia.

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Nothofagus codonandra (Baill.) Steenis

Synonym(s): *Trisyngyne codonandra* Baill. **Common name(s):** unknown

IUCN Red List Category and Criteria: Near Threatened (NT) B1ab(v)

Species profiles authors: Olivia Steed-Mundin, Wakehurst, Royal Botanic Gardens, Kew, UK; Dan Crowley, Westonbirt, The National Arboretum, UK, BGCI; Itxaso Quintana, BGCI; Stephane McCoy, Prony Resources, New Caledonia; Fabian Carriconde, New Caledonian Agronomic Institute (IAC).

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Distribution and Ecology

Endemic to New Caledonia, *Nothofagus codonandra* occurs in a number of localities across Grande Terre (Figure 1). It is most common towards the south, although fragmented populations extend north toward Voh (Baldwin, 2018). It is usually found above 600 m a.s.l., but also occurs as low as 150 m a.s.l. (Read et al., 2005).

N. codonandra is an evergreen tree 8-20 m tall, with a trunk up to 75 cm in diameter (Van Steenis, 1971). It occurs over a range of topographies, usually on ultramafic soils, but has been recorded infrequently on volcano-sedimentary soils, though here confined to skeletal soils on ridge tops (Read & Hope, 1996; J. Read pers. comm., 2022). Similarly to other *Nothofagus* species in New Caledonia, *N. codonandra* often displays monodominance, forming a dense cohort of similarly aged trees in the upper canopy. These are suggested to be successional forests, which establish following large scale-disturbances, including those caused by cyclones (Read & Jaffré, 2013). Though disturbance is considered important for populations at lower elevations, it is not clear whether high-elevation forests are similarly dependent on this to facilitate regeneration (J. Read pers. comm., 2022). *N. codonandra* is also known to form ectomycorrhizal associations (Jourand et al., 2014), which may play an important role in the ecological functioning of this species in ultramafic soils.

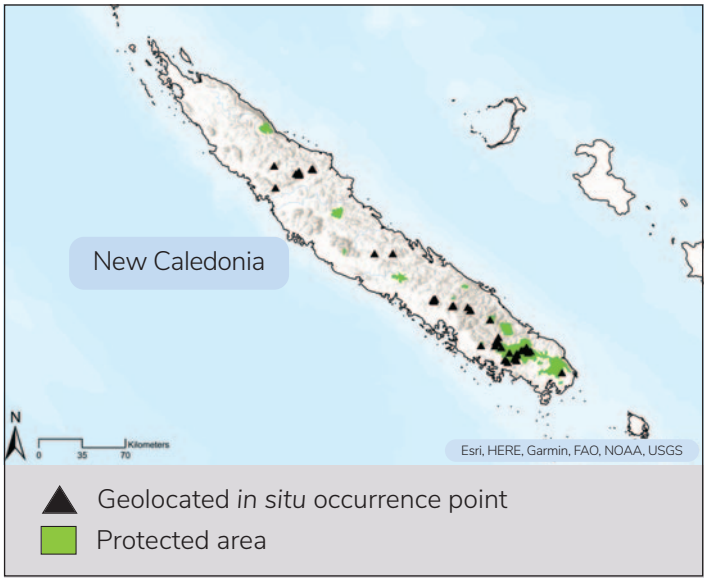

Figure 1. Documented *in situ* occurrence points for *Nothofagus codonandra* and Terrestrial Protected Areas in New Caledonia (Terrestrial Protected Areas are from UNEP-WCMC & IUCN 2022, Protected Planet).

Monodominant *Nothofagus* forests usually display high species-richness in the understorey (Read et al., 1995), with *Nothofagus* in New Caledonia commonly occurring with species in the families Podocarpaceae, Araliaceae, Cunoniaceae, Lauraceae, Myrtaceae, Sapindaceae, Euphorbiaceae and Apocynaceae (Read & Hope, 1996).

Threats to Wild Populations

Threats to wild populations were identified by reviewing *The Red List of* Nothofagus (Baldwin et al., 2018), expert consultation and literature review. Because there is limited published research on threats to *N. codonandra* specifically, the information below largely refers to *Nothofagus* species in New Caledonia in general. No threats for *N. codonandra* were reported via the Conservation Activity Questionnaire.

The threats explored below are considered the current most significant threats, categorised into medium and low impact. This categorisation has been informed by the sources listed above and have been reviewed by regional experts.

Medium Impact Threats

Development, mining, and/or roads: Mining poses a general threat to *Nothofagus* species in New Caledonia, contributing to species fragmentation and localised population loss (Baldwin, 2018). This threat has increased over the last 20 years, with the development of techniques enabling extraction from low-grade deposits that were previously unexploited (Baldwin, 2018; Jaffré et al., 2010). Ecological restoration opportunities for *Nothofagus* in New Caledonia that could help mitigate against the threat from mining are complicated by irregular seed availability which limits potential breeding programmes (S. McCoy pers. comm., 2022).

Disturbance regime modification including fire: Fire frequency has increased in New Caledonia with human settlement (Stevenson, 2004), whilst higher temperatures and sporadic rainfall are making fires more common in some parts of the territory (Baldwin, 2018). *Nothofagus* forest often occurs adjacent to maquis vegetation, which is often exposed to fire (Read & Jaffré, 2013). Indeed, several thousand hectares of forest and maquis were burnt in the Dzumac Range in 1991, including rainforest dominated by *N. codonandra* (Read et al., 1995).

Low Impact Threats

Climate change: *Nothofagus* species in general have poorly dispersed seeds and specialist soil requirements which limits their ability to migrate to higher altitude as the climate changes (Baldwin, 2018; Read & Hope, 1996).

Unknown cause- dieback: A large patch of dieback was observed in the population on Mt Koghi in 2022 (O. Steed-Mundin & D. Crowley pers. obs., 2022). Although natural regeneration is occurring, further investigation is required to understand the extent of dieback and what is causing it, including whether pests and/or pathogens are involved (see photo below).

Nothofagus codonandra, dieback and regeneration, Mt Koghi, New Caledonia (Olivia Steed-Mundin)

Conservation Activities

In 2021 and 2022, accession data were requested from *ex situ* collections for all *Nothofagus* species that were identified as threatened or Near Threatened in *The Red List of* Nothofagus (i.e. 'target species') (Baldwin et al., 2018).

In addition, past, present and planned conservation activities for these species were examined through literature review, expert consultation and via a questionnaire. Conservation Activity Questionnaires were sent out between 2021 and 2022. For *N. codonandra*, as with all *Nothofagus* species from New Caledonia, no conservation activities were reported in the questionnaire. Information on conservation activities for this species has therefore been provided by expert consultation, research papers and other published sources.

Ex situ collections reported 2021-2022

There was only one *ex situ* accession of *N. codonandra* reported in the *ex situ* survey (Table 1, Figure 2), represented by a single plant currently growing at Royal Botanic Gardens, Victoria, in Australia.

Estimated *ex situ* representation

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* living collections. Since no seed collections were reported in our research, this analysis was only performed for living collections. Forty, 60 and 80-kilometre buffers were placed around each *in situ* occurrence point and the source locality of the living *ex situ* accession (Figure 3). Collectively the *in situ* buffer area serves as the inferred native range of the species or "combined area *in situ*" (CAI40, CAI60, CAI80 respectively). The *ex situ* buffer areas represent the native range "captured" in *ex situ* collections or combined area *ex situ* (CAE 40, CAE60, CAE80 respectively). Geographic coverage of *ex situ* collections was estimated by dividing CAE by CAI and ecological coverage was estimated by dividing the number of terrestrial ecoregions present in CAE by the number of ecoregions in CAI. Results are presented in Table 2 in km^2 and as a percentage of area covered. The mean average percentage of coverage of all three buffer sizes is also presented (Table 2).

N. codonandra is poorly represented in *ex situ* collections. Only a single living accession of *N. codonandra* was reported from *ex situ* collections globally (Figure 2). Our analysis suggests this collection captures a number of populations from the south of Grande Terre (Figure 3), and represents 100% of ecological coverage and 24% of geological coverage (Table 2). However, a single individual clearly represents very limited genetic diversity. Many populations are not represented at all in *ex situ* collections and given their fragmented distribution, are likely to be genetically distinct from the southern populations (Figure 3).

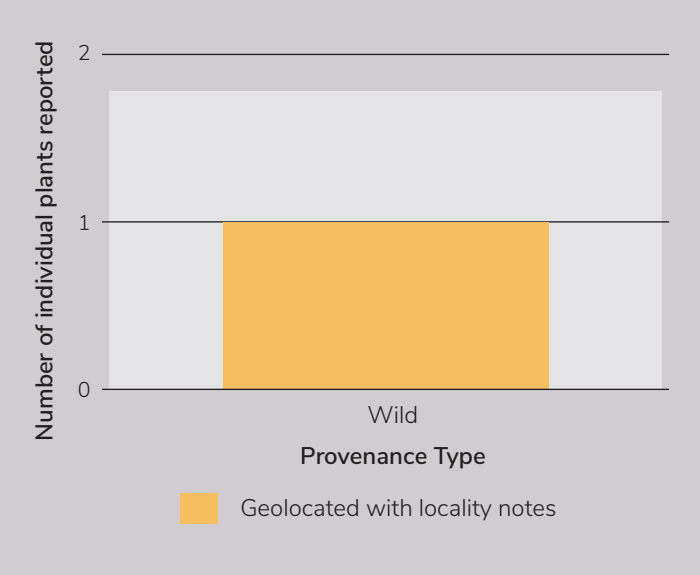

Figure 2. Quantity and origin of *Nothofagus codonandra* plants in *ex situ* living collections.

Table 1. Results from the 2021-2022 *ex situ* survey for *Nothofagus codonandra*.

Total	Number of organisations reporting *ex situ* collections	1
	Number of accessions in *ex situ* collections	1
Living collections	Number of plants in *ex situ* collections	1
	Percentage of *ex situ* plants of wild origin	100%
	Percentage of wild origin plants with known locality	100%
Seed collections	Number of accessions in *ex situ* seed collections	0

Table 2. Estimated *ex situ* representation of living plant collections for *Nothofagus codonandra*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Geographical coverage	2,722 / 14,117 **(19%)**	3,721 / 15,385 **(24%)**	4,547 / 16,318 **(28%)**	**24%**
Ecological coverage	2 / 2 **(100%)**	2 / 2 **(100%)**	2 / 2 **(100%)**	**100%**

Wild collecting and/or ex situ curation

There are no known wild collecting activities associated with this species. As with other *Nothofagus* species in New Caledonia, seed collecting initiatives are limited by the irregularity of fruiting, with mast years (e.g. 1996), followed by years of limited fruiting, in a phenological sequence which is not well understood (S. McCoy pers. comm., 2022). In addition, fallen seeds are relatively small and difficult to find on the forest floor. A focus on alternative seed collecting methods could aid future collection, however on this small territory, it is currently very specialised and logistically complex (S. McCoy pers. comm., 2022). It should also be noted that no research appears to have been carried out on the seed storage characteristics of tropical *Nothofagus* species.

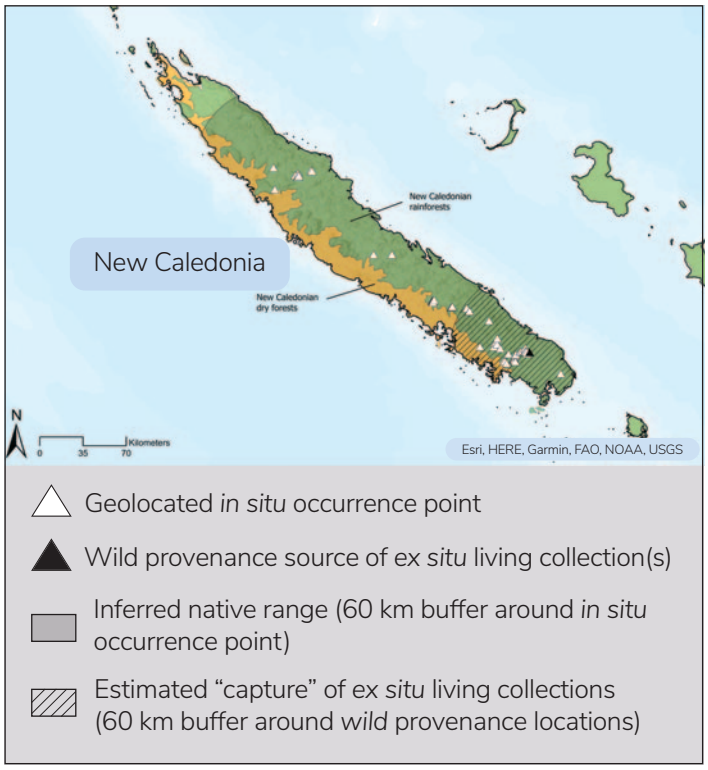

Figure 3. *Nothofagus codonandra in situ* occurrence points and *ex situ* living collection source localities. Terrestrial Ecoregions of the World for New Caledonia (Olson et al., 2001) are coloured and labelled. A 60km buffer has been placed around *in situ* occurrence points to infer the native range of *N. codonandra*. A 60km buffer has been placed around the *ex situ* source location to infer the native range captured in *ex situ* collections.

Propagation and/or breeding programmes

To date, there do not appear to have been any breeding programmes incorporating this species. Such programmes are currently limited by difficulties surrounding seed collection (see previous section).

Reintroduction, reinforcement and/or translocation

There do not appear to have been any attempted reintroductions of *N. codonandra* in New Caledonia. It is possible that, if this species has similar requirements to *Nothofagus aequilateralis*, (which also occurs on ultramafic soils), it may require ectomycorrhizal associations for successful seedling establishment. Research into a mycorrhizal inoculation to aid seedling establishment could aid future reintroduction programmes (S. McCoy & F. Carriconde pers. comm., 2022).

Land protection

A second spatial analysis was conducted to estimate the protected area coverage within the species' range, by finding the spatial intersection of CAI within protected areas. Results are presented in km^2 and percentage of area covered for 40, 60 and 80-kilometre buffers. The mean average percentage of coverage of all three buffer sizes is also presented (Table 3). The protected area coverage should be considered an estimation, as buffers around *in situ* points are likely to overestimate the distribution range of the target species. Additionally, these buffers might include non-protected habitat where the target species are unlikely to occur.

Within the inferred native range of *N. codonandra*, 6% of the land is covered by protected areas (Table 3). Protected areas in which *N. codonandra* occurs include Rivière Bleue Provincial Park, Thy Custom Reserve and Mont Do Botanical Reserve (Figure 1).

Sustainable management of land

It should be noted that not all protected areas in New Caledonia are protected from mining activities. Mining appears to be prohibited in Rivière Bleue Provincial Park and Mont Do, but not Thy forest, which is a Custom Reserve in proximity to St Louis, which has undergone historical mining and suffered from recent fires (Jaffré et al., 1996; S. McCoy pers. comm., 2022). Figure 4 shows known occurrence points in relation to areas where mining is prohibited.

Given the specific threat from mining activities in New Caledonia, a third spatial analysis was carried out to estimate the coverage of areas where mining is prohibited, by finding the spatial intersection of CAI within areas where mining is prohibited. Results are presented in km^2 and percentage of area covered for 40, 60 and 80-kilometre buffers. The mean average percentage of coverage of all three buffer sizes is also presented (Table 4).

Within the inferred native range of *N. codonandra*, 4% of the land is covered by areas where mining is prohibited (Table 4). This is lower than the estimated protected area coverage.

No other sustainable land management initiatives have been found where *N. codonandra* occurs.

Population monitoring and/or occurrence surveys

One permanent plot of *N. codonandra* is included in a long-term monitoring programme (1991-to present), providing insights into the ecology and population dynamics of *Nothofagus* forests (Read & Jaffré, 2013). Analysis of population size and structures suggests these *Nothofagus*-dominated forests are typically secondary forests that have been established after large-scale disturbances, and that periodic moderate to severe disturbance may be necessary to maintain these forests at low-to-mid-elevations in the long term. In the absence of such disturbance, the abundance of *Nothofagus* is likely to decline, with the forest canopy becoming mixed in composition. However, the type (e.g. fire vs cyclone), frequency and intensity of disturbance are likely to be critical in their effect on forest composition, though this topic requires further investigation. Notably, the population of *N. codonandra* studied at high elevation (940 m a.s.l.) contains high densities of juveniles (J. Read pers. comm., 2022), some of which, occurring in the understorey, have an estimated age range of 20-40 years old (F. Carriconde pers. comm., 2022). Further study of population dynamics of this species is needed, including across a range of elevations to investigate whether or not exogenous disturbance is needed for dominance to be maintained at high-elevation sites.

Table 3. Estimated protected area coverage for *Nothofagus codonandra*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Protected area coverage	923 / 14,117 **(7%)**	923 / 15,385 **(6%)**	923 / 16,318 **(6%)**	**6%**

Table 4. Estimated area coverage where mining is prohibited for *Nothofagus codonandra*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Prohibited mining area coverage	613 / 14,117 **(4%)**	628 / 15,385 **(4%)**	628 / 16,318 **(4%)**	**4%**

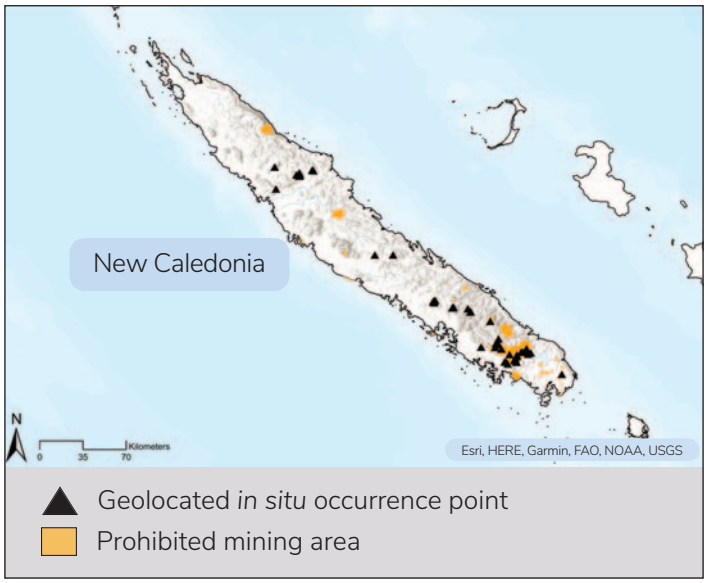

Figure 4. Documented *in situ* occurrence points for *Nothofagus codonandra* and prohibited mining areas in New Caledonia (Prohibited mining areas are from Plateforme de Téléchargment, Government of New Caledonia (GOUV.NC, 2021)).

Research

Published research which has a specific focus on conservation appears to be very limited for *N. codonandra*. However, there are some broader studies that are relevant to the species. These include studies on population dynamics of *Nothofagus* forests and monodominance (Demenois et al., 2016; Read & Jaffré, 2013; Read et al., 2018), ectomycorrhizal associations which appear to have a role in the ecological functioning of *N. codonandra* in ultramafic soils (Carriconde et al., 2019; Jourand et al., 2014), and fungal inoculations for improving soil aggregate stability in ultramafic soils in New Caledonia (Demenois et al., 2017). All of these could provide insight for future conservation and/or reintroduction programmes of *N. codonandra* in New Caledonia.

Education, outreach and/ or training

There appear to be no known initiatives in place for *N. codonandra*.

Species protection policies

There are species protection policies in place for all *Nothofagus* species in the Northern Province. In addition, *Nothofagus* forest habitat in the Southern Province is protected by the Southern Province Environmental Code by its rainforest heritage habitat status , with controls against logging, mining and fire management prioritisation. (Délibération n° 25-2009/APS, 2009).

Nothofagus codonandra, New Caledonia (Benôit Henry)

Priority Conservation Actions

Results of the Conservation Activity Questionnaire

There were no responses related to *N. codonandra* in the Conservation Activity Questionnaire.

Conclusion and Recommendations

The following conclusion and recommendations have been compiled by synthesising the research, data and analysis collated in this report, as well as via expert consultation.

This species is listed as Near Threatened on the IUCN Red List (Baldwin et al., 2018). The major threats are mining and fire and there are also threats from climate change and dieback (cause unknown). Our research found just a single plant in *ex situ* living collections globally, no *ex situ* seed collections and no conservation activities associated with this species. In addition, the majority of this species' range does not fall within protected areas.

In situ and *ex situ* conservation efforts for all *Nothofagus* species from New Caledonia are constrained by practical issues with collecting seeds and seedling establishment. An initial focus on facilitating seed collection of wild populations is therefore recommended followed by research into seedling establishment (potentially with ectomycorrhizal inoculations) to help facilitate potential breeding programmes.

Priority areas of research should focus on the phenological sequence of seed production, and fungal inoculations required for seedling establishment. In addition, it is recommended that there is investigation into the dieback of *N. codonandra* on Mt Koghi and surveys to determine whether it is present, and to what extent, in other populations.

Nothofagus codonandra, New Caledonia (Benôit Henry)

Practical initiatives could include seed-collecting methodologies, training, and programmes to facilitate collecting of wild populations.

Establishing genetically comprehensive *ex situ* collections is also recommended. This could potentially be via seed banking, though there have been no studies to date on whether tropical *Nothofagus* species have orthodox seed storage characteristics, hence seed collection would need to be supported by research into this. The creation of *ex situ* living collections would therefore be recommended in the interim, once constraints with seedling establishment are overcome and propagation protocols are developed.

Finally, it is recommended for research into the potential threat of fire to specific populations, with a view to prioritise seed collection in populations at highest risk.

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Nothofagus crenata Steenis

Synonym(s): *Trisyngyne crenata* (Steenis) Heenan & Smissen. **Common name(s):** Ira Yiyima; Karapeh

IUCN Red List Category and Criteria: Vulnerable (VU) B1ab(iii,v)

Species profiles authors: Olivia Steed-Mundin, Wakehurst, Royal Botanic Gardens, Kew, UK; Dan Crowley, Westonbirt, The National Arboretum, UK, BGCI; Itxaso Quintana, BGCI; Oliver Paul, PNG Forest Research Institute, Lae National Herbarium, Papua New Guinea; Reza Saputra, West Papua Natural Resources Conservation Agency (Balai Besar KSDA Papua Barat), Ministry of Environment and Forestry, Indonesian New Guinea

Suggested citation: Steed-Mundin, O., Crowley, D., Quintana I., Paul, O., & Saputra, R. (2024). *Nothofagus crenata* Steenis. In Steed-Mundin, O., Crowley, D., Quintana, I., & Wenham, J. *Conservation Gap Analysis of* Nothofagus. Wakehurst, UK: Royal Botanic Gardens, Kew.

Distribution and Ecology

Nothofagus crenata has a restricted range and is known from a small number of localities on the island of New Guinea (Baldwin, 2018): three in Papua New Guinea and one in Indonesian New Guinea (Lorentz National Park) (Figure 1). There is another reported population in the Owen Stanley Range at Kokoda, Northern Province, Papua New Guinea, that requires further investigation (O. Paul pers. comm., 2022).

Unlike most *Nothofagus* species in this region, which occur solely in lower montane forests, *N. crenata* has a broad altitudinal distribution. One population near Lake Kubutu, Papua New Guinea occurs between 800 and 950 m a.s.l. (Read & Hope, 1996); another has been recorded at 2300m a.s.l. (Beehler & Marshal, 2012).

N. crenata is an evergreen tree growing to 40 m tall, with a trunk up to 1 m in diameter (Van Steenis, 1953). Information about its ecology is limited, however field notes from herbarium records describe it as both a dominant species in mixed forests (Bijmoer et al., 2022) as well as forming more or less pure stands on ridges and slopes, where it grows in shallow, humic-rich topsoil over limestone (Orrell & Informatics Office, 2022).

Co-occurring species include members of the families Lauraceae, Elaeocarpaceae, Cunoniaceae, as well as species in the genera *Syzygium* and *Podocarpus* (Beehler & Marshall, 2012). It is also known to occur with *Nothofagus starkenborghiorum* and *Nothofagus brassii* (Beehler & Marshall, 2012).

Nothofagus crenata, Type Voucher (Naturalis Biodiversity Center (licensed under http://creativecommons.org/publicdomain/zero/1.0/))

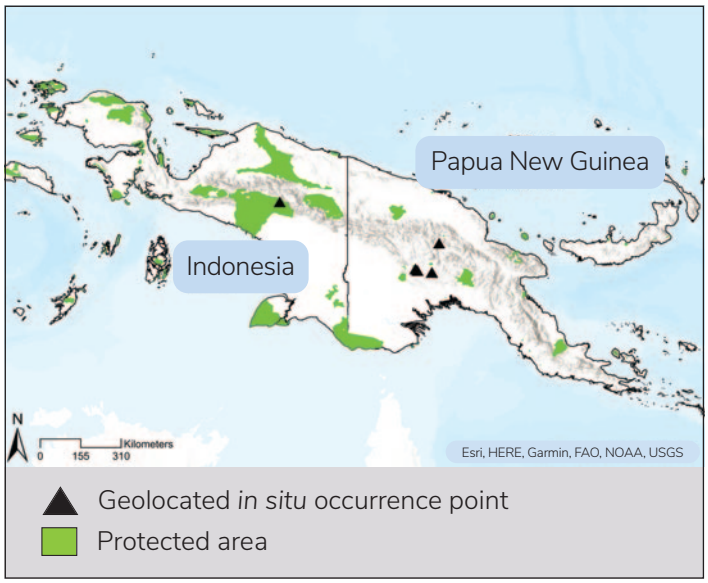

Figure 1. Documented *in situ* occurrence points for *Nothofagus crenata* and Terrestrial Protected Areas in the island of New Guinea (Terrestrial Protected Areas are from UNEP-WCMC & IUCN 2022, Protected Planet).

Threats to Wild Populations

Threats to wild populations were identified by reviewing the recent *The Red list of* Nothofagus (Baldwin et al., 2018), expert consultation and literature review. Because there is limited published data relating to threats to *N. crenata* specifically, the information below largely refers to *Nothofagus* species on the island of New Guinea in general. No threats for *N. crenata* were reported via the Conservation Activity Questionnaire.

The threats explored below are considered the current most significant threats, categorised into medium and low impact. This categorisation has been informed by the sources listed above and have been reviewed by regional experts.

Medium Impact Threats

Extremely restricted population and/or genetic diversity loss: *N. crenata* is only known from four localities. If one or more of the populations are in decline, it could have a significant impact on the remaining individuals and genetic diversity of the species. However, botanical records from New Guinea are limited, so the number of recorded populations may not be accurate.

Land use change - agriculture and/or silviculture & Logging and/or wild harvesting: There has been significant deforestation in Papua New Guinea over the last 50 years- 15% of tropical forest has been cleared (1972-2002) and a further 8% degraded by logging (Shearman et al., 2009). In Indonesian New Guinea, 0.75 million hectares of old growth forest were cleared 2001-2019 (Gaveau et al., 2021). For a species with such a small number of populations, deforestation at a single locality poses a significant threat to the overall population size and genetic diversity.

Low Impact Threats

Pests and/or pathogens: Large patches of dieback have been observed for some time in even-aged *Nothofagus* forests in or close to areas where *N. crenata* occurs (i.e. Lorentz National Park, West Papua and Southern Highlands, Papua New Guinea) (Read & Hope, 1996; R. Saputra pers. comm., 2022). The contributing factors are not well understood. It is possible that a pathogen such as *Phytophthora cinnamomi* (which has been isolated from soil samples) is involved, however research to date is inconclusive (Arentz, 1988; R. Saputra pers. comm., 2022). Abundant regeneration in the diseased stands has, until recently, suggested that it is not limiting the distribution or regeneration of *Nothofagus* species (Read & Hope, 1996). However, dieback appears to be worsening with climate change and since the construction of the Trans Papua highway through Lorentz National Park (UNESCO, 2017). It should be noted that it is not currently reported whether this dieback is affecting *N. crenata* specifically.

Development, mining, and/or roads: In Lorentz National Park, recent infrastructure development projects including the construction of the Trans Papua Highway, may have a continued impact on species that occur there, including *N. crenata* (UNESCO, 2017).

Disturbance regime modification including fire: Fire is considered the most important driver of change in high altitude forest in Papua New Guinea (Shearman et al., 2009), where some populations of *N. crenata* occur. The limited number of populations make it particularly vulnerable to the threat of fire.

Conservation Activities

In 2021 and 2022, accession data were requested from *ex situ* collections for all *Nothofagus* species that were identified as threatened or Near Threatened in *The Red List of* Nothofagus (i.e. 'target species') (Baldwin et al., 2018). There were no *ex situ* accessions recorded for this species.

In addition, past, present and planned conservation activities for these species were examined through literature review, expert consultation and conduction of a questionnaire. Conservation Activity Questionnaires were sent out in 2021 and 2022. For *N. crenata*, as with all *Nothofagus* species from New Guinea, no conservation activities were reported in the questionnaire. Information on conservation activities for this species has therefore been provided by expert consultation, research papers and other published sources.

Ex situ collections reported 2021- 2022

No *ex situ* collections were reported.

Estimated *ex situ* representation

No *ex situ* collections were reported.

Wild collecting and/or *ex situ* curation

There are currently no known wild collecting activities or *ex situ* collections. The phenology of the species is poorly understood and no research appears to have been carried out into the seed storage characteristics of tropical *Nothofagus* species.

Propagation and/or breeding programmes

There are no known population or breeding programmes for this species.

Reintroduction, reinforcement and/or translocation

There are no known reintroduction programmes.

Land protection

A spatial analysis was conducted to estimate the protected area coverage within the species' range. Forty, 60 and 80-kilometre buffers were placed around each *in situ* occurrence point. Collectively the *in situ* buffer area serves as the inferred native range of the species or "combined area *in situ*" (CAI40, CAI60, CAI80 respectively). By finding the spatial intersection of CAI within protected areas, protected area coverage was estimated. Results are presented in km^2 and percentage of area covered for 40, 60 and 80-kilometre buffers (Table 1). The mean average percentage of coverage of all three buffer sizes is also presented (Table 1). The protected area coverage should be considered an estimation, as buffers around *in situ* points are likely to overestimate the distribution range of the target species. Additionally, these buffers might include non-protected habitat where the target species are unlikely to occur.

Within the inferred native range of *N. crenata* a mean average 2% of the land is covered by protected areas (Table 1), including Lorentz National Park in Indonesian New Guinea (Figure 1). There are also reports of a population in the Kokoda Track Conservation area in Papua New Guinea which require further investigation.

Table 1. Estimated protected area coverage for *Nothofagus crenata*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Protected area coverage	416 / 20,112 **(2%)**	787 / 41,465 **(2%)**	1,173 / 66,554 **(2%)**	**2%**

Sustainable management of land

The Lorentz National Park where one population of *N. crenata* is known to occur in Indonesian New Guinea is a UNESCO World Heritage Site (UNESCO, 2017). It is administered by the Indonesian Park Service for the Directorate for Nature Conservation, and a draft management plan has been produced. However, monitoring and management is hindered by limited funding and a limited number of staff, and there are continued threats including road building and illegal logging (IUCN & UNEP-WCMC, 2017).

The Kokoda Track Conservation area in Papua New Guinea, where there is an unconfirmed population of *N. crenata*, is visited by tourists all year round. However, funding for plant conservation and preservation of biodiversity is limited. Funding for the Kokoda Track Authority to manage the track is currently provided by the Australian Government, and the area was submitted by the Papua New Guinea Government for tentative World Heritage listing in 2006 (UNESCO, 2023).

Population monitoring and/or occurrence surveys

There have been no published monitoring or occurrence surveys. However, a plant survey conducted within Lorentz National Park in 2018 recorded *N. crenata* as present (H. Saputra pers. comm., 2022).

Research

There appears to be limited published research on the species. A report into the factors involved in *Nothofagus* species dieback in Lorentz National Park, Indonesian New Guinea, is currently in progress. Several pathogens and insects which attack *Nothofagus* species have been found, but have not yet been identified (H. Saputra pers. comm., 2022).

Education, outreach and/or training

There are no known initiatives in place for *N. crenata*.

Species protection policies

There are no known species protection policies for *N. crenata*.

Priority Conservation Actions

Results of the Conservation Activity Questionnaire

There were no responses related to *N. crenata* in the Conservation Activity Questionnaire.

Conclusion and Recommendations

The following conclusion and recommendations have been compiled by using the research, data and analysis collated in this report, as well as via expert consultation.

N. crenata is currently known from just four populations and has been assessed as Vulnerable on the IUCN Red List (Baldwin et al., 2018). It currently has very limited conservation activities associated with it and no known *ex situ* collections, hence practical conservation action is needed.

Documented occurrences were largely recorded more than 45 years ago. It is therefore recommended that population surveys are carried out first in the known localities to assess if populations appear to be declining, lacking recruitment, or facing threats from human impact. Results will inform specific conservation activities which are likely to include seed collecting for genetically representative *ex situ* collections and research into phenology, seed storage behaviour, propagation protocols and seedling establishment, which appear to be poorly understood for all of the threatened or Near Threatened species from New Guinea. Some related work has been carried out on phenology and propagation of *Nothofagus grandis* from Papua New Guinea, which could potentially be extended (T. Kuria pers. comm., 2022).

The possible population reported in Kokoda should be investigated to see if it occurs there. Depending on the results, it may be necessary to update the species' IUCN Red List assessment.

Supporting current efforts to establish the factors involved in dieback in Lorentz National Park, Indonesian New Guinea and the Southern Highlands, Papua New Guinea is also a priority.

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Nothofagus cunninghamii (Hook.) Oerst.

Synonym(s): *Fagus cunninghamii* Hook., *Lophozonia cunninghamii* (Hook.) Heenan & Smissen.
Common name(s): Myrtle Beech

IUCN Red List Category and Criteria: Vulnerable (VU) A4bce

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Distribution and Ecology

Endemic to Australia, *Nothofagus cunninghamii* is found on the island of Tasmania and in the state of Victoria (Figure 1). It is the dominant tree species in much of southeastern Australia's cool temperate rainforest (Duncan et al., 2016), occurring in areas where rainfall exceeds 1500 mm per year or over 50 mm in the driest months (Read & Brown, 1996). The species is more common in Tasmania, occupying a range of more than a million hectares, where it occurs as the dominant species in c.700,000 ha of Tasmania's cool temperate rainforest and related scrub habitat (Department of Natural Resources and Environment Tasmania, 2020b). It also occurs in c.61,000 ha of rainforest communities dominated by paleoendemic tree species such as *Nothofagus gunnii*, *Athrotaxis selaginoides*, *A. cupressoides* and *Lagarostrobos franklinii*. *N. cunninghamii* is also a common understory tree within more than 309,000 ha of old growth wet eucalypt forests dominated by species such as *Eucalyptus delegatensis* subsp. *tasmaniensis*, *E. obliqua* and *E. regnans* (Department of Natural Resources and Environment Tasmania, 2020b).

In Victoria, its distribution is relatively restricted to three main regions — the Central Highlands, Otway Ranges, and Strzelecki Ranges-Wilsons Promontory. It is restricted to small stands on south to east facing slopes and river gullies (Read & Brown, 1996).

N. cunninghamii ranges from being a compact multi-stemmed shrub under 1m tall in alpine areas, to a tree reaching 40 m in height (Read & Brown, 1996). Individuals are long-lived, but have a slow growth rate, taking up to 25 years to reach reproductive maturity (Read & Brown, 1996). The species exhibits mast flowering; in the mast years, seed viability also tends to be high, whilst in non-mast years, viability is low (Read & Brown, 1996). Most seeds fall within 20 m of the parent plant but may travel up to 150 m (Hickey et al., 1983).

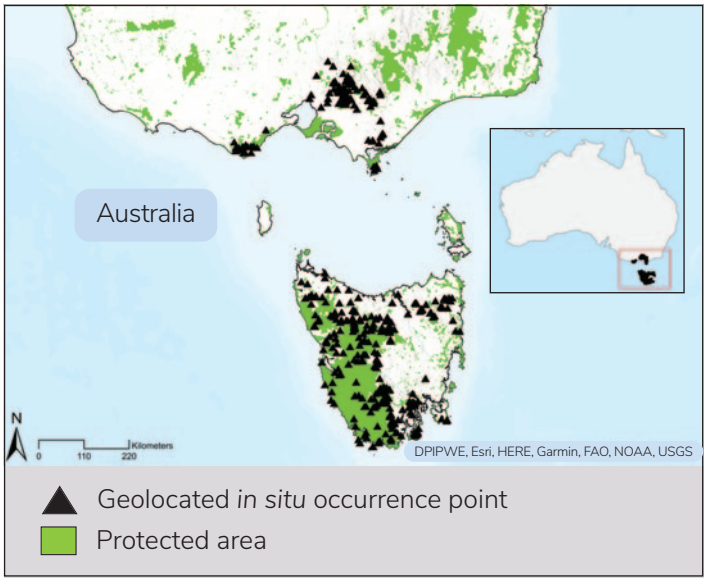

Figure 1. Documented *in situ* occurrence points for *Nothofagus cunninghamii* and Terrestrial Protected Areas in Australia (Terrestrial Protected Areas are from UNEP-WCMC & IUCN 2022, Protected Planet).

Threats to Wild Populations

Threats to wild populations were identified by reviewing *The Red List* of Nothofagus (Baldwin et al., 2018b), expert consultation, literature review, and via the Conservation Activity Questionnaire. A comprehensive list of all threats identified for *N. cunninghamii* is available in Appendix C. From the questionnaire, eight respondents from a total of eight organisations provided threat data for *N. cunninghamii* (Figure 2).

The threats explored below are considered the current most significant threats, categorised into high, medium and low impact. This categorisation has been informed by the sources listed above and has been reviewed by regional experts.

High Impact Threats

Disturbance regime modification including fire: The IUCN Red List assessment identified fire as the greatest threat to *N. cunninghamii* both in Victoria and Tasmania. The species has already experienced severe losses, with a reduction in seedling recruitment and therefore regeneration, whilst climate change and anthropogenic fire regimes are increasing the threat from fire further (Baldwin et al., 2018a). *N. cunninghamii* appears to be poorly adapted to fire due to its slow growth rate, the length of time to reach reproductive maturity, lack of mechanisms to protect seed from fire and its limited seed dispersal capacity. When burnt, *N. cunninghamii* trees are usually killed, although they can resprout after low intensity and some moderate intensity fires (Barker, 1990; G. Jordan pers. comm., 2022).

Lake Gorden, Tasmania. Fire damage, 2008
(Jo Wenham)

Nothofagus cunninghamii, Bruny Island, Tasmania. Appearance consistent with myrtle wilt infection (Olivia Steed-Mundin)

Pests and/or pathogens: This was the third most common threat identified by respondents to the Conservation Activity Questionnaire (Figure 2). *N. cunninghamii* is fatally susceptible to the hyphomycetes pathogenic myrtle wilt fungus (*Chalara australis*). The disease was first described in Tasmania in 1973, where it has since been shown to be widespread in rainforests. The most common risk is to mature trees and in areas with increased human disturbance (Howard, 1973). The smaller Victorian populations, in combination with risk of fire, are suspected to be at greater risk from myrtle wilt (Cameron & Turner, 1996). In Tasmania, although a 1994 study found that the then current levels of myrtle wilt would be unlikely to lead to any permanent change in forest structure (Packham, 1994), there have recently been informal reports that myrtle wilt is becoming more prevalent within reserves (J. Balmer pers. comm., 2022).

Medium Impact Threats

Climate change: This was the most commonly identified threat to *N. cunninghamii* by respondents to the Conservation Activity Questionnaire (Figure 2) and has been predicted to cause future population decline (Baldwin et al., 2018a). One area of concern is the increased risk of fire. Climate change has already led to an increase in frequency of dry lightning events resulting in increased area and frequency of bushfire events (Styger, Marsden-Smedley & Kirkpatrick, 2018). Whilst future predicted changes in climate are likely to double the climatic opportunities for rainforest to burn in Tasmania (Love et al., 2016; Styger et al., 2018). Fragmentation of extant populations and genetic diversity loss is another concern. If fragmentation of the range of *N. cunninghamii* increases under future climate change as predicted (Worth et al., 2014), then Victorian populations will probably be vulnerable to loss of genetic diversity. In contrast, western and north eastern Tasmania not only harbour most of the diversity in the species but are also predicted to contain the most suitable climates for the species under projected climate change models (Worth et al., 2014).

Low Impact Threats

Logging and/or wild harvesting & Development, mining and/or roads: Although development, mining and/or roads was the second most common threat identified in the Conservation Activity Questionnaire and wild harvesting was also identified as a threat (Figure 2), it is important to note that these threats have been at least partly mitigated by legislation, although this varies across the species range.

In Victoria, logging was clearly a historical concern, however native timber harvesting was due to officially end by 1st January 2024 in Immediate Protection Areas covering a number of localities where *N. cunninghamii* occurs (State Government of Victoria, 2023). In Tasmania, 93% of *N. cunninghamii* rainforests are reported to occur in the Tasmanian reserve estate (Department of Natural Resources and Environment, 2020a), however, only 49% of these reserved rainforests are in formal reserves with IUCN categories i, ii, & iii, where they are protected from both timber harvesting and mining. This data is also in general accord with Mackey et al. (2017), who reported that only 43% of the Temperate Rainforest in Tasmania are in reserve categories where either logging and/or mining is permitted. To get a better understanding of the extent to which timber harvesting and clearing may have been impacting *N. cunninghamii* specifically within the Tasmanian reserve estate, it would be useful to include insights from the Department of Natural Resources and Environment Tasmania, to delineate reserve areas which are potentially subject to logging and/or mining in relation to extant populations of *N. cunninghamii*.

It should also be noted that anthropogenic disturbance (e.g. from logging and mining) appears to increase the prevalence of myrtle wilt (Packham, 1994), which further highlights the importance of understanding these threats.

Land use change - agriculture and/or silviculture- Although this was a common threat identified in the Conservation Activity Questionnaire (Figure 2) and has also been identified as a threat on the IUCN Red list (Baldwin et al., 2018a), evidence for this as a threat at the current time appears to be somewhat limited. In Victoria the cessation of the logging of native trees (State Government of Victoria, 2023) will reduce the likelihood of this threat. In Tasmania, data suggests the rate of forest clearance declined in the period 2015-2021 and for non-eucalypt forests specifically (i.e. the forest type in which this species commonly occurs), there was only a 0.1% decline in area during that time (Forest Practices Authority, 2022).

Other considerations

It is important to note that although this species was assessed by IUCN Red List as Vulnerable with threats from fire, habitat loss, poor regeneration, timber harvest and myrtle wilt infection (Baldwin et al., 2018b), in Victoria, the species is more severely affected by these threats than in Tasmania. In Tasmania, none of the rainforest communities dominated by *N. cunninghamii* are listed as Threatened Native Vegetation Communities under State legislation (Tasmanian Government, 2023a) or nationally under the Environment Protection and Biodiversity Conservation Act of 1999 (Australian Government, 2000). Likewise, as a species it is considered common and widespread and therefore has not been listed as threatened under Tasmania's Threatened Species Protection Act of 1995 (Tasmanian Government, 2023b).

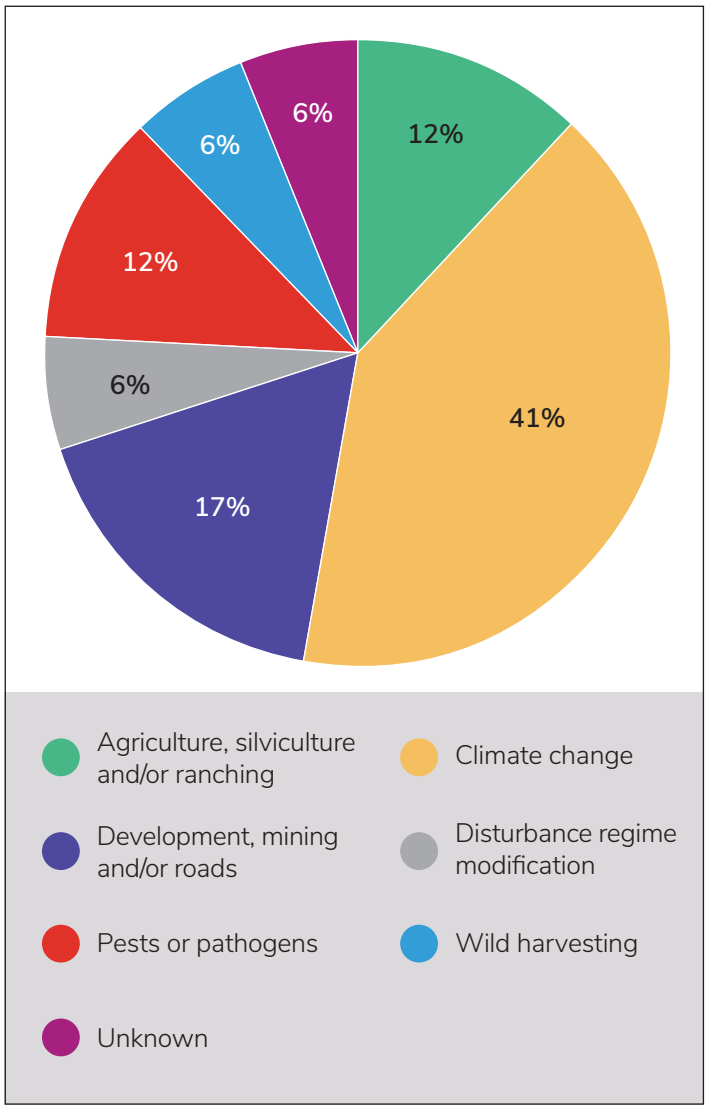

Figure 2. Threats to *Nothofagus cunninghamii* reported by respondents to the Conservation Activity Questionnaire. The chart shows the proportion of responses relating to each threat. Only threat categories that were reported are shown. The total number of respondents for *N. cunninghamii* was eight, from eight organisations

N. cunninghamii temperate rainforest, Mount Field National Park, Tasmania (Jo Wenham)

Conservation Activities

In 2021 and 2022 accession data were requested from *ex situ* collections for all *Nothofagus* species that were identified as threatened or Near Threatened in *The Red List of* Nothofagus (i.e. 'target species' (Baldwin el al., 2018b). A total of 30 organisations reported having *ex situ* collections for *N. cunninghamii* (Table 1).

In addition, past, present and planned conservation activities for these species were also examined through literature review, expert consultation and conduction of a questionnaire. Conservation Activity Questionnaires were sent out between 2021 and 2022. From all respondents, nine organisations reported being actively involved in conservation activities for *N. cunninghamii* (Figure 5).

Ex situ collections reported 2021- 2022

There are 212 *ex situ* accessions including living plants and seeds held at 30 organisations (Table 1). These include 409 plants in living collections (Table 1; Figure 3) and 255,354 seeds belonging to ten seed accessions (Table 1; Table 2). Of the 30 organisations who hold accessions, 9 of them are in the country of origin.

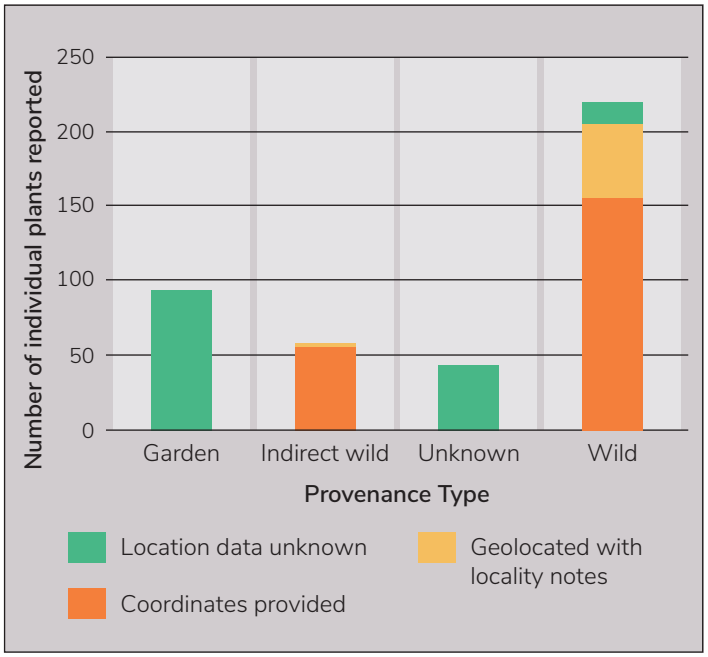

Figure 3. Quantity and origin of *Nothofagus cunninghamii* plants in *ex situ* living collections.

Table 1. Results from the 2021-2022 *ex situ* survey for *Nothofagus cunninghamii*.

Total	Number of organisations reporting *ex situ* collections	30
	Number of accessions in *ex situ* collections	212
Living collections	Number of accessions in *ex situ* living collections	202
	Number of plants in *ex situ* collections	409 in living collections 1 in nurseries
	Percentage of *ex situ* plants of wild origin	54%
	Percentage of wild origin plants with known locality	92%
Seed collections	Number of accessions in *ex situ* seed collections	10
	Number of seeds in *ex situ* seed collections	255,354
	Percentage of *ex situ* seed accessions of wild origin	100%
	Percentage of wild origin *ex situ* seed accessions with known locality	100%

Table 2. Quantity and origin of *Nothofagus cunninghamii* seeds in *ex situ* collections.

Ex situ seed accession	Quantity of seed	Provenance	Locality data
1	30	Wild	Coordinates provided
2	900	Wild	Coordinates provided
3	1230	Wild	Coordinates provided
4	2156	Wild	Coordinates provided
5	2441	Wild	Coordinates provided
6	2794	Wild	Coordinates provided
7	4900	Wild	Coordinates provided
8	6338	Wild	Coordinates provided
9	11100	Wild	Coordinates provided
10	223465	Wild	Coordinates provided

Nothofagus cunninghamii, seed collecting, Mount Field National Park, Tasmania (Dan Luscombe)

Estimated *ex situ* representation

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* living and seed collections. Forty, 60 and 80-kilometre buffers were placed around each *in situ* occurrence point and the source locality of each living *ex situ* accession (Figure 4). Collectively the *in situ* buffer area serves as the inferred native range of the species or "combined area *in situ*" (CAI40, CAI60, CAI80 respectively). The *ex-situ* buffer areas represent the native range "captured" in *ex situ* collections or combined area *ex situ* (CAE 40, CAE60, CAE80 respectively). Geographic coverage of *ex situ* collections was estimated by dividing CAE by CAI and ecological coverage was estimated by dividing the number of terrestrial ecoregions present in CAE by the number of ecoregions in CAI. Results are presented in Tables 3 & 4 in km^2 and as a percentage of area covered, the mean average percentage of coverage of all three buffer sizes is also presented.

Even though *N. cunninghamii* plants and seeds are relatively numerous in *ex situ* collections, the geographic coverage provided by these collections is just 53% and 49% respectively (Tables 3 & 4) This is because many populations, in both Tasmania and Victoria, are not represented *ex situ* (Figure 4).

Table 3. Estimated *ex situ* representation of living plant collections for *Nothofagus cunninghamii*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Geographical coverage	37,066 / 100,775 **(37%)**	64,041 / 119,491 **(54%)**	89,843 / 133,097 **(68%)**	**53%**
Ecological coverage	4 / 6 **(67%)**	6 / 6 **(100%)**	6 / 6 **(100%)**	**89%**

Table 4. Estimated *ex situ* representation of seed collections for *Nothofagus cunninghamii*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Geographical coverage	37,441 / 100,775 **(37%)**	62,328 / 119,491 **(52%)**	78,449 / 133,097 **(59%)**	**49%**
Ecological coverage	5 / 6 **(83%)**	5 / 6 **(83%)**	5 / 6 **(83%)**	**83%**

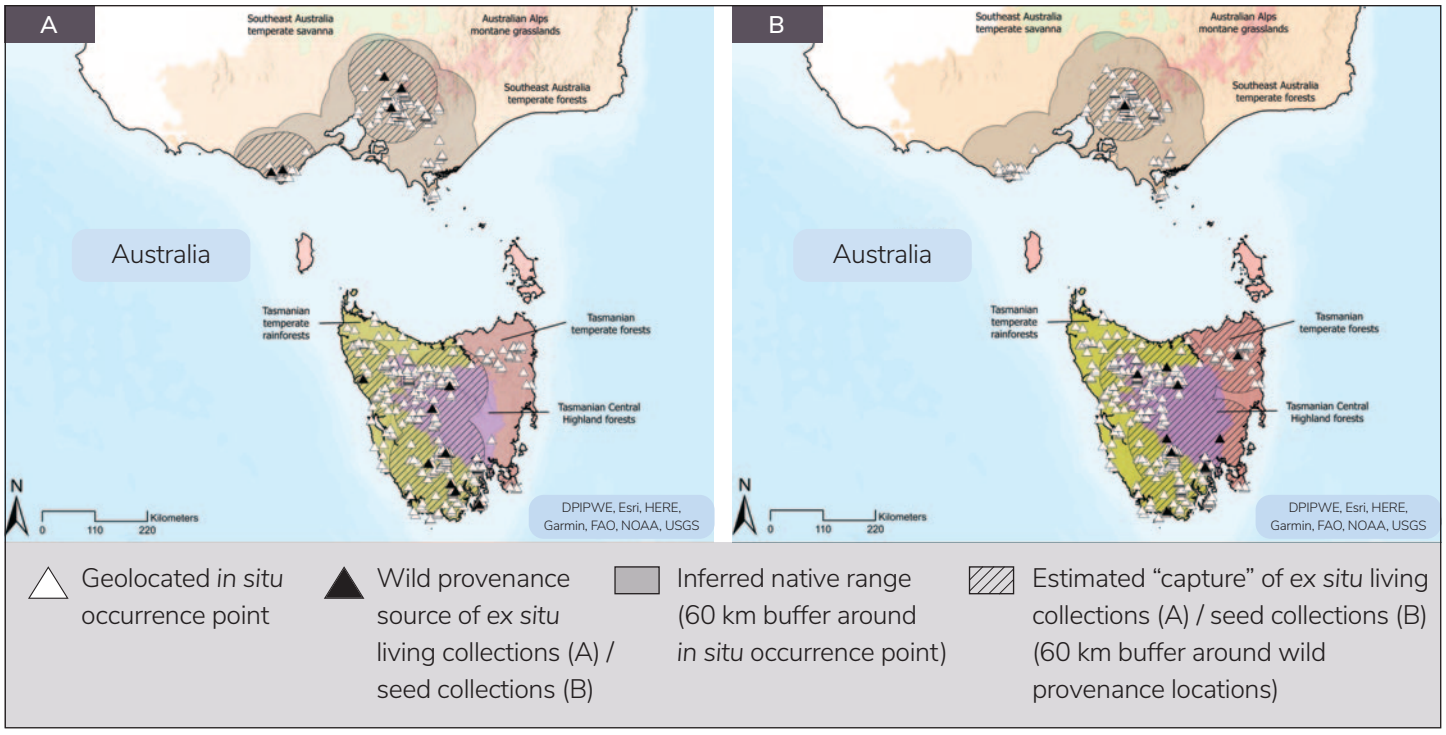

Figure 4. *Nothofagus cunninghamii in situ* occurrence points and *ex situ* source localities for A) living collections and B) seed accessions. Terrestrial Ecoregions of the World for southern Australia and Tasmania (Olson et al., 2001) are coloured and labelled. A 60km buffer has been placed around *in situ* occurrence points to infer the native range of *N. cunninghamii*. A 60km buffer has been placed around the *ex situ* source location to infer the native range captured in *ex situ* accessions.

Wild collecting and/or ex situ curation

In the Conservation Activity Questionnaire, two organisations reported to be carrying out collecting and/or distributing germplasm and two reported to be pollen and/or seed banking.

Although there are 410 plants in *ex situ* living collections, a large quantity came from similar localities or the same collection events. There are therefore significant gaps in *ex situ* representation including the most northerly populations in Tasmania and the southernmost populations in Victoria (Figure 4).

There are limited published studies investigating seed longevity of *N. cunninghamii ex situ*, however a study into Chilean *Nothofagus* species concluded that five species show orthodox seed storage behaviour but the quality of seed lots requires attention and further study (León-Lobos & Ellis, 2005). Germination testing of *N. cunninghamii* seed stored for two years by the Tasmanian Seed Conservation Centre shows high level and rapid germination, whilst initial germination tests held in the Millennium Seed Bank generally support the view that *Nothofagus* species have orthodox storage requirements (R. Davies pers. comm., 2021). However, since some species have shown a small decline in viability, indicating that viability may be short lived, further study and testing will be undertaken from September 2023 (R. Davies pers. comm., 2021).

Propagation and/or breeding programmes

Conservation horticulture was reported by eight organisations in the Conservation Activity Questionnaire and one respondent reporting to be carrying out cryopreservation and/or micropropagation activities (Figure 5).

Reintroduction, reinforcement and/or translocation

No population reinforcement or introduction activities were reported in the Conservation Activity Questionnaire (Figure 5) however a small-scale reintroduction was previously undertaken in the Victorian Highlands after an intense fire event, to assist in the long term-recovery (Just & Beardsell, 2013).

Land protection

A second spatial analysis was conducted to estimate the protected area coverage within the species' range, by finding the spatial intersection of CAI within protected areas. Results are presented in km^2 and percentage of area covered for 40, 60 and 80-kilometre buffers. The mean average percentage of coverage of all three buffer sizes is also presented (Table 5). The protected area coverage should be considered an estimation, as buffers around *in situ* points are likely to overestimate the distribution range of the target species. Additionally, these buffers might include non-protected habitat where the target species are unlikely to occur.

Within the inferred native range of *N. cunninghamii* 31% of the land is covered by protected areas (Table 5). This includes the majority of populations in Tasmania (Figure 1), where 90% of the 761,000 ha of cool temperate rainforest vegetation is within the Tasmanian reserve system and 77% of the 761,000 ha of Tasmania's rainforest is within formally dedicated reserves on public land (Department of Natural Resources and Environment Tasmania, 2020a). Our analysis showed fewer *N. cunninghamii* populations in Victoria are in protected areas (Figure 1).

Table 5. Estimated protected area coverage for *Nothofagus cunninghamii*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Protected area coverage	33,057 / 100,775 **(33%)**	36,773 / 119,491 **(31%)**	38,853 / 133,097 **(29%)**	**31%**

Sustainable management of land

In the Conservation Activity Questionnaire, only one organisation reported to be carrying out habitat restoration for *N. cunninghamii* (Figure 5). That said there has been considerable expansion of Tasmania's reserve network over the last three decades including additional reservations added as recently as 2013 to ensure rainforest and old growth forests are better preserved. This included the change in tenure of some previously logged areas which following 2013 had some rehabilitation works undertaken to assist in the recovery of mature forest species (Australian Government, 2019). In Victoria, native timber harvesting was officially due to cease by January 2024 in Immediate Protection Areas covering a number of localities where *N. cunninghamii* occurs (State Government of Victoria, 2023).

Population monitoring and/or occurrences surveys

There were no monitoring programmes reported in the Conservation Activity Questionnaire. However, a previously published study monitored *N. cunninghamii* populations for myrtle wilt in Tasmania over 12-18 years. This indicated that the situation was stable, with no permanent changes to the forest structure, but recommended further monitoring every 10 years (Packham et al., 2008). In addition, a small pilot survey is currently being carried out by Inala Jurassic Garden, Bruny Island, to assess the current extent of myrtle wilt in local populations.

Research

Six organisations reported to be undertaking research associated with *N. cunninghamii* in the Conservation Activity Questionnaire (Figure 5). There are also a number of previously published research papers which are particularly relevant to the conservation of *N. cunninghamii*. This includes a population genetics study across populations in Tasmania and Australia which found high levels of genetic diversity and gene flow, indicating the species is relatively robust to population fragmentation, especially in Tasmania. However, there was some evidence of bottlenecking in small populations more than 20 km from other populations (Duncan et al., 2016). Another study found there to be regionally distinctive genetics for the species reflecting the evolutionary and glacial separation in the populations (Worth et al., 2009).

There have also been a number of studies into the fire dynamics/ecology of *Nothofagus* forest and/or cool temperate rainforest. These indicated that *N. cunninghamii* rainforest appears to be able to recover naturally from fire as long the preceding fire interval is not too short (Barker, 1990). Single fire events do not usually eliminate *N. cunninghamii* or cool temperate rainforest from a site, although it may take a long time to recover from fire. The recommended minimum fire intervals for maintaining these rainforest communities is 200 years (Leonard, 2021).

The previous studies on myrtle wilt (Packham, 1994; Packham et al., 2008) provide useful data on myrtle wilt and could be used as a baseline and methodology for future work.

Education, outreach and training

Six organisations reported to be carrying out public awareness or education activities in the Conservation Activity Questionnaire, which was the second most commonly reported activity (Figure 5). At Inala Jurassic Garden for example, they highlight the potential impact of myrtle wilt on the species in their education and interpretation programmes.

Species protection policies

There are no known species protection policies specifically regarding *N. cunninghamii* and no activities relating to this were reported in the Conservation Activities Questionnaire. However, it is important to note that day to day management is undertaken in the protected areas across Australia to protect native biodiversity and vegetation, with management agencies implementing protection policies and regulation routinely. For example, the Parks and Wildlife Service in Tasmania manage the issue of myrtle wilt when constructing and maintaining walking tracks by ensuring that they minimise disturbance in rainforest habitats, they also regulate access to reserve areas and police recreational usage and illegal activities. (J. Balmer pers. comm., 2022).

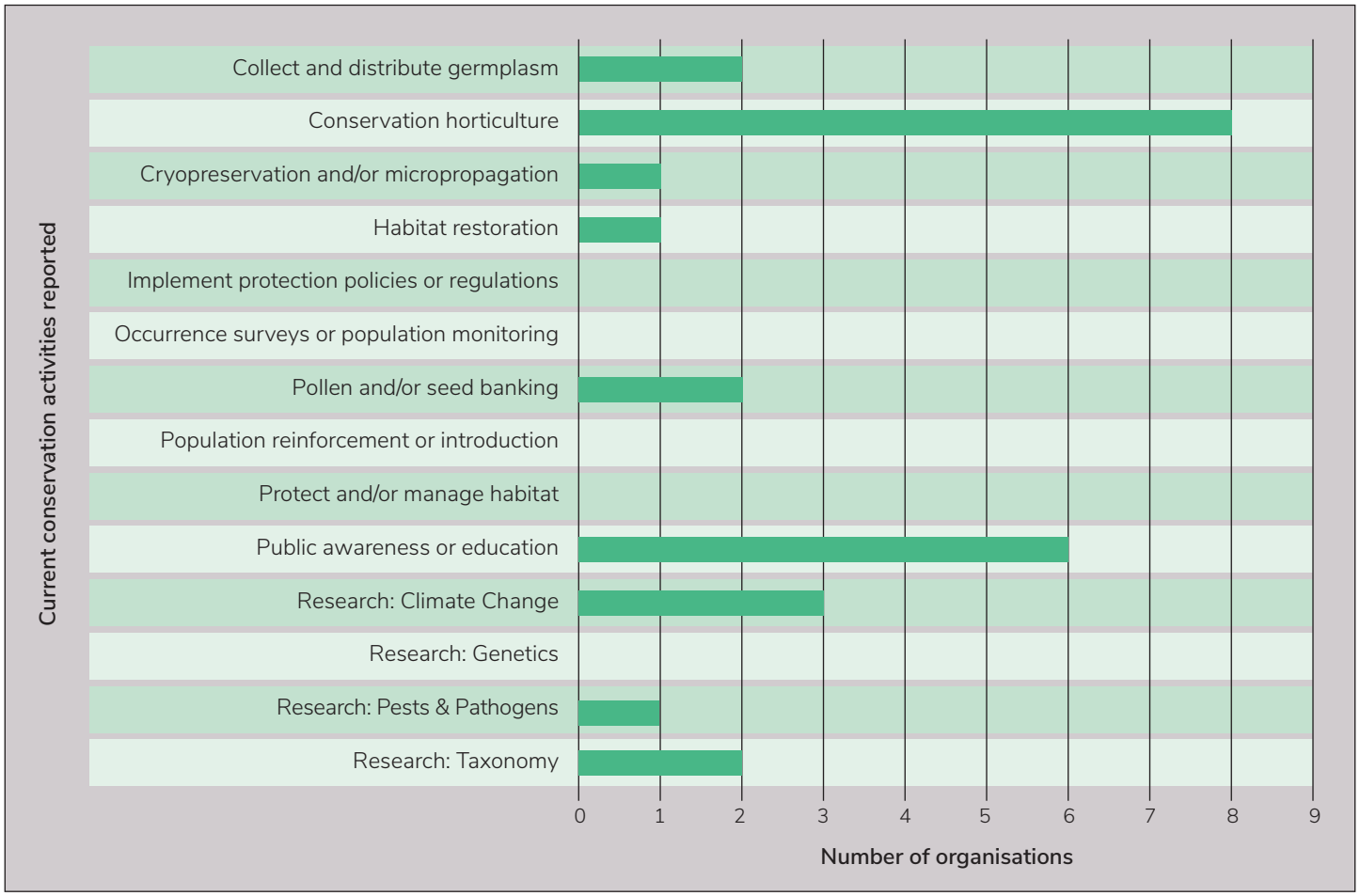

Figure 5. Number of organisations reporting specific conservation activities for *Nothofagus cunninghamii* in the Conservation Activity Questionnaire. The total number of organisations who reported conservation activities for *N. cunninghamii* was nine.

Priority Conservation Actions

Results of the Conservation Activity Questionnaire

A Conservation Activity Questionnaire was sent out to identify priority conservation actions that should be undertaken for the future conservation of *N. cunninghamii*. There were nine respondents from nine organisations. Public awareness or education, conservation horticulture and protect and/or manage habitat, were highlighted most frequently as priority actions that are needed for the future conservation of the species (Figure 6).

Conclusion and Recommendations

The following conclusion and recommendations have been compiled by using the research, data and analysis collated in this report, as well as expert consultation.

N. cunninghamii is currently assessed as Vulnerable on the IUCN Red List assessment (Baldwin et al., 2018b). Fire is identified as the greatest threat to *N. cunninghamii*, along with the fatal disease myrtle wilt, which anecdotal reports suggest may be becoming more prevalent within reserves (J. Balmer pers. comm., 2022). Our research has found that there are significant gaps in *ex situ* collections, with representation lacking from some populations in both Victoria and Tasmania, whilst a significant proportion of the inferred range of *N. cunninghamii* particularly in Victoria, falls outside of protected areas.

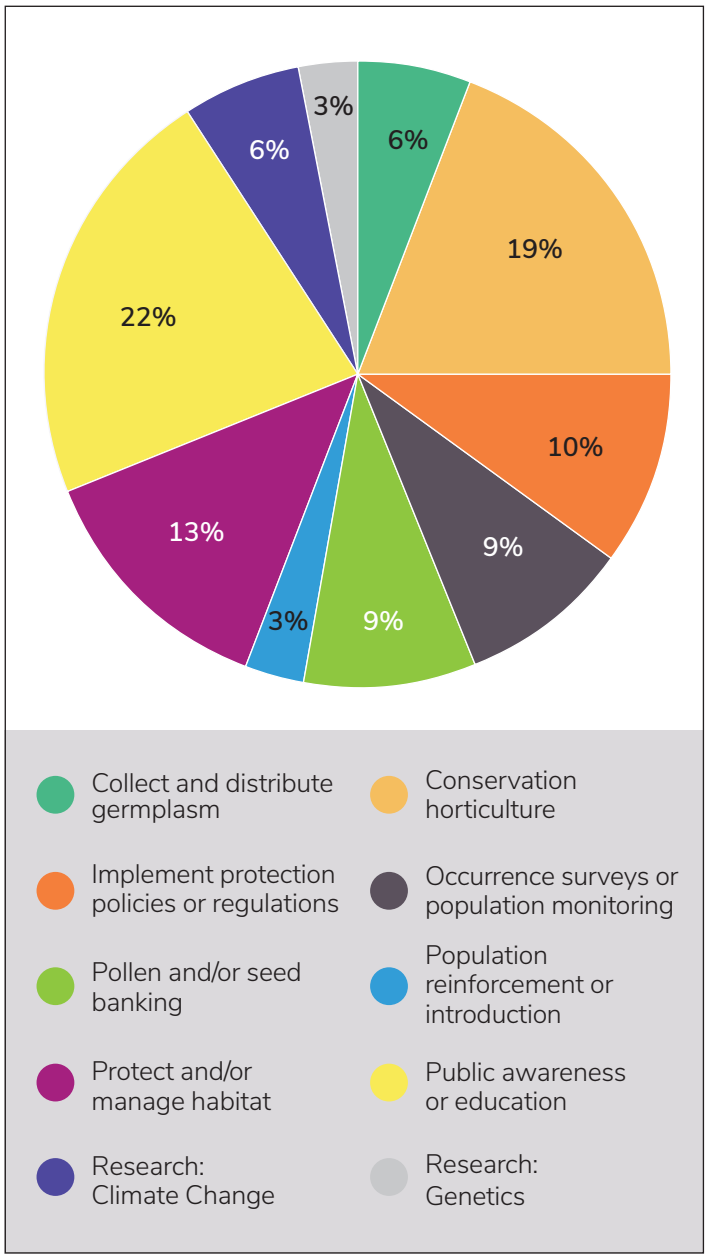

Figure 6. Priority conservation actions needed for the future conservation of *Nothofagus cunninghamii* reported by respondents to the Conservation Activity Questionnaire. The chart shows the proportion of responses identifying conservation actions as a priority. Only action categories that were identified are shown. The total number of respondents was nine, from nine organisations.

It is therefore recommended that there is focus on seed collection, banking and long-term storage of the underrepresented populations to ensure genetically representative *ex situ* living and seed collections. In addition, material should be collected from those localities which are deemed most vulnerable to threats and those which fall outside of protected areas. Since there are no known studies into the long-term seed storage characteristics of this species, it is recommended that this work is also supported by storage and germination trials to establish the longevity of banked seed.

Given the reported increase in prevalence of myrtle wilt and the time gap since comprehensive surveying has been undertaken, it is also recommended research is conducted to investigate the current threat from this disease. A project was launched by Inala Jurassic Garden in 2023 to monitor myrtle wilt on Bruny Island, Tasmania, using baseline data and methodologies from previous studies, which will help determine the current level of threat from myrtle wilt in the area. It is recommended that this work is broadened to assess the current extent and threat of myrtle wilt in other populations in Tasmania and Victoria.

It would also be useful to further investigate the perceived threat from logging, development, agriculture/silviculture and mining to the species. This should include analysis of more recent reserve data in Tasmania with input from the Department of Natural Resources and Environment Tasmania, who can specifically delineate the data according to reserved areas which are potentially subject to logging and/or mining. Data on recent areas harvested and cleared would also assist in interpreting the degree of threat posed by the timber and mining industries.

Finally, it is recommended that the IUCN Red List assessment for *N. cunninghamii* is updated. The species is most widespread in Tasmania, where it is not currently listed as threatened under Tasmania's Threatened Species Protection Act 1995. In addition, any updated data relating to threats from myrtle wilt and logging, mining and development could be incorporated into the assessment.

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N. cunninghamii temperate rainforest, Mount Field National Park, Tasmania (Jo Wenham)

Nothofagus discoidea (Baum.-Bod.) Steenis

Synonym(s): *Trisyngyne discoidea* Baum.-Bod. **Common name(s):** unknown

IUCN Red List Category and Criteria: Endangered (EN) B1ab(i,ii,iii,v)+2ab(i,ii,iii,v)

Species profiles authors: Olivia Steed-Mundin, Wakehurst, Royal Botanic Gardens, Kew, UK; Dan Crowley, Westonbirt, The National Arboretum, UK, BGCI; Itxaso Quintana, BGCI; Stephane McCoy, Prony Resources, New Caledonia; Fabian Carriconde, New Caledonian Agronomic Institute (IAC).

Suggested citation: Steed-Mundin, O., Crowley, D., Quintana I., McCoy, S., & Carriconde, F. (2024). *Nothofagus discoidea* (Baum.-Bod.) Steenis. In: Steed-Mundin, O., Crowley, D., Quintana, I., & Wenham, J. *Conservation Gap Analysis of* Nothofagus. Wakehurst, UK: Royal Botanic Gardens, Kew.

Distribution and Ecology

Endemic to New Caledonia, *Nothofagus discoidea* has a relatively restricted distribution, known from a small number of localities (Figure 1), mostly below 500 m a.s.l (Read et al., 2005). Populations found in the south of Grande Terre include Thy Forest, Mois de Mai, Faux Bon Secours, Rivière des Pirogues and Col de Mouirange. One population is found further north at Tonine at higher altitude (Read & Hope, 1996; Baldwin, 2018). The southern sub-populations are up to 20 km from each other and the northern one is 100 km from these. This disjunct distribution suggests either that this species was once more widespread, or that the isolated populations may have been mobile due to climate shifts, although they may never have extended far beyond their current geographic range (Read & Hope, 1996).

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N. discoidea is an evergreen tree, reaching 10-20 m tall (Van Steenis, 1971). Populations are largely restricted to ultramafic soils, but have been reported on granodiorite at Thy, and on soils modified by gabbro near Col de Mouirange (Read et al., 2006). It can dominate the upper canopy or can co-dominate with *Nothofagus aequilateralis*. Co-occurring taxa include members of Euphorbiaceae, Burseraceae, Malvaceae, Araliaceae and Stemonuraceae (Read et al., 2000).

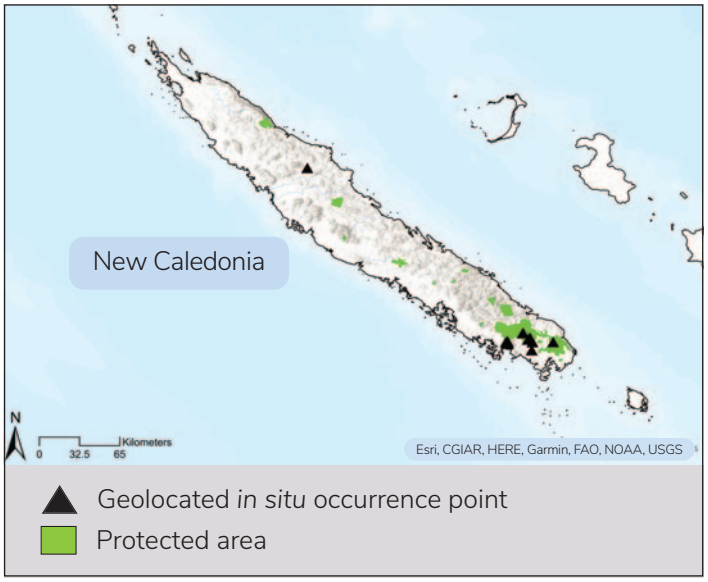

Figure 1. Documented *in situ* occurrence points for *Nothofagus discoidea* and Terrestrial Protected Areas in New Caledonia (Terrestrial Protected Areas are from UNEP-WCMC & IUCN 2022, Protected Planet).

Threats to Wild Populations

Threats to wild populations were identified by reviewing *The Red List of* Nothofagus (Baldwin et al., 2018), expert consultation and literature review. Because there is limited information about threats to this species specifically, much of the information below refers to *Nothofagus* species generally in New Caledonia. No threats for *N. discoidea* were reported via the Conservation Activity Questionnaire.

The threats explored below are considered the current most significant threats, categorised into high and medium impact. This categorisation has been informed by the sources listed above and have been reviewed by regional experts.

Nothofagus discoidea, New Caledonia (Dan Crowley)

High Impact Threats

Disturbance regime modification including fire: The IUCN Red List assessment identified fire as the greatest threat to *N. discoidea* (Baldwin, 2018). Higher temperatures and sporadic rainfall are making fires more frequent in some parts of New Caledonia. As a lower elevation species, *N. discoidea* is at particular risk, and part of its natural range is already experiencing repeated fires annually (Baldwin, 2018). These fires, along with climate change, may turn humid rainforests into xerophytic woodland and maquis, which reduces regeneration potential (Baldwin, 2018).

Medium Impact Threats

Climate change: *Nothofagus* species in general have poorly dispersed seeds and specialist soil requirements which limits their ability to migrate to higher altitudes in response to climate change (Read & Hope, 1996; Baldwin, 2018).

Development, mining, and/or roads: For plant species which occur on the metal-rich ultramafic soils of New Caledonia, nickel mining poses a generalised threat contributing to species fragmentation and localised population loss (Baldwin, 2018). This threat has increased over the last 20 years, with the development of techniques enabling extraction from low-grade deposits that were previously unexploited (Jaffré et al., 2010; Baldwin, 2018).

Dieback (unknown cause): Patches of dieback were observed in one population of *N. discoidea* in 2022 (O. Steed-Mundin & D. Crowley pers. obs., 2022). Although natural regeneration appears to be occurring, further investigation is required to understand the extent of dieback, and what is causing it, including whether pests and/or pathogens are involved and the long-term implications.

Conservation Activities

In 2021 and 2022 accession data were requested from *ex situ* collections for all *Nothofagus* species that were identified as threatened or Near Threatened in *The Red List of* Nothofagus (i.e. 'target species') (Baldwin et al., 2018). There were no *ex situ* accessions of *N. discoidea* reported.

In addition, past, present and planned conservation activities for these species were examined through literature review, expert consultation and conduction of a questionnaire. Conservation Activity Questionnaires were sent out in 2021 and 2022. For *N. discoidea*, as with all *Nothofagus* species from New Caledonia, no conservation activities were reported. Information on conservation activities for this species has therefore been provided by expert consultation, research papers and other published sources.

Ex situ collections reported 2021–2022

No *ex situ* collections were reported.

Nothofagus discoidea seedlings, with ectomycorrhizal fungi present on the roots, Prony Resources Nursery, New Caledonia (Stephane McCoy)

Estimated *ex situ* representation

No *ex situ* collections were reported.

Wild collecting and/or *ex situ* curation

There are no known wild collecting activities associated with *N. discoidea*. All seed collecting initiatives associated with *Nothofagus* in New Caledonia are limited by the irregularity of fruiting, with mast years (e.g. 1996), followed by years of limited fruiting, in a phenological sequence which is not well understood (S. McCoy pers. comm., 2022). In addition, fallen seeds are small and difficult to find on the forest floor. A focus on alternative seed collecting methods could aid future collection from remote sites which are logistically complex (S. McCoy pers. comm., 2022). It should also be noted that no research appears to have been carried out on the seed storage characteristics of tropical *Nothofagus* species.

Propagation and/or breeding programmes

There appears to be no current breeding programmes. Propagation is severely limited by the problems with seed collection (see previous section). However, *N. discoidea* has previously been propagated successfully by Prony Resources plant nursery in New Caledonia (S. McCoy pers. comm., 2022) (See photo to the left).

Reintroduction, reinforcement and/or translocation

There do not appear to have been any attempted reintroductions of *N. discoidea* in New Caledonia. It is possible that, if this species has similar requirements to *N. aequilateralis*, (which also occurs on ultramafic soils), then it may require ectomycorrhizal associations for successful seedling establishment. Research into a mycorrhizal inoculation to aid seedling establishment could aid future reintroduction programmes (S. McCoy & F. Carriconde pers. comm., 2022).

Land protection

A spatial analysis was conducted to estimate the protected area coverage. Forty, 60 and 80-kilometre buffers were placed around each *in situ* occurrence point. Collectively the *in situ* buffer area serves as the inferred native range of the species or "combined area *in situ*" (CAI40, CAI60, CAI80 respectively). By finding the spatial intersection of CAI within protected areas, protected area coverage was estimated. Results are presented in km^2 and percentage of area covered for 40, 60 and 80-kilometre buffers (Table 1). The mean average percentage of coverage of all three buffer sizes is also presented (Table 1). The protected area coverage should be considered an estimation, as buffers around *in situ* points are likely to overestimate the distribution range of the target species. Additionally, these buffers might include non-protected habitat where the target species are unlikely to occur.

Within the inferred native range of *N. discoidea*, 9% of the land is covered by protected areas (Table 1). A number of the southern populations are found in protected areas (Figure 1) including Thy Forest Customary Reserve and Rivière Bleue Provincial Park.

Sustainable management of land

It should be noted that not all protected areas in New Caledonia are protected from mining activities. Mining is reportedly prohibited in Rivière Bleue Provincial Park, but not Thy forest, a Custom Reserve in proximity to St Louis which has undergone historical mining and suffered from recent fires (Jaffré et al., 1996; S. McCoy pers. comm., 2022). Figure 2 shows known occurrence points of *N. discoidea* in relation to areas where mining is prohibited.

Given the specific threat from mining activities in New Caledonia, a second spatial analysis was carried out to estimate the coverage of areas where mining is prohibited, by finding the spatial intersection of CAI within areas where mining is prohibited. Results are presented in km^2 and percentage of area covered for 40, 60 and 80-kilometre buffers, the mean average percentage of coverage of all three buffer sizes is also presented (Table 2).

Within the inferred native range of *N. discoidea*, 6% of the land is covered by areas where mining is prohibited (Table 2). This is lower than the estimated protected area coverage.

No other sustainable land management initiatives have been reported where *N. discoidea* occurs.

Table 1. Estimated protected area coverage for *Nothofagus discoidea*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Protected area coverage	787 / 6,794 **(12%)**	845 / 9,894 **(9%)**	878 / 12,949 **(7%)**	**(9%)**

Table 2. Estimated area coverage where mining is prohibited for *Nothofagus discoidea*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Prohibited mining area coverage	507 / 6,794 **(7%)**	577 / 9,894 **(6%)**	605 / 12,949 **(5%)**	**(6%)**

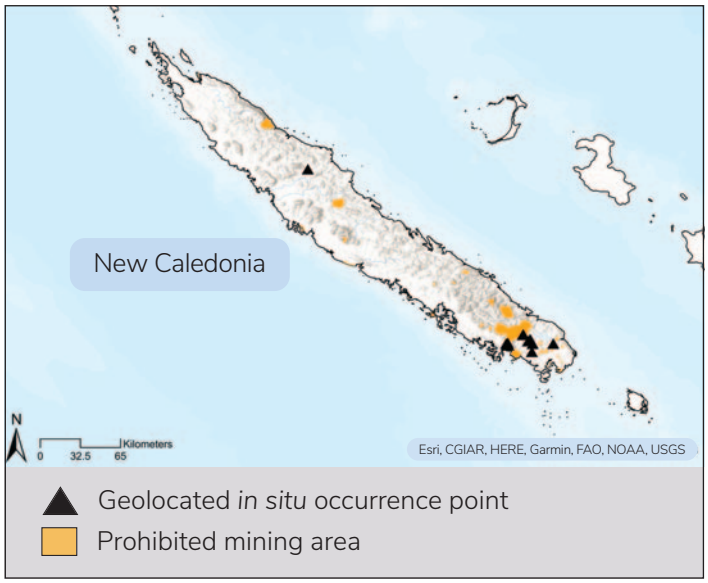

Figure 2. Documented *in situ* occurrence points for *Nothofagus discoidea* and prohibited mining areas in New Caledonia (Prohibited mining areas are from Plateforme de Téléchargment, Government of New Caledonia (GOUV.NC, 2021)).

Population monitoring and/or occurrence surveys

One permanent plot of *N. discoidea* is included in a long-term monitoring programme (1991-to present), providing insights into the ecology and population dynamics of *Nothofagus* forests in New Caledonia (Read & Jaffré, 2013). Analysis of population size structures suggests that *Nothofagus*-dominated forests, including those dominated by *N. discoidea*, are secondary forests that have been established after large-scale disturbances, and that moderate to severe disturbance may be necessary to maintain these forests at low-to-mid-elevations in the long term. In the absence of such disturbance, the abundance of *Nothofagus* is likely to decline, with the forest canopy becoming mixed in composition. However, the type (e.g., fire vs cyclone), frequency and intensity of disturbance are likely to be critical in their effect on forest composition and need further investigation. Observations of other *N. discoidea*-dominated forests suggest similar population structures (J. Read pers. comm., 2022), but further study is needed.

Research

Published research specifically focusing on *N. discoidea* is limited. However, there are some broader studies, mostly relating to the other *Nothofagus* species in New Caledonia, that provide potential insights for future conservation and/or reintroduction programmes. These include studies on population dynamics of *Nothofagus* forests and monodominance (Demenois et al., 2016; Read et al., 1995; Read & Jaffré, 2013; Read et al., 2018), ectomycorrhizal associations which appear to have a role in the ecological functioning of *Nothofagus* in ultramafic soils (Jourand et al., 2014; Carriconde et al., 2019), and fungal inoculations for improving soil aggregate stability in ultramafic soils in New Caledonia (Demenois et al., 2017).

Education, outreach and/or training

There are no known initiatives in place for *N. discoidea*.

Species protection policies

There are species protection policies in place for all *Nothofagus* species in the Northern Province of New Caledonia. In addition, *Nothofagus* forest habitat in the Southern Province is protected by the Southern Province Environmental Code, specifically its rainforest heritage habitat status, with controls against logging, mining and fire management prioritisation (Délibération n° 25-2009/APS, 2009).

Priority Conservation Actions

Results of the Conservation Activity Questionnaire

There were no responses related to *N. discoidea* in the Conservation Activity Questionnaire.

Conclusion and Recommendations

The following conclusion and recommendations have been compiled by synthesising the research, data and analysis collated in this report, as well as via expert consultation.

This species only occurs in a few localities across New Caledonia and has been listed as Endangered on the IUCN Red List (Baldwin et al., 2018). There are no *ex situ* collections of *N. discoidea* and no *in situ* conservation activities were reported in our study. The major threats are fire, mining, climate change and dieback (unknown cause), whilst the majority of this species' range does not fall within protected areas or areas where mining is prohibited.

In situ and *ex situ* conservation efforts for all *Nothofagus* species from New Caledonia are constrained by practical issues with collecting seeds and seedling establishment. An initial focus on facilitating seed collection of wild populations is therefore recommended followed by research into seedling establishment (potentially with ectomycorrhizal inoculations) to help facilitate potential breeding programmes.

Priority areas of research should focus on the phenological sequence of seed production, and fungal inoculations required for seedling establishment. In addition it is recommended that there is investigation into the apparent dieback of *N. discoidea* and surveys to determine whether it is present and to what extent in other populations.

Practical initiatives could include seed-collecting methodologies, training, and programmes to facilitate collecting of wild populations. Prony Resources nursery has a well-established breeding and reintroduction programme in place for other endemic taxa from New Caledonia. These conservation initiatives would aim to facilitate similar programmes for *N. discoidea*.

In addition, establishing genetically comprehensive *ex situ* collections is recommended. This could potentially be via seed banking, though there have been no studies to date on whether tropical *Nothofagus* species have orthodox seed storage characteristics, hence seed collection would need to be supported by research into this. The creation of *ex situ* living collections would therefore be recommended in the interim, once constraints with seedling establishment are overcome and propagation protocols are developed.

Finally, it is recommended for research into the potential threat of fire to specific populations, with a view to prioritise seed collection in populations at highest risk.

Given that *N. discoidea* has been assessed as Endangered and has no conservation activities associated with it, it is recommended that priority is given to conservation of this species (along with *Nothofagus baumanniae*) in New Caledonia.

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Nothofagus glauca (Phil.) Krasser

Synonym(s): *Fagus glauca* Phil.; *Lophozonia glauca* (Phil.) Heenan & Smissen; *Nothofagus megalocarpa* Reiche.
Common name(s): Hualo, Roble Blanco, Roble Colorado, Roble Maulino

IUCN Red List Category and Criteria: Vulnerable (VU) A2c

Species profiles authors: Paula Moraga Stefanini, University of Concepción, Chile; Olivia Steed-Mundin, Wakehurst, Royal Botanic Gardens, Kew, UK; Dan Crowley, Westonbirt, The National Arboretum, UK, BGCI; Itxaso Quintana, BGCI; Cristian Echeverria, University of Concepción.

Suggested citation: Stefanini Moraga, P., Steed-Mundin, O., Crowley, D., Quintana I., Echeverria, C. (2024). *Nothofagus glauca* (Phil.) Krasser. In Steed-Mundin, O., Crowley, D., Quintana, I., & Wenham, J. *Conservation Gap Analysis of* Nothofagus. Wakehurst, UK: Royal Botanic Gardens, Kew.

Distribution and Ecology

Nothofagus glauca is endemic to central Chile, discontinuously distributed between the Coastal range and the Andes range from Melipilla, Metropolitan Region (34°09'S) to Quilleco, Ñuble Region (37°27'S) (Figure 1). In the coastal range the species occurs between Alhué and Río Itata and occupies altitudes between 150 to 800 m a.s.l. In the Andes range it occurs between the Molina foothills to San Fabián de Alico, below 1200 m a.s.l. (Muñoz & Serra, 2007; Muñoz et al., 2013). It generally grows on steep, northern, western and eastern slopes in a Mediterranean climate and is adapted to prolonged periods of droughts (Barstow et al., 2017).

Nothofagus glauca, Reserva Nacional Los Ruiles, Chile (Paulina Hechenleiter)

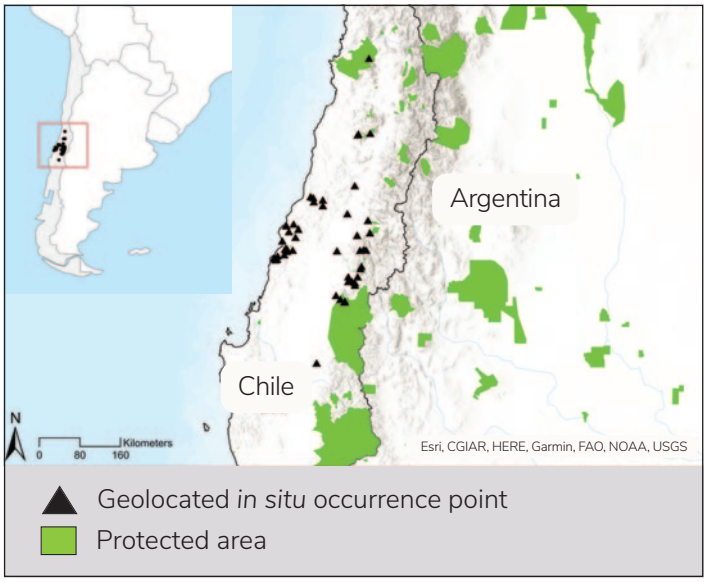

Figure 1. Documented *in situ* occurrence points for *Nothofagus glauca* and Terrestrial Protected Areas in Chile (Terrestrial Protected Areas are from UNEP-WCMC & IUCN 2022, Protected Planet).

N. glauca is a deciduous, shade-intolerant tree that can grow up to 30 m (Hechenleitner et al., 2005; Barstow et al., 2017). On lower slopes it occurs with sclerophyllous species such as *Cryptocarya alba*, *Lithraea caustica*, *Aristotelia chilensis* and *Lomatia hirsuta*. In valleys, it is associated with other *Nothofagus* species such as *N. obliqua*, *N. dombeyii*, as well as *N. x leoni* (a hybrid between *N. glauca* and *N. obliqua*) (Muñoz & Serra, 2007). It is frequent in the Roble-Hualo and Ciprés de la Cordillera forest types (Fierro-Salinas et al., 1998).

Threats to Wild Populations

Threats to wild populations were identified by reviewing *The Red List of* Nothofagus (Baldwin et al., 2018), expert consultation, literature review, and via the Conservation Activity Questionnaire. A comprehensive list of all threats identified for *N. glauca* is available in Appendix C. From the questionnaire, 18 respondents from a total of 15 organisations provided threat data for *N. glauca* (Figure 2).

The threats explored below are considered the current most significant threats, categorised into high, medium and low impact. This categorisation has been informed by the sources listed above and have been reviewed by regional experts.

High Impact Threats

Invasive species: Invasive species competition was one of the most commonly identified threats by respondents to the Conservation Activity Questionnaire (Figure 2). Indeed, post-fire invasion by exotic species such as *Pinus radiata*, *Genista monspessulana*, *Acacia melanoxylon*, and *Acacia dealbata* significantly reduce the possibility of natural regeneration for *N. glauca*, with these exotic species establishing, dominating and displacing *N. glauca* and other native species (Gómez & Bustamante, 2022; Litton & Santelices, 2002).

Disturbance regime modification including fire: Disturbance regime modification was the third most common threat identified by respondents to the Conservation Activity Questionnaire. The warmer temperatures and low humidity that predominates in the summer season linked to climate change (Santelices-Moya et al., 2020) and the greater occurrence of dry *Pinus* plantations (Barstow et al., 2017), appear to be contributing to an increasing intensity and occurrence of fires (Barstow et al., 2017). Furthermore, the populations of this species are located in areas with a predominantly Mediterranean climate and where human settlements are concentrated. These factors make these forests more prone to detrimental impact from forest fires (Santelices-Moya et al., 2020). In 2017 one of the largest forest fires known to have occurred in Chile, affected an important part of the remaining *N. glauca* forests (White et al., 2020).

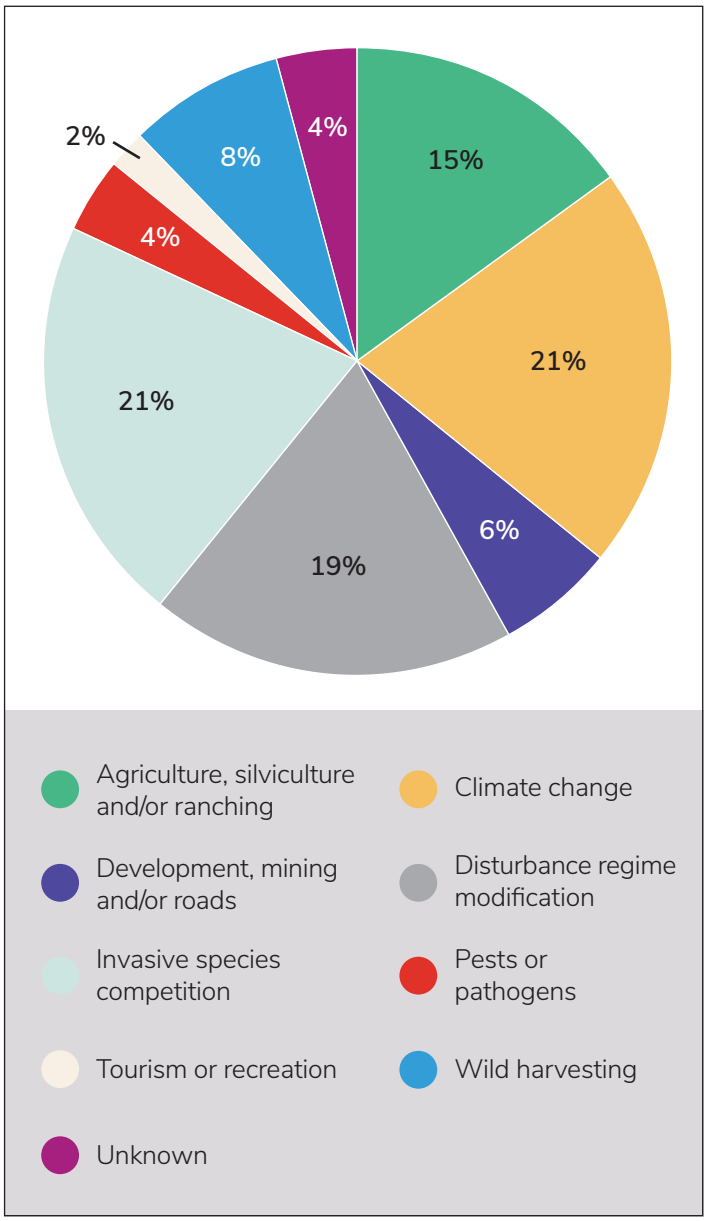

Figure 2. Threats to *Nothofagus glauca* reported by respondents to the Conservation Activity Questionnaire. The chart shows the proportion of responses relating to each threat. Only threat categories that were reported are shown. The total number of respondents was 18, from 15 organisations.

Medium Impact Threats

Climate change: Climate change was one of the most commonly identified threats by respondents to the Conservation Activity Questionnaire (Figure 2). There is evidence that future climate scenarios might lead to a reduction of suitable habitat for *Nothofagus* forests (Alarcón & Cavieres, 2015), with models also predicting that *Nothofagus* species, including *N. glauca*, will show a distributional shift towards higher elevation and higher latitude (Alarcón & Cavieres, 2018).

Land use change - agriculture and/or silviculture & Logging and/or wild harvesting: Agriculture, silviculture and /or ranching was the fourth most commonly identified threat to this species in the Conservation Activity Questionnaire, and wild harvesting was the fifth most common (Figure 2). Indeed, the area covered by the Chilean Maulino forest, composed mainly of *N. glauca*, has already decreased significantly due to anthropic activities such as agriculture and forestry (Fajardo & Alaback, 2005; Echeverría et al., 2006; Echeverría et al., 2019). *N. glauca* populations have declined considerably as a result of forest clearing and replacement with fast-growing species, resulting in the fragmentation of its populations, which now exist within a forest matrix dominated by *Eucalyptus* species and *P. radiata* plantations (Litton & Santelices, 2002; Muñoz et al., 2013; Santelices-Moya et al., 2020).

Low Impact Threats

Pests and/or pathogens: *N. glauca* populations are impacted by the pre-dispersal predation of seeds by the larvae of the microlepidoptera *Perzelia arda*. This plant-animal interaction can result in a loss of up to 57% of seeds, which can reduce the regeneration potential of this species (Burgos et al., 2008; Barstow et al., 2017).

Nothofagus glauca, Cerro Poqui, Chile (Nicolás Lavandero)

Conservation Activities

In 2021 and 2022 accession data were requested from *ex situ* collections for all *Nothofagus* species that were identified as threatened or Near Threatened in the *The Red List of* Nothofagus (i.e. 'target species') (Baldwin et al., 2018). A total of 24 organisations reported having *ex situ* collections of *N. glauca* (Table 1).

In addition, past, present, and planned conservation activities for these species were examined through literature review, expert consultation, and conduction of a questionnaire. Conservation Activity Questionnaires were sent out between 2021 and 2022. From all respondents, 17 organisations reported being actively involved in several conservation activities relating to *N. glauca*, with many undertaking multiple activities (Figure 5).

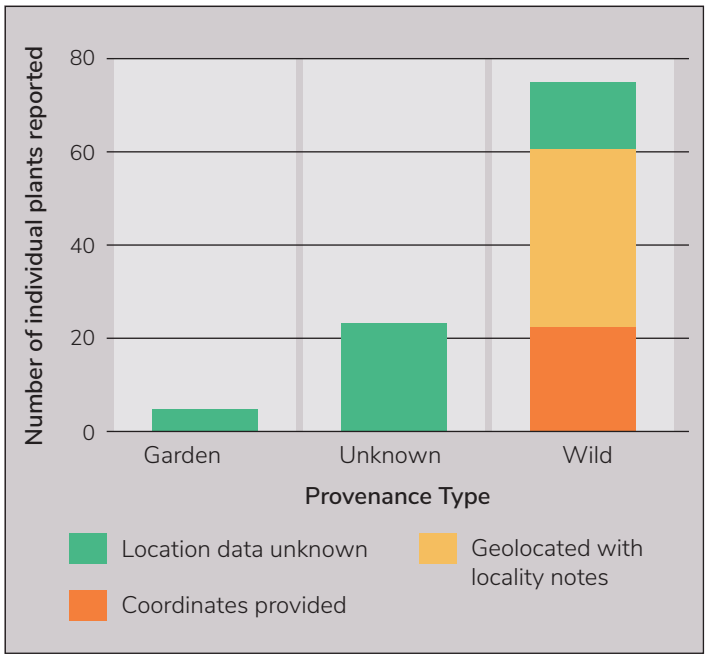

Figure 3. Quantity and origin of *Nothofagus glauca* plants in *ex situ* living collections.

Ex situ collections reported 2021- 2022

There are 78 *ex situ* accessions including living plants and seeds held at 24 organisations (Table 1). These include 102 plants in living collections(Figure 3), 22,558 seeds belonging to eight seed accessions (Table 2) and >15,000 plants in nurseries to be used in reintroduction programmes (Table 1). Five of the seed accessions and six plant accessions are held by Chilean organisations .

Table 2. Quantity and origin of *Nothofagus glauca* seeds in *ex situ* collections.

Ex situ seed accession	Quantity of seed	Provenance	Locality data
1	108	Wild	Geolocated using locality notes
2	151	Wild	Coordinates provided
3	852	Wild	Coordinates provided
4	898	Wild	Coordinates provided
5	1935	Wild	Coordinates provided
6	1975	Wild	Coordinates provided
7	15000	Wild	Coordinates provided
8	1639	Unknown	Unknown

Table 1. Results from the 2021-2022 *ex situ* survey for *Nothofagus glauca*.

Total	Number of organisations reporting *ex situ* collections	24
	Number of accessions in *ex situ* collections	78
Living collections	Number of accessions in *ex situ* living collections	70
	Number of plants in *ex situ* collections	102 in living collections 15,535 in nurseries
	Percentage of *ex situ* plants of wild origin	73%
	Percentage of wild origin plants with known locality	81%
Seed collections	Number of accessions in *ex situ* seed collections	8
	Number of seeds in *ex situ* seed collections	22,558
	Percentage of *ex situ* seed accessions of wild origin	93%
	Percentage of wild origin *ex situ* seed accessions with known locality	99%

Estimated *ex situ* representation

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* living and seed collections. Forty, 60 and 80-kilometre buffers were placed around each *in situ* occurrence point and the source locality of each accession (Figure 4). Collectively the *in situ* buffer area serves as the inferred native range of the species or "combined area *in situ*" (CAI40, CAI60, CAI80 respectively). The *ex situ* buffer areas represent the native range "captured" in *ex situ* collections or combined area *ex situ* (CAE40, CAE60, CAE80 respectively). Geographic coverage of *ex situ* collections was estimated by dividing CAE by CAI and ecological coverage was estimated by dividing the number of terrestrial ecoregions present in CAE by the number of ecoregions in CAI. Results are presented in Tables 3 & 4 in km^2 and as a percentage of area covered. The mean average percentage of coverage of all three buffer sizes is also presented.

N. glauca appears to be relatively numerous in *ex situ* collections. However, a number of populations are not captured by these *ex situ* collections (Figure 4), with plant collections only providing 54% geographic coverage (Table 3) and seed collections 46% geographic coverage (Table 4).

Nothofagus glauca, fruit containing immature seed, Wakehurst, UK (Olivia Steed-Mundin)

Table 3. Estimated *ex situ* representation of living plant collections for *Nothofagus glauca*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Geographical coverage	27,660 / 51,311 **(54%)**	43,231 / 80,612 **(54%)**	57,087 / 105,414 **(54%)**	**54%**
Ecological coverage	2 / 2 **(100%)**	3 / 4 **(75%)**	4 / 4 **(100%)**	**92%**

Table 4. Estimated *ex situ* representation of seed collections for *Nothofagus glauca*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Geographical coverage	19,479 / 51,311 **(38%)**	37,932 / 80,612 **(47%)**	57,205 / 105,414 **(54%)**	**46%**
Ecological coverage	2 / 2 **(100%)**	3 / 4 **(75%)**	4 / 4 **(100%)**	**92%**

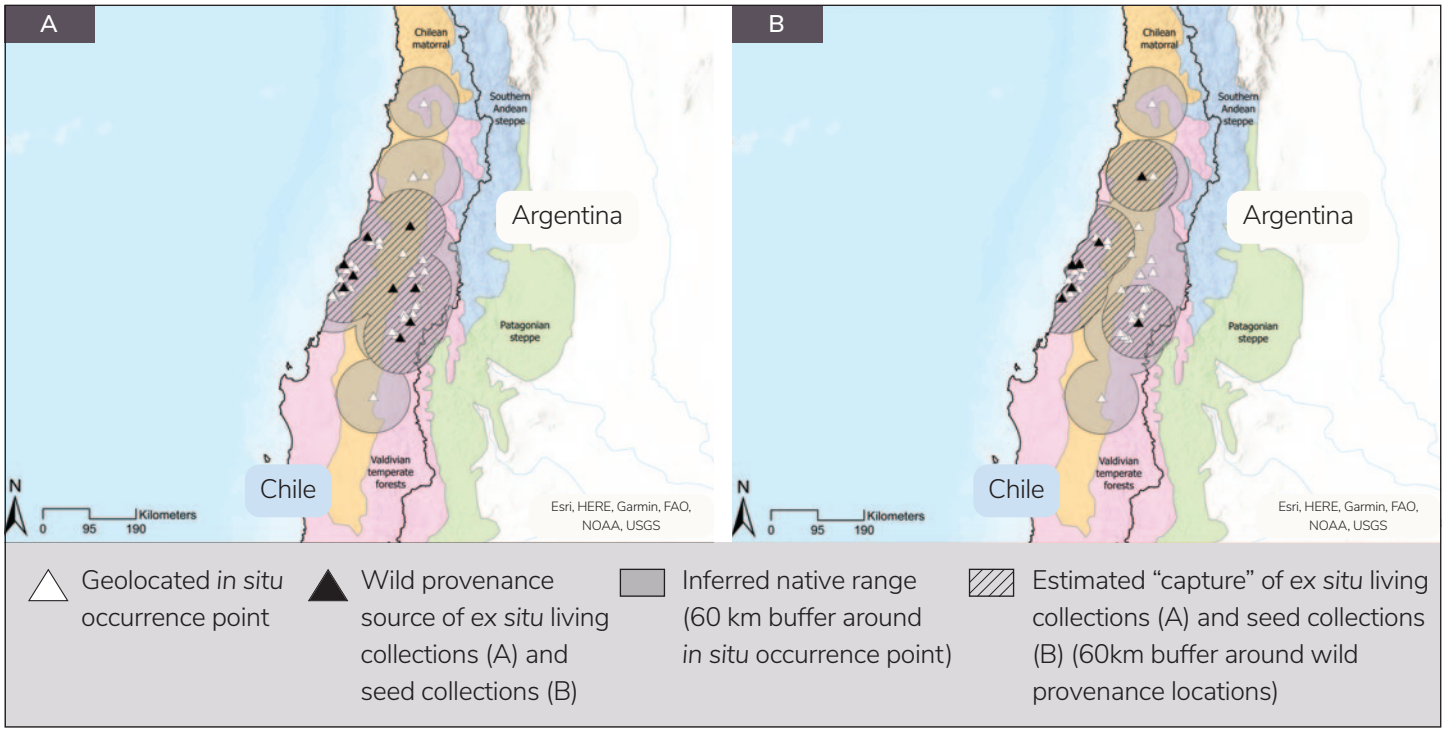

Figure 4. *Nothofagus glauca in situ* occurrence points and ex *situ* source localities for A) living collections and B) seed collections. Terrestrial Ecoregions of the World (Olson et al., 2001) are coloured and labelled. A 60 km buffer has been placed around *in situ* occurrence points to infer the native range of *N. glauca*. A 60 km buffer has been placed around the ex *situ* source location to infer the native range captured in ex *situ* collections.

Wild collecting/or *ex situ* curation

In the Conservation Activities Questionnaire, nine organisations reported they were collecting and distributing germplasm of *N. glauca* and four reported seed or pollen banking (Figure 5).

Some examples of this activity in Chile include the Seed, Genetics and Entomology Centre of the National Forestry Corporation, forestry companies and the Forestry Institute of Chile (INFOR), who have been collecting seeds of this species to produce plants for ex *situ* collections as well as restoration and reforestation projects. Whilst Radal Siete Tazas National Park and Radal Siete Tazas National Reserve also have ex *situ* collections of *N. glauca*.

Propagation and/or breeding programmes

The University of Chile is carrying out a propagation programme for *N. glauca* at their Pantanillos property, (K. Peña pers. comm., 2022). The National Forestry Corporation, the Forestry Institute of Chile and commercial forestry companies also propagate *N. glauca* to supply plants for restoration and reforestation projects. In addition, nine organisations reported to be undertaking conservation horticulture in the Conservation Activity Questionnaire (Figure 5).

Reintroduction, reinforcement, and/or translocation

Five organisations reported carrying out population reinforcement or reintroductions in the Conservation Activities Questionnaire (Figure 5). Researchers from the University Católica of Maule have conducted reintroduction programmes on a private property, where they have been collecting seeds of the species for planting (R. Santelices pers. comm., 2022). Also, the Chilean Forestry Institute produces plants of this species to reintroduce them at sites where the seeds were collected. The University of Chile has also planted *N. glauca* individuals at Pantanillos (K. Peña pers. comm., 2022).

Land protection

A second spatial analysis was conducted to estimate the protected area coverage within the species' range, by finding the spatial intersection of CAI within protected areas. Results are presented in km^2 and percentage of area covered for 40, 60 and 80-kilometre buffers. The mean average percentage of coverage of all three buffer sizes is also presented (Table 5). The protected area coverage should be considered an estimation, as buffers around *in situ* points are likely to overestimate the distribution range of the target species. Additionally, these buffers might include unprotected habitat where the target species are unlikely to occur.

Our analysis found that within the inferred native range of *N. glauca*, just 10% of the land is covered by protected areas (Table 5). *N. glauca* is found in four protected areas of the National System of State Protected Areas (SNASPE in Chile) (Figure 1): Radal Siete Tazas National Reserve and Altos de Lircay National Reserve, located in the foothills of the Andes Mountain range in the Maule region; Los Ruiles National Reserve and Los Queules National Reserve, located in the coastal mountain range of the Maule region. This species is also present in Parque Cordillera Los Quemados, a private protected area located in the Achibueno river basin in the Maule region (Fundación Hualo, 2019), as well as a private property of the University Católica of Maule (R. Santelices pers. comm., 2022).

Sustainable management of land

In the Conservation Activities Questionnaire seven organisations reported to be carrying out habitat restoration and four reported to be protecting and/or managing habitat (Figure 5).

In Los Ruiles National Reserve, the invasion of *P. radiata* is managed by mechanical and chemical methods on a permanent basis (Members of Maule region's National Forestry Corporation pers. comm., 2022). Restoration actions of *N. glauca* forest in the Maule Region have been implemented in areas owned by forestry companies and are considered to be of high conservation value (CMPC, 2018). Also, a project entitled Direct Seeding: Technique for the Recovery of Native Forests of Roble-Hualo Forest, financed by the National Forest Corporation's (CONAF) Native Forest Research Fund, is being developed on lands owned by forestry companies (Instituto Forestal de Chile, 2018).

Population monitoring and/or occurrence surveys

This activity was reported by four organisations in the Conservation Activity Questionnaire (Figure 5). This includes monitoring activities being carried out at Ruiles de Empedrado and Hualos de Loncos, properties owned by forestry companies where the post-fire regeneration of *N. glauca* and other species has been evaluated. In addition, the invasion of *P. radiata* and the threat of illegal logging of individuals of *N. glauca* is being monitored (CMPC, 2018).

Research

There was significant research activity reported in the Conservation Activity Questionnaire, largely associated with climate change (six organisations), but also on taxonomy, pests and pathogens and genetics (Figure 5). More specifically, researchers have been studying the infraspecific variation of this species in order to provide guidelines to inform future research on its genetic diversity (Santelices-Moya et al., 2020), as well as the species' response to natural and human disturbances (Fajardo & Alaback, 2005). Other studies are focused on the structure and dynamics of forest stands and seed dispersal and regeneration (Navarro-Cerrillo et al., 2020), seed production and pre-dispersal predation (Burgos et al., 2008), as well as research on pre-germination treatments for germination and seedling establishment (Cabello et al., 2019), nursery cultivation of the species (Santelices et al., 1996), and effect of temperature on the germination of seeds from five provenances of *N. glauca* (Santelices-Moya et al., 2022). Recent research has described the spatial pattern of forest dominated by *N. glauca* and *Nothofagus alessandrii* as a reference for ecological restoration purposes (Fajardo et al., 2022).

Table 5. Estimated protected area coverage for *Nothofagus glauca*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Protected area coverage	5,072 / 51,311 **(10%)**	7,987 / 80,612 **(10%)**	10,577 / 105,414 **(10%)**	**10%**

Education, outreach, and/or training

Eight organisations reported carrying out public awareness or education initiatives in the Conservation Activity Questionnaire (Figure 5). In Los Ruiles National Reserve for example, education is implemented through talks and guided tours for visitors where the importance of protecting the *Nothofagus* species present in the Maulino forest ecosystem is highlighted (Members of Maule region's National Forestry Corporation pers. comm., 2022). Education and training are also carried out at Pantanillo, which is owned by the University of Chile.

Species protection policies

Three organisations who completed the Conservation Activity Questionnaire reported that they are carrying out activities associated with implementing protection policies or regulations (Figure 5). However, it should be noted that under Chile's Regulations for the Classification of Wild Species (RCE in Spanish), *N. glauca* was declared in 2007 as 'out of danger' (Muñoz & Serra, 2007) and it can therefore be harvested legally under the application of The Forest Management Plan of Native Forest (CONAF, 2018).

Nothofagus glauca, Reserva Nacional Los Ruiles, Chile (Nicolás Lavandero)

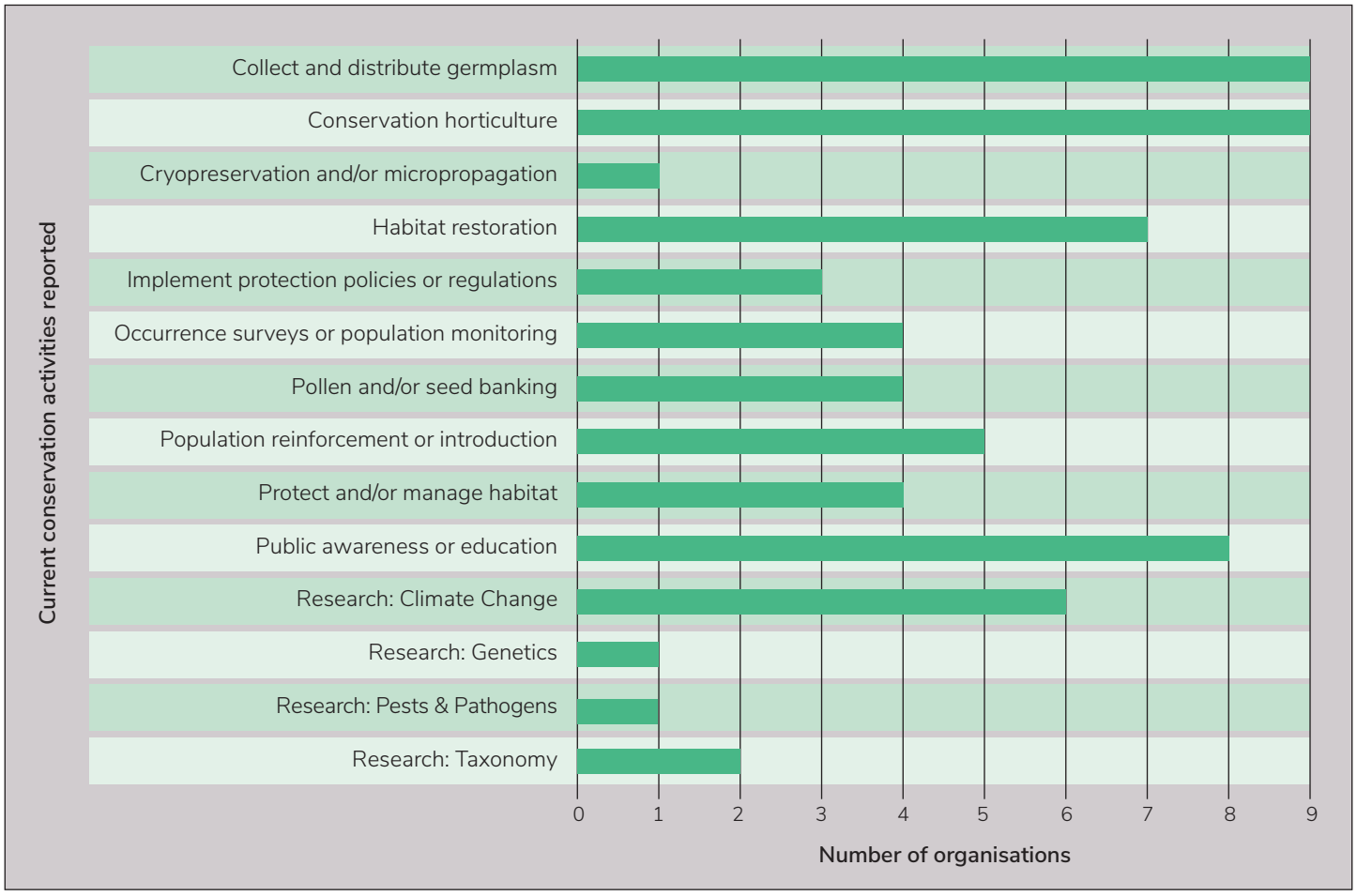

Figure 5. Number of organisations reporting specific conservation activities for *Nothofagus glauca* in the Conservation Activity Questionnaire. Total number of organisations who reported conservation activities associated with *N. glauca* was 17.

Priority Conservation Actions

Results of Conservation Activity Questionnaire

A Conservation Activity Questionnaire was sent out to identify priority conservation actions that should be undertaken for the future conservation of *N. glauca*. There were 19 respondents from 16 organisations. The priority actions identified most frequently by respondents were: implementation of protection policies, protection and/or management of habitat, public awareness or education and habitat restoration (Figure 6).

Conclusion and Recommendations

The following conclusion and recommendations have been compiled by using the research, data and analysis collated in this report, as well as expert consultation.

N. glauca is categorised as Vulnerable on the IUCN Red List (Baldwin et al., 2018), particularly threatened by fire, invasive species, climate change and land use change. A number of important restoration and conservation activities have already been undertaken, which are helping to recover degraded forests and conserve the species both *in situ* and *ex situ*. It is recommended that these continue, along with supplementary focus in the following areas:

Firstly, the current distribution and status of wild populations of *N. glauca* needs to be assessed with a view to producing updated distribution maps. The 2017 and 2023 fires may have affected southern populations of *N. glauca* on the coast and Andes ranges, and survey work is required to establish the extent of their impact.

Population analysis could potentially lead to a change of the conservation status assigned by RCE (Regulations for the Classification of Wild Species, in Chile) and the IUCN Red List assessment, and would underpin the protection policies that have been identified as required for the conservation of this species. Indeed, since our analysis estimates that so little of the species' natural range falls within protected areas (10%) such protection policies would be particularly important to support conserving this species *in situ*. The most southerly population of *N. glauca* is found in a small isolated, unprotected fragment, therefore, protection and restoration is urgently required.

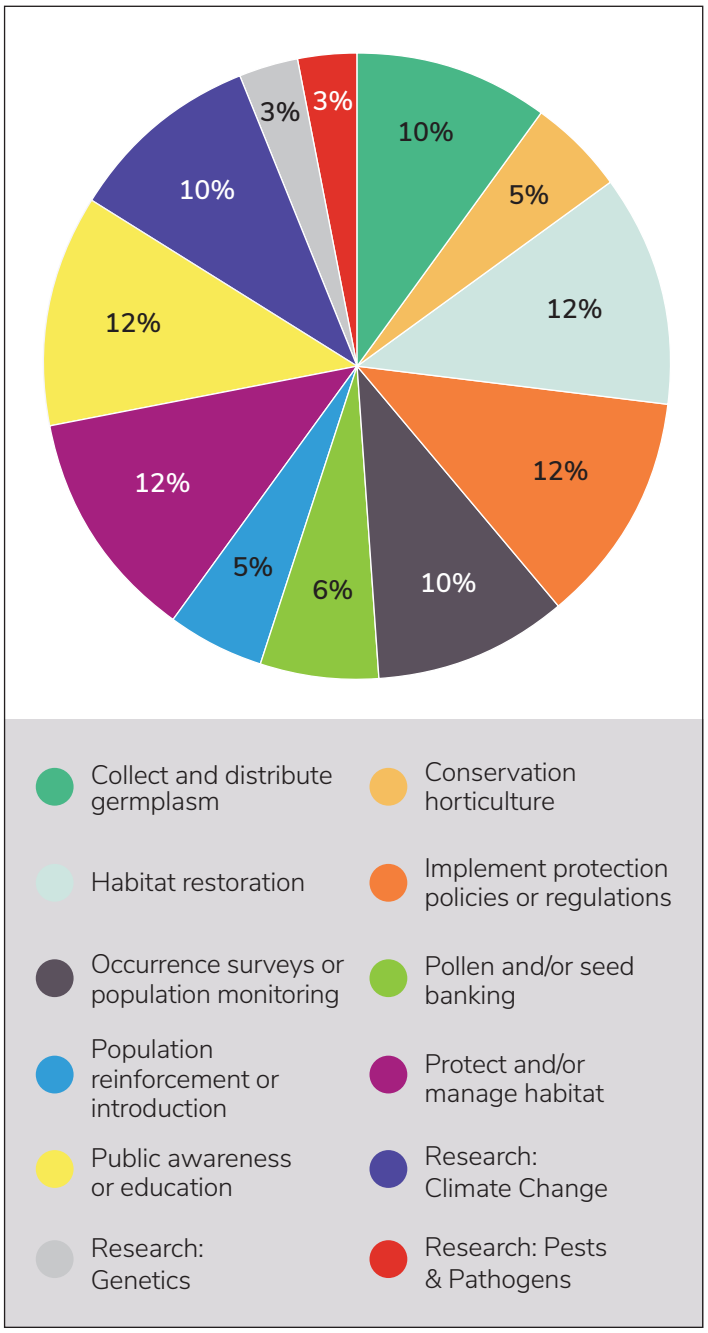

Figure 6. Priority conservation actions needed for the future conservation of *Nothofagus glauca* reported by respondents to the Conservation Activity Questionnaire. Chart shows the proportion of responses identifying conservation actions as a priority. Only action categories that were identified are shown. The total number of respondents was 19, from 16 organisations.

Nothofagus glauca, Reserva Nacional Los Ruiles, Chile (Nicolás Lavandero)

Given that remnant populations of *N. glauca* occur in a matrix of exotic species plantations, resources are required to manage the invasion of these exotic species at a larger scale and to enable *N. glauca* to regenerate and establish.

In situ conservation should be supported by genetically representative *ex situ* collections, especially given the threat from fire to wild populations. Our analysis highlighted a number of populations that are not represented in seed and/or plant collections (e.g. the most southerly populations), so these should be prioritised.

Finally, it should be noted that in 2022 a conservation project funded by Fondation Franklinia was initiated to target the conservation, ecological restoration and capacity building to benefit the three threatened *Nothofagus* species native to South America, including *N. glauca*. The project is led by Universidad de Concepción, working with Chilean institutions Universidad de Chile, Instituto Forestal (INFOR), Universidad Católica del Maule, Universidad de Talca, INIA and Club del Árbol de Talca, with support from BGCI. Some of the recommendations noted here will be actioned as part of this project.

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Nothofagus gunnii (Hook.f.) Oerst.

Synonym(s): *Fagus gunnii* (Hook.f.); *Fuscospora gunnii* (Hook.f.) Heenan & Smissen
Common name(s): Deciduous Beech, Tanglefoot Beech, The Fagus

IUCN Red List Category and Criteria: Near Threatened B1ab(iii)

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Distribution and Ecology

Endemic to west and central Tasmania, Australia (Figure 1), *Nothofagus gunnii* is the only deciduous species of *Nothofagus* occurring naturally outside of South America and is restricted to cool montane regions at moderate-high altitudes (Read & Brown, 1996). It is most abundant at altitudes between 900 and 1200 m a.s.l. and is usually restricted to the most fire protected areas, and on the western and central plateau mountains in areas with high rainfall. It is predominantly found in communities of short rainforest and montane and subalpine rainforest scrub (Kitchener & Harris, 2013), but is absent from the east of the island (Figure 1). It often grows in association with *Athrotaxis selaginoides* or *Athrotaxis cupressoides*, but sometimes associates with montane conifers such as *Diselma archeri* and *Microcachrys tetragona* (Kitchener & Harris, 2013).

Nothofagus gunnii, Tarn Shelf Mt Field, Tasmania (Jo Wenham)

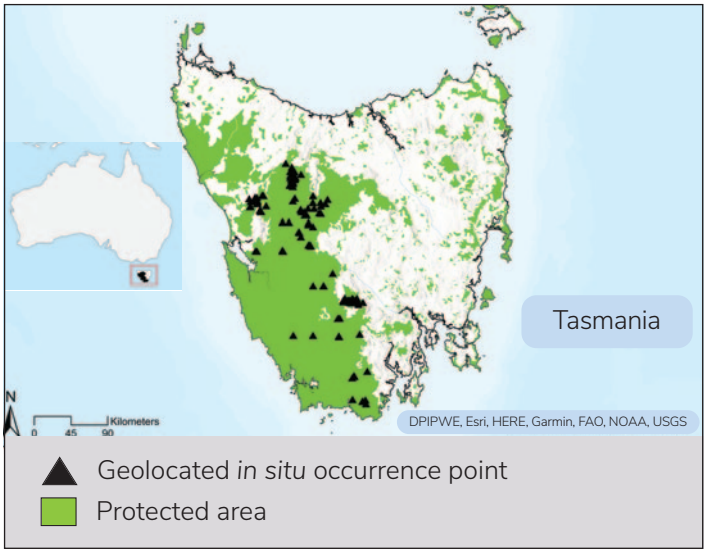

Figure 1. Documented *in situ* occurrence points for *Nothofagus gunnii* and Terrestrial Protected Areas in Australia (Terrestrial Protected Areas are from UNEP-WCMC & IUCN 2022, Protected Planet). Please note that we have amended *N. gunnii* occurrence points from the IUCN Red List Assessment (Baldwin et al., 2018a) based on regional experts consultation and data points from Natural Values Atlas (Department of Natural Resources and Environment Tasmania, 2023).

In sheltered sites *N. gunnii* can grow to 15 m, but it is predominantly a medium straggling shrub between 0.5-5 m. (Read & Brown, 1996). It flowers from October to February, and fruits from March to May (Hewson, 1989; Johnson, 2020). Seed has low viability except in mast years (Read, 1989).

Threats to Wild Populations

Threats to wild populations were identified by reviewing *The Red List of* Nothofagus (Baldwin et al., 2018b), expert consultation, literature review, and via the Conservation Activity Questionnaire. A comprehensive list of all threats identified for *N. gunnii* is available in Appendix C. From the questionnaire, five respondents from a total of five organisations provided threat data for *N. gunnii* (Figure 2).

The threats explored below are considered the current most significant threats, categorised into high and low impact. This categorisation has been informed by the sources listed above and have been reviewed by regional experts.

High Impact Threats

Climate change: Climate change was the most common threat to *N. gunnii* identified by respondents to the Conservation Activity Questionnaire (Figure 2) and was an important threat identified in the species' IUCN Red List assessment (Baldwin et al., 2018a). The major threat from climate change comes from the change in fire regimes (G. Jordan pers. comm., 2022) and the reduction in resilience to fire shown by extant populations (Mariani et al., 2019). It is also worth noting *Nothofagus* species have poorly dispersed seeds in general, which may limit their ability to migrate to higher altitude as the climate changes (Read & Hope, 1996). In addition, extreme weather events can cause localised death of vegetation - as witnessed in *N. gunnii* populations at Cradle Mountain in 2014 (Visoiu & Whinam, 2015). Although such events are still rare, they are likely to become more regular as a result of climate change (Visoiu & Whinam, 2015).

Disturbance regime modification including fire: Disturbance regime modification was identified as a threat by one of the five respondents to the Conservation Activity Questionnaire (Figure 2), and the IUCN Red List also identified fire as an important threat to the species (Baldwin et al., 2018a). Indeed, fire is the main disturbance in South East Australia and in the last 200 years fire activity has increased in Tasmania and now exceeds any point in the last 12,000 years (Mariani & Fletcher, 2017). *N. gunnii* appears to be extremely fire-sensitive and its regeneration is limited post-fire (Read & Brown, 1996). This restricts its distribution to the most fire-protected locations (Read & Brown, 1996). The impact of fire may be exacerbated by the poor seed dispersal of the species, which restricts its capacity to colonise burnt areas (G. Jordan pers. comm., 2022). A significant fire in the Central Plateau in 2016 did not reach *N. gunnii* populations, however it did affect montane rainforest (G. Jordan pers. comm., 2022).

Low Impact Threats

Pests and/or pathogens: Although pests and/or pathogens was identified as a threat in the Conservation Activity Questionnaire (Figure 2), diseases that affect other *Nothofagus* species in Australia such as *Phytophthora* and myrtle wilt have not been officially recorded for *N. gunnii*.

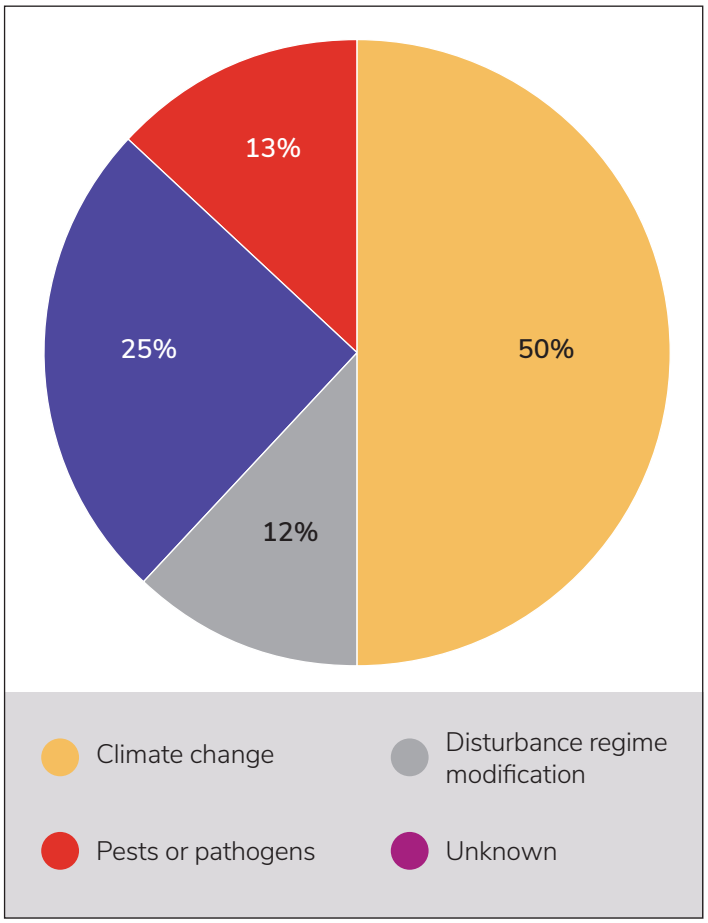

Figure 2. Threats to *Nothofagus gunnii* reported by respondents to the Conservation Activity Questionnaire. The chart shows the proportion of responses relating to each threat. Only threat categories that were reported are shown. The total number of respondents was five.

Conservation Activities

In 2021 and 2022 accession data were requested from *ex situ* collections for all *Nothofagus* species that were identified as threatened or Near Threatened in *The Red List of* Nothofagus (i.e. 'target species') (Baldwin et al., 2018b). A total of six organisations reported having *ex situ* accessions of *N. gunnii* (Table 1).

In addition, past, present, planned and future conservation activities for these species were also examined through literature review, expert consultation, and conduction of a questionnaire. Conservation Activity Questionnaires were sent out 2021 and 2022. From all respondents, five organisations reported being actively involved in several conservation activities relating to *N. gunnii* (Figure 5).

Ex situ collections reported 2021–2022

There are 18 *ex situ* accessions including living plants and seeds held in the six organisations (Table 1). These include 27 plants in living collections (Figure 3) and 26,079 seeds belonging to seven seed accessions (Table 2). Of the six organisations who hold accessions, four of them are in the country of origin.

Table 1. Results from the 2021-2022 *ex situ* survey for *Nothofagus gunnii*.

Total	Number of organisations reporting *ex situ* collections	6
	Number of accessions in *ex situ* collections	18
Living collections	Number of accessions in *ex situ* living collections	11
	Number of plants in *ex situ* collections	27 in living collections 4 in nurseries
	Percentage of *ex situ* plants of wild origin	100%
	Percentage of wild origin plants with known locality	66%
Seed collections	Number of accessions in *ex situ* seed collections	7
	Number of seeds in *ex situ* seed collections	26,079
	Percentage of *ex situ* seed accessions of wild origin	100%
	Percentage of wild origin *ex situ* seed accessions with known locality	100%

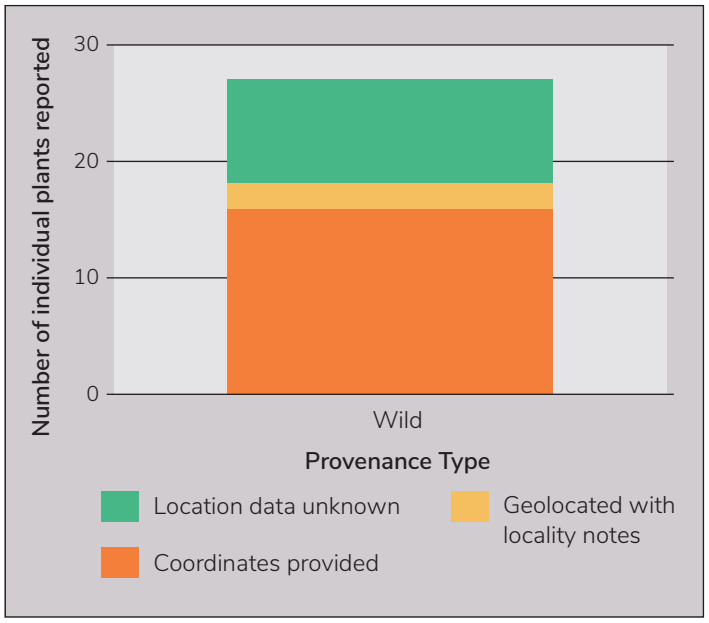

Figure 3. Quantity and origin of *Nothofagus gunnii* plants in *ex situ* living collections.

Table 2. Quantity and origin of *Nothofagus gunnii* seeds in *ex situ* collections.

Ex situ seed accession	Quantity of seed	Provenance	Locality data
1	75	Wild	Coordinates provided
2	77	Wild	Coordinates provided
3	147 (estimated from 0.507 grams)	Wild	Coordinates provided
4	1456	Wild	Coordinates provided
5	3226	Wild	Coordinates provided
6	7080	Wild	Coordinates provided
7	14018	Wild	Coordinates provided

Estimated *ex situ* representation

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* living and seed collections. Forty, 60 and 80-kilometre buffers were placed around each *in situ* occurrence point and the source locality of each *ex situ* accession (Figure 4). Collectively the *in situ*- buffer area serves as the inferred native range of the species or "combined area *in situ*" (CAI40, CAI60, CAI80 respectively). The *ex situ* buffer areas represent the native range "captured" in *ex situ* collections or combined area *ex situ* (CAE40, CAE60, CAE80 respectively). Geographic coverage of *ex situ* collections was estimated by dividing CAE by CAI and ecological coverage was estimated by dividing the number of terrestrial ecoregions present in CAE by the number of ecoregions in CAI. Results are presented in Tables 3 & 4 in km^2 and as a percentage of area covered, the mean average percentage of coverage of all three buffer sizes is also presented.

Nothofagus gunnii, Seed collecting, Tarn Shelf Mt Field, Tasmania (Jo Wenham)

N. gunnii is not particularly well represented in *ex situ* collections. Our research found only 27 plants of wild provenance (Figure 3) and seven seed accessions, most of which were collected in Mount Field National Park and in Mount Read (Figure 4). Although some other populations are represented in *ex situ* collections, the number of individuals in each accession is low and there is no representation from more southerly populations (Figure 4). *Ex situ* plant collections represent just 54% of geographic coverage (Table 3), and seed collections represent 55% geographic coverage (Table 4). However, in relation to seed collections, it is worth noting that despite the relatively poor geographical representation, there is in fact a significant number of seeds in *ex situ* collections (>26,000).

Wild collecting and/or *ex-situ* curation

Although no organisations reported collecting and distributing germplasm in the Conservation Activity Questionnaire, four organisations did report to be carrying out conservation horticulture and another one reported to be carrying out pollen and seedbanking (Figure 5).

Table 3. Estimated *ex situ* representation of living plant collections for *Nothofagus gunnii*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Geographical coverage	10,023 / 30,512 **(33%)**	21,075 / 38,876 **(54%)**	33,467 / 45,338 **(74%)**	**54%**
Ecological coverage	2 / 2 **(100%)**	2 / 2 **(100%)**	3 / 3 **(100%)**	**100%**

Table 4. Estimated *ex situ* representation of seed collections for *Nothofagus gunnii*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Geographical coverage	10,200 / 30,512 **(33%)**	21,397 / 38,876 **(55%)**	34,041 / 45,338 **(75%)**	**55%**
Ecological coverage	2 / 2 **(100%)**	2 / 2 **(100%)**	3 / 3 **(100%)**	**100%**

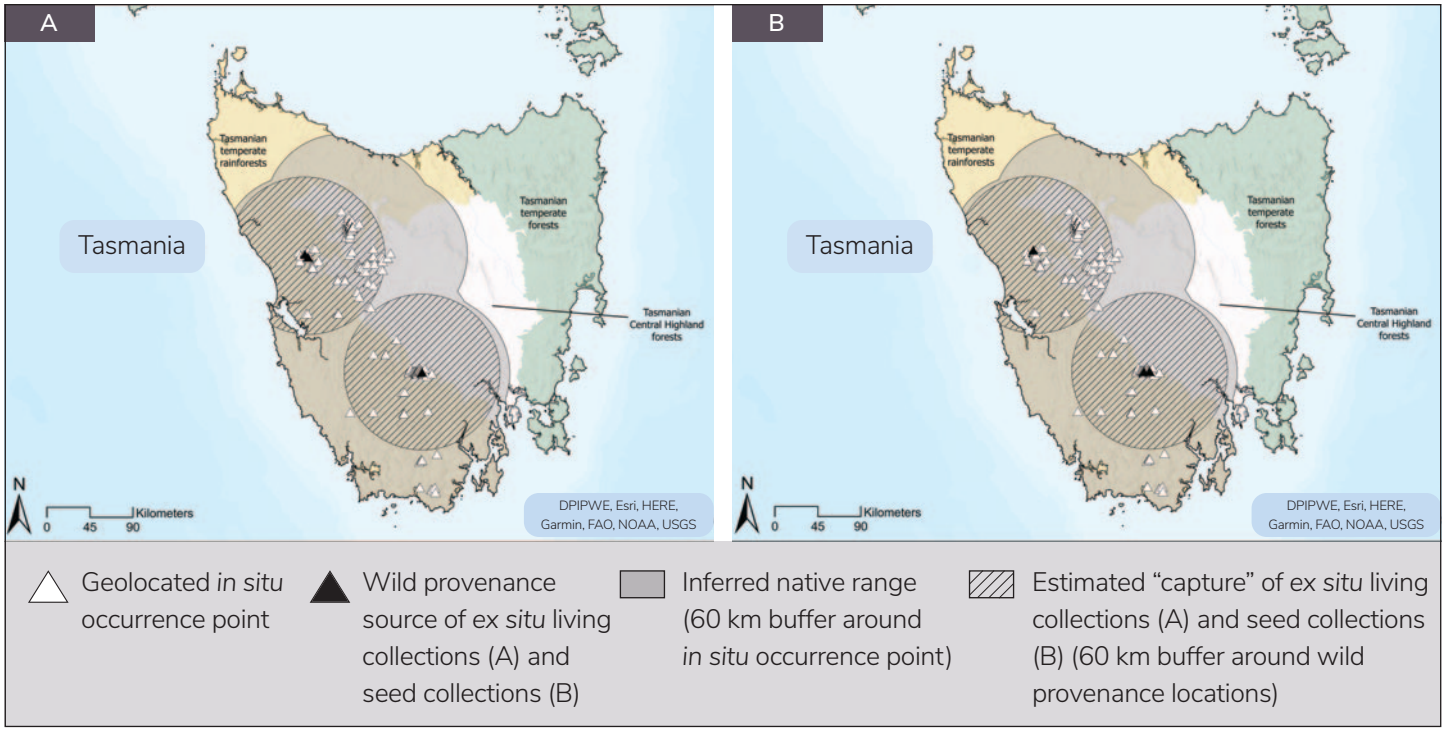

Figure 4. *Nothofagus gunnii in situ* occurrence points and *ex situ* source localities for A) living collections and B) seed collections. Terrestrial Ecoregions of the World (Olson et al., 2001) are coloured and labelled. A 60km buffer has been placed around *in situ* occurrence points to infer the native range of *N. gunnii*. A 60km buffer has been placed around the *ex situ* source location to infer the native range captured in *ex situ* collections. Please note that we have amended *N. gunnii* occurrence points from the IUCN Red List Assessment (Baldwin et al., 2018a) based on regional experts consultation and data points from Natural Values Atlas (Department of Natural Resources and Environment Tasmania, 2023).

A number of collaborators in botanic gardens have reported challenges to establishing *N. gunnii ex situ*, with seedlings often failing to reach maturity. In addition, there are further reports of poor performance in cultivation generally, which some anecdotal evidence suggests may be associated with thermal regimes (G. Jordan pers. comm., 2022). Greater understanding of these issues is required before more significant living collections can be established *ex situ*.

There are limited studies investigating seed longevity of *N. gunnii ex situ*, however, a study into Chilean *Nothofagus* concluded that five species show orthodox seed storage behaviour but the quality of seed lots requires attention and further study (León-Lobos & Ellis, 2005). Germination tests carried out by the Tasmanian Seed Conservation Centre (TSCC) on stored seeds for three years achieved 60-90% germination (J. Wood pers. comm., 2022), whilst initial germination tests carried out by the Millennium Seed Bank also suggest that *Nothofagus* seeds have in general orthodox storage requirements (R. Davies pers. comm., 2021). However, some species in the Millennium Seed Bank are showing a small decline in viability, so further study and testing will be undertaken from 2022 to collect data (R. Davies pers. comm., 2021).

Propagation and/or breeding programmes

There was only one micropropagation/ cryopreservation activity reported in the Conservation Activity Questionnaire and no other activities associated with breeding programmes (Figure 5).

Germination trials and seedling establishment trials are currently underway at Wakehurst, RBG Kew. The team successfully germinated and pricked out seedlings, adding a granular mycorrhizal to the compost. Survival rate was poor post-germination, however the two remaining seedlings are now growing well in pots/potting mediums that mimic natural rock crevices (see image p. 119). Understanding and addressing the issues associated with seedling establishment would be a prerequisite to enable future breeding programs.

Reintroduction, reinforcement and/or translocation

There were no reintroduction programmes for *N. gunnii* reported in this study. Addressing the issues associated with seedling establishment would be needed to facilitate this if required.

Land protection

A second spatial analysis was conducted to estimate the protected area coverage within the species' range, by finding the spatial intersection of CAI within protected areas. Results are presented in km^2 and percentage of area covered for 40, 60 and 80-kilometre buffers. The mean average percentage of coverage of all three buffer sizes is also presented (Table 5). The protected area coverage should be considered an estimation, as buffers around *in situ* points are likely to overestimate the distribution range of the target species. Additionally, these buffers might include non-protected habitat where the target species are unlikely to occur.

Our analysis found that within the inferred native range of *N. gunnii*, 59% of the land is covered by protected areas (Table 5). This is notably lower than other studies, for example early mapping of *N. gunnii* populations at 1:100,000 scale estimated that around 70% was in protected reserves (Robertson & Duncan, 1991). More recent mapping from high resolution aerial imagery estimated 73% of populations occur within dedicated formal conservation reserves and 26% occur within other reserve types providing less secure protection (Department of Natural Resources and Environment Tasmania, 2020). Results obtained from these two specific studies on *N. gunnii* are likely to be more accurate than those estimated from buffers around *in situ* points (G. Jordan pers. comm., 2023).

Sustainable management of land

Although there were no specific activities reported in the Conservation Activity Questionnaire associated with sustainable land management (Figure 5), it should be noted that a significant proportion of *N. gunnii* populations occur within formal conservation reserves (Parks and Wildlife Service, 1999), with ongoing management practices and specific management plans in place to protect plant communities and biodiversity. Lake Johnston Nature Reserve for example, which lies within the biggest single patch of *N. gunnii*, has a management plan in place to protect the native flora within it (Parks and Wildlife Service, 1999). In addition, the Tasmanian Wilderness World Heritage Area fire management plan has recommended the preparation of 'Reserve Values Fire Protection Plans' for areas with concentrations of important biological value such as significant populations of *N. gunnii* (Department of Natural Resources and Environment Tasmania, 2022).

Population monitoring and/or occurrences surveys

There were no monitoring programmes of *N. gunnii* reported in the Conservation Activity Questionnaire (Figure 5). However, all bush fires are mapped in Tasmania and where they intersect with known areas of high conservation value these are reported. Where necessary impacts are assessed with ground staff. No fire has intersected with areas of *N. gunnii* since this system of management has been introduced (J. Balmer pers. comm., 2022).

Research

There was only one research activity reported in the Conservation Activity Questionnaire, which related to taxonomy (Figure 5), however, other relevant research has been published. This includes a recent study on how climate change reduces resilience to fire in subalpine rainforests (Mariani et al., 2019). In addition, a study into the effects of recent lightning induced forest fires on *Athrotaxis cupressoides* and its associated paleoendemic species (such as *N. gunnii*) (Jordan et al., 2015) provided information about current and future pressures on these plant communities (Bowman et al., 2021).

Table 5. Estimated protected area coverage for *Nothofagus gunnii*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Protected area coverage	20,020 / 30,512 **(66%)**	22,809 / 38,877 **(59%)**	24,047 / 45,339 **(53%)**	**59%**

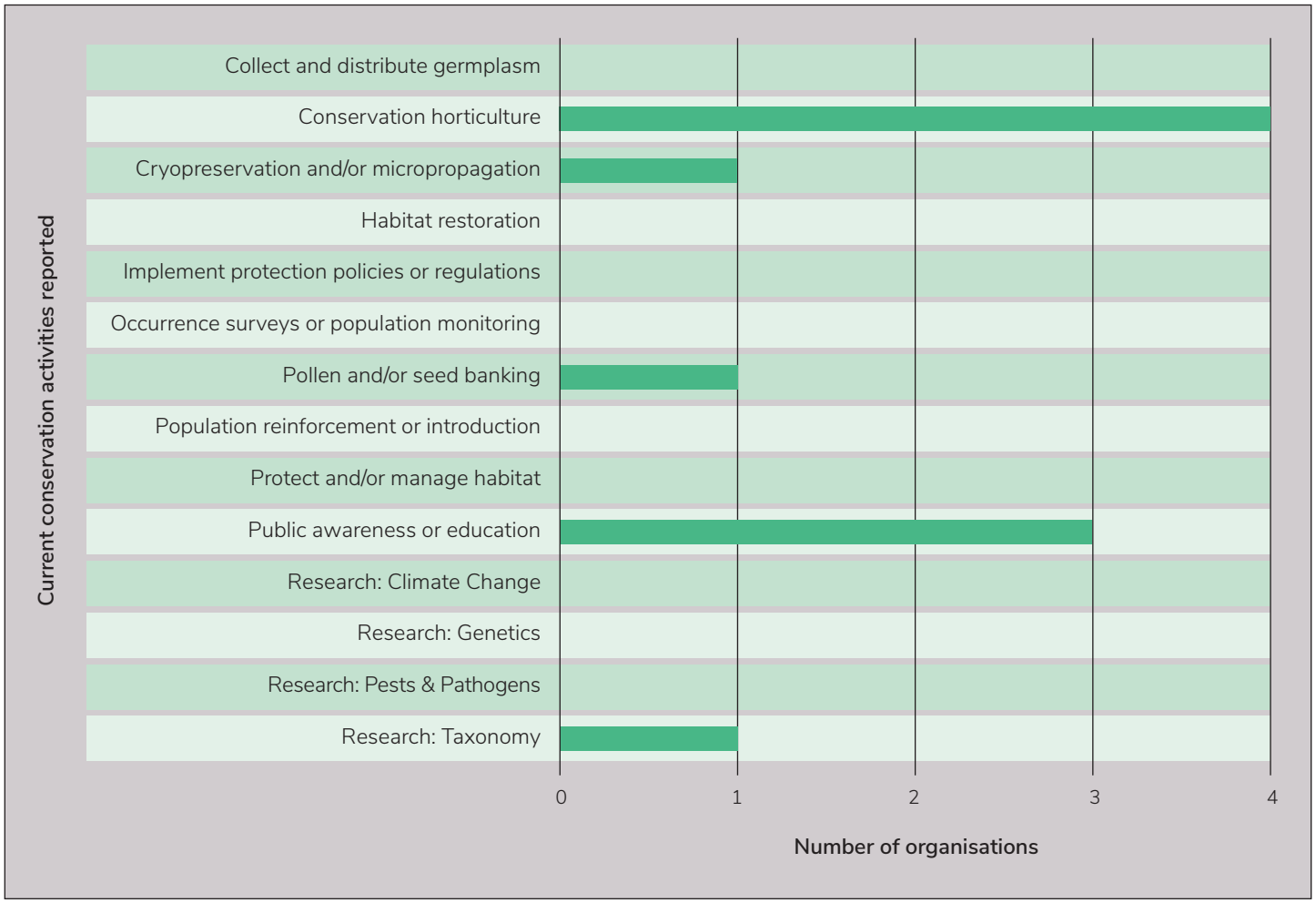

Figure 5. Number of organisations reporting specific conservation activities for *Nothofagus gunnii* in the Conservation Activity Questionnaire. Total number of organisations who reported conservation activities for *N. gunnii* was five.

Education, outreach, and/or training

Public awareness or education was one of the most common activities reported in the Conservation Activity Questionnaire, with three organisations reporting it (Figure 5) including Inala Jurassic Garden and National Botanic Garden of Wales.

Species protection policies

Although there were no responses in relation to species protection policies in the Conservation Activities Questionnaire (Figure 5), two of the three vegetation communities in which *N. gunnii* is a co-dominant (Athrotaxis cupressoides – *N. gunnii* rainforest and scrub; *Athrotaxis selaginoides*– *N. gunnii* rainforest and scrub), are listed on the Tasmanian Schedule of Threatened Native Vegetation Communities, which gives these communities additional legislative protection irrespective of land tenure (Tasmanian Government, 2023; Department of Natural Resources and Environment Tasmania, 2021).

In addition, *N. gunnii* is a species which occurs predominantly on land managed by Tasmania's Parks and Wildlife Service (J. Balmer pers. comm., 2022). It is a highly valued and well-known species, being Australia's only winter deciduous plant. *N. gunnii* rainforest and scrub vegetation, along with other paleoendemic rainforest communities, has a higher priority status for protection from bushfires, than most other natural values (J. Balmer pers. comm., 2022).

Nothofagus gunnii seedling, 'crevice planting', Wakehurst nursery, UK (Chris Jenkins)

Priority conservation actions

Results of the Conservation Activity Questionnaire

A Conservation Activity Questionnaire was sent to identify priority conservation actions that should be undertaken for the future conservation of *N. gunnii*. There were six respondents from six organisations. Protection and/or management of habitat, public awareness or education and pollen and/or seed banking were highlighted most frequently as priority actions that are needed for the future conservation of the species (Figure 6).

Conclusion and Recommendations

The following conclusion and recommendations have been compiled by using the research, data and analysis collated in this report, as well as expert consultation.

The IUCN Red List Assessment found *N. gunnii* to be Near Threatened (Baldwin et al., 2018b), with major threats including fire and climate change. Our research has shown limited *ex situ* plant and seed collections, which do not represent the full range of the species. There are also challenges to conservation including difficulties with seedling establishment and *ex situ* cultivation, knowledge gaps surrounding the viability of this species in seed banks, as well as a lack of published data on population genetics. That said, a significant proportion of the extant populations occur in established and well managed conservation reserves.

Conservation priorities should include continued seed banking and long-term storage of the under-represented populations of *N. gunnii* across its natural distribution especially from the most threatened and under-represented populations. A population genetics study would be welcomed to guide collection priorities and ensure genetically representative collections.

Research and monitoring programmes investigating the current distribution, effects of climate change and increased wildfire occurrences near to *N. gunnii* populations would also be welcomed.

Conducting propagation and seedling establishment trials is a major priority. This could enable the production of propagation protocols, increase success of propagation, and facilitate future breeding programmes. It would also be useful to research the broader issues with cultivation *ex situ*, which would also help facilitate more significant and representative *ex situ* living collections. The species would benefit from storage and germination trials to determine the longevity of seed stored in seed banks.

Finally, it is recommended that the amended occurrence data used in this analysis is used to update the IUCN Red List Assessment.

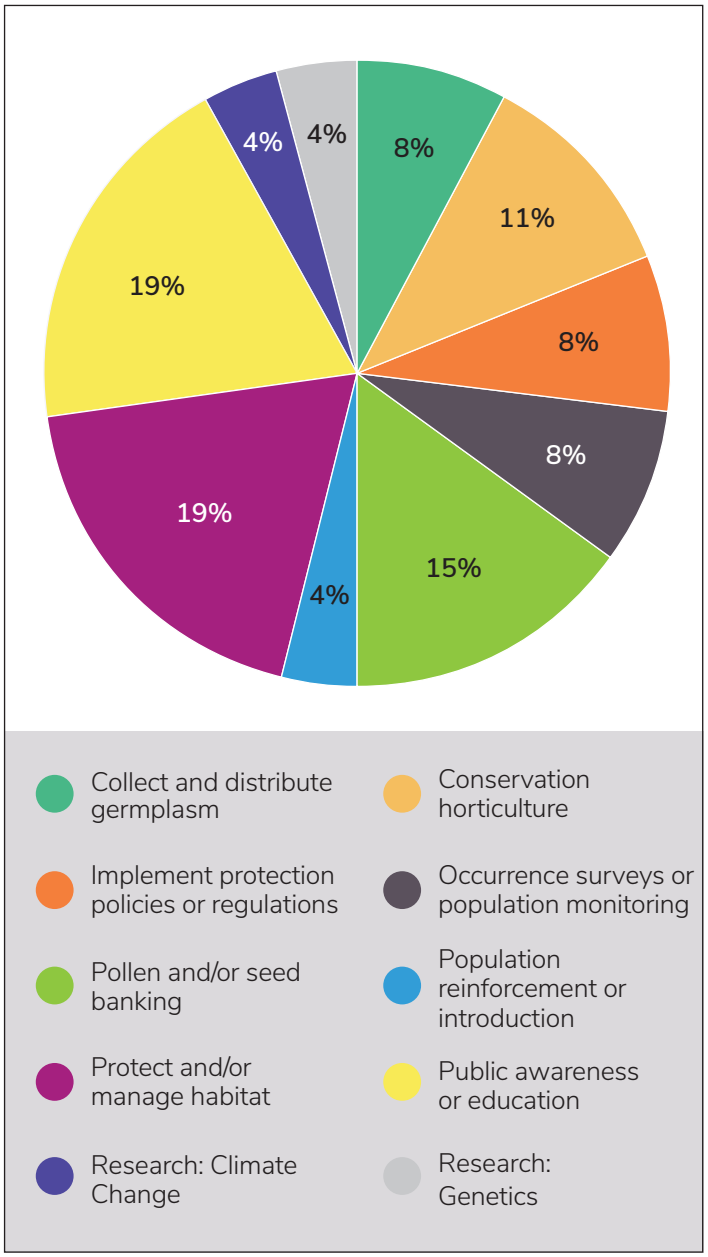

Figure 6. Priority conservation actions needed for the future conservation of *Nothofagus gunnii* reported by respondents to the Conservation Activity Questionnaire. The chart shows the proportion of responses identifying conservation actions as a priority. Only action categories that were identified are shown. The total number of respondents was six.

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Nothofagus macrocarpa (A.DC.) F.M.Vázquez & R.A.Rodr.

Synonym(s): *Fagus obliqua* var. *macrocarpa* A.DC.; *Nothofagus obliqua* var. *macrocarpa* (A.DC.) Reiche; *Lophozonia macrocarpa* (A.DC.) Heenan & Smissen.
Common name(s): Roble de Santiago, Roble, Hualle, Pellín, Roble pellín, Hualo, Roble blanco

IUCN Red List Category and Criteria: Vulnerable (VU) B1ab(iii)

Species profiles authors: Alejandra Martínez-Moraga, University of Concepción, Chile; Olivia Steed-Mundin, Wakehurst, Royal Botanic Gardens, Kew, UK; Dan Crowley, Westonbirt, The National Arboretum, UK, BGCI; Itxaso Quintana, BGCI; Cristian Echeverria, University of Concepción.

Suggested citation: Martínez-Moraga, A., Steed-Mundin, O., Crowley, D., Quintana I., Echeverria, C. (2024). *Nothofagus macrocarpa* (Phil.) Krasser. In Steed-Mundin, O., Crowley, D., Quintana, I., & Wenham, J. *Conservation Gap Analysis of* Nothofagus. Wakehurst, UK: Royal Botanic Gardens, Kew.

Distribution and Ecology

Commonly known as Roble de Santiago (Santiago's oak), *Nothofagus macrocarpa* is native to central Chile (Ravenna, 2002). In the Coastal Range, the species is discontinuously distributed in the coastal cordillera sector, from Cerro Campanita, Valparaíso region (32°55' S), to the south of Melipilla, Libertador Bernardo O'Higgins region (34°06' S). It also occurs in the Cordillera de Los Andes sector from San Fernando (34°50' S) to Longavi (36°14' S) (Figure 1). It occupies altitudes between 500–2,000 m a.s.l. (Baldwin, 2018) and is a deciduous tree reaching 10-25 m tall, with a trunk diameter of up to 1.2 m.

N. macrocarpa forests represent the northern limit of the distribution of the genus in South America (Gajardo, 2001). The species occurs in temperate and Mediterranean type ecosystems (Venegas-González et al., 2018a). *N. macrocarpa* is usually a dominant forest tree (Baldwin, 2018), which can often occur in pure stands particularly at higher elevations (Mathiasen et al., 2020). Its current distribution largely consists of small, fragmented populations at high elevation, which are considered remnants of a past wide-spread distribution that developed under different climatic conditions. Extant stands are often second-growth forests, persisting in a matrix of intensive land use (Mathiasen et al., 2020).

At lower elevations *N. macrocarpa* is commonly associated with species such as *Lomatia hirsuta*, *Azara dentata*, *Maytenus boaria*, *Schinus montana*, *Ribes punctatum*, *Berberis actinacantha*, and *Calceolaria meyeniana* (Baldwin, 2018; Mathiasen et al., 2020).

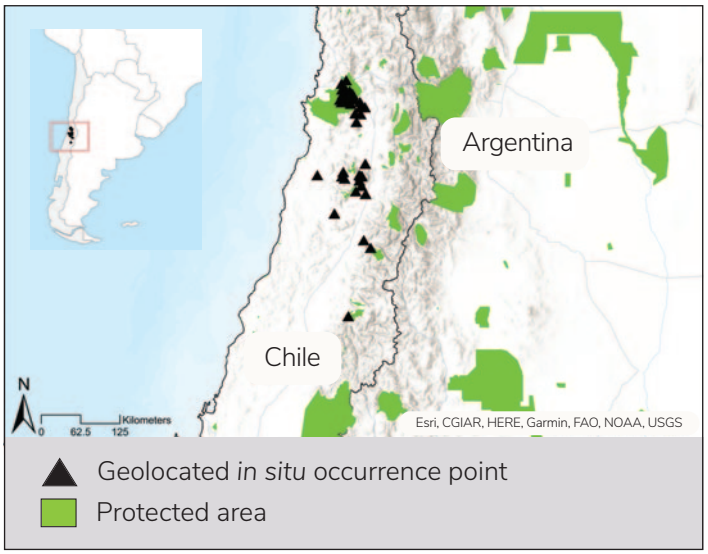

Figure 1. Documented *in situ* occurrence points for *Nothofagus macrocarpa* and Terrestrial Protected Areas in Chile (Terrestrial Protected Areas are from UNEP-WCMC & IUCN, 2022, Protected Planet).

Threats to Wild Populations

Threats to wild populations were identified by reviewing *The Red List of* Nothofagus (Baldwin et al., 2018), expert consultation, literature review, and via the Conservation Activity Questionnaire. A comprehensive list of all threats identified for *N. macrocarpa* is available in Appendix C. From the questionnaire, five respondents from a total of four organisations provided threat data for *N. macrocarpa* (Figure 2).

The threats explored below are considered the current most significant threats, categorised into high, medium and low impact. This categorisation has been informed by the sources listed above and have been reviewed by regional experts.

High Impact Threats

Climate change: Climate change was the most commonly identified threat by respondents to the Conservation Activity Questionnaire (Figure 2). The formation of *N. macrocarpa* forest occurred thousands of years ago under different climatic conditions to those experienced now (Donoso et al., 2010). Extant populations, found largely at high altitude, are dependent on the continuation of specific microclimatic conditions (Golowasch et al., 1982), and have limited capacity to migrate as the climate changes.

Some researchers also indicate that the decrease in the number of seedlings may be a result of climatic changes towards aridity accelerated by anthropogenic disturbances (Paskoff, 1970; Varela, 1976). Low growth rates have also been related to prolonged droughts (Venegas-González et al., 2018b) and to the marginal conditions of the sites where most *N. macrocarpa* individuals are found (Donoso et al., 2010).

Natural regeneration issues: *N. macrocarpa* shows a lack of natural regeneration (Gajardo, 2001; Pacheco, 2008), and has the lowest growth rate of all Chilean *Nothofagus* (Donoso et al., 2010). The species displays irregular seed production cycles, and produces a high percentage of empty seeds, due to seed abortion and insect attacks (Cabello, 2004). In addition, many extant stands are second-growth forests that have not yet reached sexual maturity and hence do not produce seed (Donoso, 1982; Cabello, 2004; Mathiasen et al., 2020). Additionally, in cases where seeds are found, the large amount of soil organic matter usually prevents seed germination, and stands often have very closed canopies which impede regeneration (Donoso, 1982).

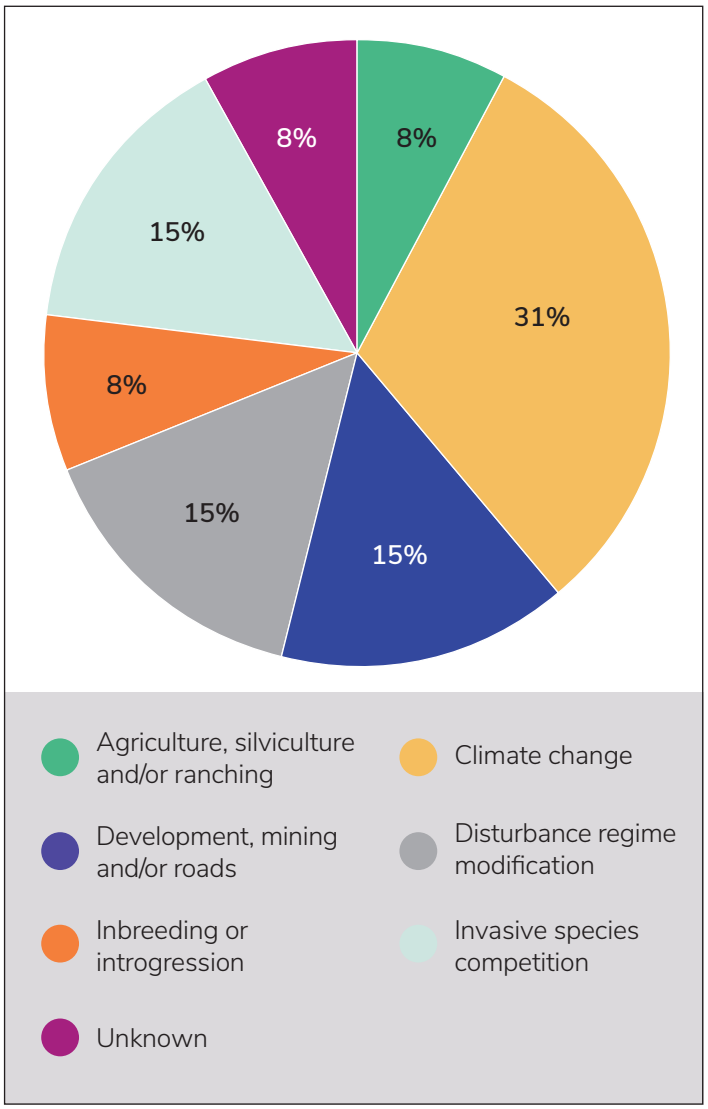

Figure 2. Threats to *Nothofagus macrocarpa* reported by respondents to the Conservation Activity Questionnaire. Chart shows the proportion of responses relating to each threat. Only threat categories that were reported are shown. The total number of respondents was five, from four organisations.

Medium Impact Threats

Land use change - agriculture and/or silviculture: The forest ecosystems of central Chile have been subjected to intensive exploitation pressure for more than 300 years (Baldwin, 2018; Donoso et al., 2010). Forests have been historically used for charcoal burning and overgrazing, which has had a negative impact on the species (Rundel & Weisser, 1975).

Invasive species: Invasive species competition was a commonly identified threat from the Conservation Activity Questionnaire (Figure 2). Degradation of the tree canopy favours swift colonisation of sclerophyllous forests that can displace *Nothofagus* forests (Luebert & Pliscoff, 2004). However, the greatest threat is the commercial monoculture of exotic species such as *Pinus radiata* and *Eucalyptus globulus* (A. Maureira pers. comm., 2022). In some areas, plantations of these species are replacing *N. macrocarpa* habitat in areas previously degraded by forest logging (A. Maureira pers. comm., 2022).

Development, mining, and/or roads: Development mining and/or roads was commonly identified as a threat for the species in Conservation Activity Questionnaire (Figure 2). A high proportion of *N. macrocarpa* trees in Cerro El Roble have been cut down for mining activities since the 15th century (Rundel & Weisser, 1975; Golowasch et al., 1982).

Low Impact Threats

Tourism and/or recreation: *N. macrocarpa* forests in the Santuario de la Naturaleza Cerro El Roble (Metropolitana region) have been damaged by the impact of visitors and their discarded waste. In 2018, the association of Comuneros de La Capilla de Caleu decided to close the Santuario to focus more on conservation than on tourism (Errazuriz, 2019). It should be noted however, that this threat was not identified in the Conservation Activity Questionnaire (Figure 2).

Nothofagus macrocarpa, Cerro El Roble, Chile (Nicolás Lavandero)

Conservation Activities

In 2021 and 2022 accession data were requested from *ex situ* collections for all *Nothofagus* species that were identified as threatened or Near Threatened in *The Red List of* Nothofagus (i.e. 'target species') (Baldwin et al., 2018). A total of nine organisations reported accessions of *N. macrocarpa* (Table 1).

Past, present, and planned conservation activities for these species were examined through literature review, expert consultation, and conduction of a questionnaire. Conservation Activity Questionnaires were sent out between 2021 and 2022. From all respondents, four organisations reported being actively involved in several conservation activities relating to *N. macrocarpa* (Figure 5).

Ex situ collections reported 2021- 2022

There are 12 *ex situ* accessions including living plants and seeds held at nine organisations (Table 1). These include 23 plants in living collections (Figure 3) and 22,369 seeds belonging to two seed accessions (Table 2). Of the nine organisations holding *ex situ* collections, one is a Chilean organisation, INIA, who holds the two known seed accessions of this species (Table 2).

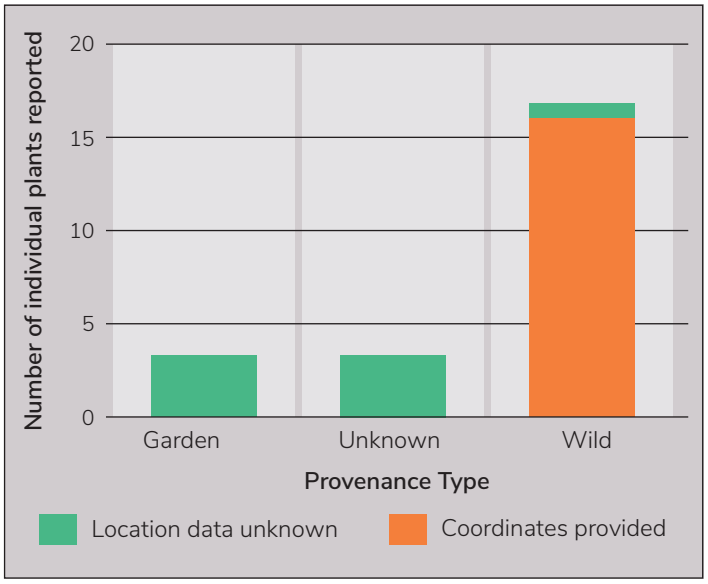

Figure 3. Quantity and origin of *Nothofagus macrocarpa* plants in *ex situ* living collections.

Table 2. Quantity and origin of *Nothofagus macrocarpa* seeds in *ex situ* collections.

Ex situ seed accession	Quantity of seed	Provenance	Locality data
1	1538	Wild	Coordinates provided
2	20831	Wild	Coordinates provided

Table 1. Results from the 2021-2022 *ex situ* survey for *Nothofagus macrocarpa*.

Total	Number of organisations reporting *ex situ* collections	9
	Number of accessions in *ex situ* collections	12
Living collections	Number of accessions in *ex situ* living collections	10
	Number of plants in *ex situ* collections	23 in living collections 1 in nurseries
	Percentage of *ex situ* plants of wild origin	74%
	Percentage of wild origin plants with known locality	94%
Seed collections	Number of accessions in *ex situ* seed collections	2
	Number of seeds in *ex situ* seed collections	22,369
	Percentage of *ex situ* seed accessions of wild origin	100%
	Percentage of wild origin *ex situ* seed accessions with known locality	100%

Estimated *ex situ* representation

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* living and seed collections. Forty, 60 and 80-kilometre buffers were placed around each *in situ* occurrence point and the source locality of each *ex situ* accession (Figure 4). Collectively the *in situ* buffer area serves as the inferred native range of the species or "combined area *in situ*" (CAI40, CAI60, CAI80 respectively). The *ex situ* buffer areas represent the native range "captured" in *ex situ* collections or combined area *ex situ* (CAE40, CAE60, CAE80 respectively). Geographic coverage of *ex situ* collections was estimated by dividing CAE by CAI and ecological coverage was estimated by dividing the number of terrestrial ecoregions present in CAE by the number of ecoregions in CAI. Results are presented in Tables 3 & 4 in km^2 and as a percentage of area covered. The mean average percentage of coverage of all three buffer sizes is also presented. It should be noted these results should be considered an estimation. Due to the restricted and fragmented distribution of *Nothofagus* species in Chile, particularly for *N. macrocarpa* and *N. alessandrii*, the size of the buffers might lead to an overestimation of both *in situ* occurrence and *ex situ* collection representation. Even if a coarse spatial scale aids the identification of gaps in *ex situ* collections, studies at a finer spatial scale are recommended for more specific results.

The results show that *N. macrocarpa* is not well represented in *ex situ* collections relative to other temperate *Nothofagus* species. There are just 23 plants in living collections, all from a similar collection locality (Figure 4A), capturing just 20% of the geographic range for this species (Table 3). Although there are a significant number of seeds in *ex situ* collections (c.22,000), they represent just two wild collections and both come from a similar collection locality (Figure 4B), only capturing 19% geographic coverage of the natural range (Table 4).

Nothofagus macrocarpa fruits, Altos de Cantillana, Chile (Nicolás Lavandero)

Table 3. Estimated *ex situ* representation of living plant collections for *Nothofagus macrocarpa*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Geographical coverage	5,006 / 34,361 **(15%)**	11,073 / 52,882 **(21%)**	18,176 / 70,175 **(26%)**	**20%**
Ecological coverage	2 / 3 **(67%)**	3 / 3 **(100%)**	3 / 3 **(100%)**	**89%**

Table 4. Estimated *ex situ* representation of seed collections for *Nothofagus macrocarpa*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Geographical coverage	4,966 / 34,361 **(14%)**	10,080 / 52,882 **(19%)**	16,215 / 70,175 **(23%)**	**19%**
Ecological coverage	2 / 3 **(67%)**	2 / 3 **(67%)**	3 / 3 **(100%)**	**78%**

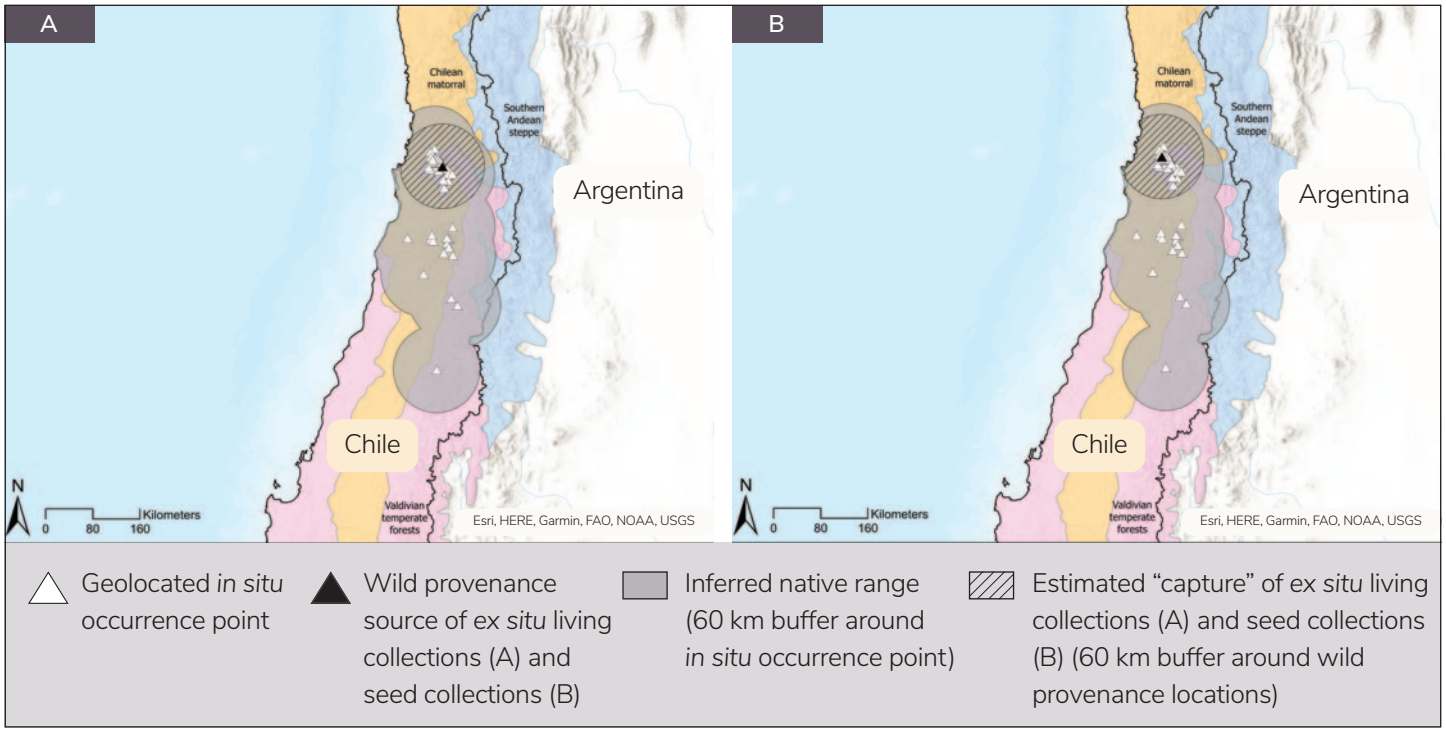

Figure 4. *Nothofagus macrocarpa in situ* occurrence points and *ex situ* source localities for A) living collections and B) seed collections. Terrestrial Ecoregions of the World (Olson et al., 2001) are coloured and labelled. A 60km buffer has been placed around *in situ* occurrence points to infer the native range of *N. macrocarpa*. A 60km buffer has been placed around the *ex situ* source location to infer the native range captured in *ex situ* collections.

Nothofagus macrocarpa, Altos de Cantillana, Chile (Nicolás Lavandero)

Table 5. Estimated protected area coverage for *Nothofagus macrocarpa*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Protected area coverage	3,126 / 34,361 **(9%)**	4,279 / 52,882 **(8%)**	4,563 / 70,175 **(7%)**	**8%**

Wild collecting and/or *ex situ* curation

No current seed banking activities were identified in the Conservation Activity Questionnaire and only one organisation, The National Botanic Garden in Viña del Mar, reported that they were collecting germplasm (Figure 5). However, employees of Roblería del Cobre de Loncha National Reserve have collected seeds to send them to Corporación Nacional Forestal's (CONAF) Seed, Genetics and Entomology Center, Chile. CONAF has also studied the viability of *N. macrocarpa* seeds and its propagation (A. Maureira pers. comm., 2022). In addition, two organisations who responded to the Conservation Activity Questionnaire reported carrying out Conservation Horticulture (Figure 5).

Propagation and/or breeding programmes

In 2007, The University of Chile worked on a vegetative propagation programme in Cerro El Roble Natural Sanctuary, but trials were not successful. More recently, the University began to work on a few breeding programmes to propagate the species in some areas of the Maule region, (K. Peña pers. comms., 2022). In addition, nurseries in Santiago such as Vivero Nativos de Cantillana and Vivero Pumahuida are propagating and selling seedlings of native species including *N. macrocarpa* (CONAF, 2019).

Reintroduction, reinforcement and/or translocation

In the Conservation Activities Questionnaire only one organisation reported carrying out population reinforcement or reintroductions (Figure 5). The University of Chile has worked on a native forest project funded by CONAF to study the seeding and planting of *N. macrocarpa* in Cerro El Roble Natural Sanctuary from 2009 to 2011 (K. Peña pers. comm., 2022).

Land protection

A second spatial analysis was conducted to estimate the protected area coverage with the species' range, by finding the spatial intersection of CAI within protected areas. Results are presented in km^2 and percentage of area covered for 40, 60 and 80-kilometre buffers, the mean average percentage of coverage of all three buffer sizes is also presented (Table 5). The protected area coverage should be considered an estimation, as buffers around *in situ* points are likely to overestimate the distribution range of the target species. Additionally, these buffers might include non-protected habitat where the target species are unlikely to occur.

Within the inferred native range of *N. macrocarpa*, on average 8% of the land is covered by protected areas (Table 5). Protected areas where *N. macrocarpa* occurs in the Libertador General Bernardo O'Higgins region are: Alto Huemul Natural Sanctuary, Cerro Poqui Natural Sanctuary and Roblería del Cobre de Loncha National Reserve (Figure 1). In the Metropolitan region the protected areas are: Cerro El Roble Natural Sanctuary, San Juan de Piche Natural Sanctuary and Altos de Cantillana (Figure 1). In the Valparaiso region *N. macrocarpa* is found in La Campana National Park (Figure 1).

Sustainable management of land

In the Conservation Activities Questionnaire one organisation reported to be carrying out habitat restoration for *N. macrocarpa* and two reported to be protecting and/or managing habitat (Figure 5).

The Altos de Cantillana's management plan includes activities such as invasive exotic species control, monitoring of critical points against irresponsible tourism, and prevention and control of fires (Corporación Altos de Cantillana, 2024). Also, during fire season, Altos de Cantillana closes the reserve to visitors and works with CONAF's staff in fire watchtowers to prevent fires in the forests (F. Romero pers. comm., 2022).

Nothofagus macrocarpa, Roblería del Cobre de Loncha, Chile (Alejandro Maureira)

Population monitoring and/or occurrence surveys

This activity was reported by two organisations in the Conservation Activity Questionnaire (Figure 5).

The University of Chile established permanent plots in the Cerro El Roble Natural Sanctuary for monitoring population dynamics, though no further information was available at the time of writing (K. Peña pers. comm., 2022). Academics from Mayor University, Santiago de Chile, worked in Altos de Cantillana and Altos de Huemul monitoring *N. macrocarpa*'s dendrochronology and seed regeneration (A. Venegas pers. comm., 2022). In addition, these researchers undertake permanent surveillance patrols in Roblería del Cobre de Loncha National Reserve to monitor the population and mitigate threats such as illegal oak logging or fires (A. Maureira pers. comm., 2022).

Altos de Cantillana Corporation works with park rangers to monitor *N. macrocarpa* and address its threats. They have an exclusion trial plot in one *N. macrocarpa* forest to monitor forest recovery. Also, a project focused on mountain conservation funded by the Global Environment Facility (GEF) is monitoring in the same area, particularly studying *Leucheria cantillanensis*, a perennial herb, which is associated with *N. macrocarpa* forest (F. Romero pers. comm., 2022).

Research

Although only one organisation reported carrying out research into *N. macrocarpa* in the Conservation Activity Questionnaire (Figure 5), there has been significant research into this species, with a number of additional studies currently in progress.

Multiple studies using dendrochronological methods for *N. macrocarpa* populations, have been developed (González, 2010; Venegas-González et al., 2018a; Venegas-González et al., 2019). Because *N. macrocarpa* is considered a relic species, academics are using it as a climate change indicator. Experts from the University of Chile and Mayor University have also recently published research about how climate change is affecting the growth of *N. macrocarpa* in central Chile (Mathiasen et al., 2020; Matskovsky et al., 2021; Venegas-González et al., 2018b). Currently, research focused on mycorrhizal fungi associated with *N. macrocarpa* is being carried out by the University of Chile (A. Venegas pers. comm., 2022). In addition, researchers from both universities are working on a project funded by the Native Forest Research Fund granted by CONAF, in which they are sampling wild populations of *N. macrocarpa* where dendrological growth patterns can be found (A. Maureira pers. comm., 2022). Also, information on structure, composition, and plant communities related to *N. macrocarpa* have been recently researched, including work analysing genetic variability within these communities (A. Venegas pers. comm., 2022).

Finally, experts from different universities and research centres recently commenced a collaborative project for the three threatened *Nothofagus* species in Chile, *N. glauca*, *N. alessandrii* and *N. macrocarpa* (K. Peña pers. comm., 2022). This project is funded by Fondation Franklinia.

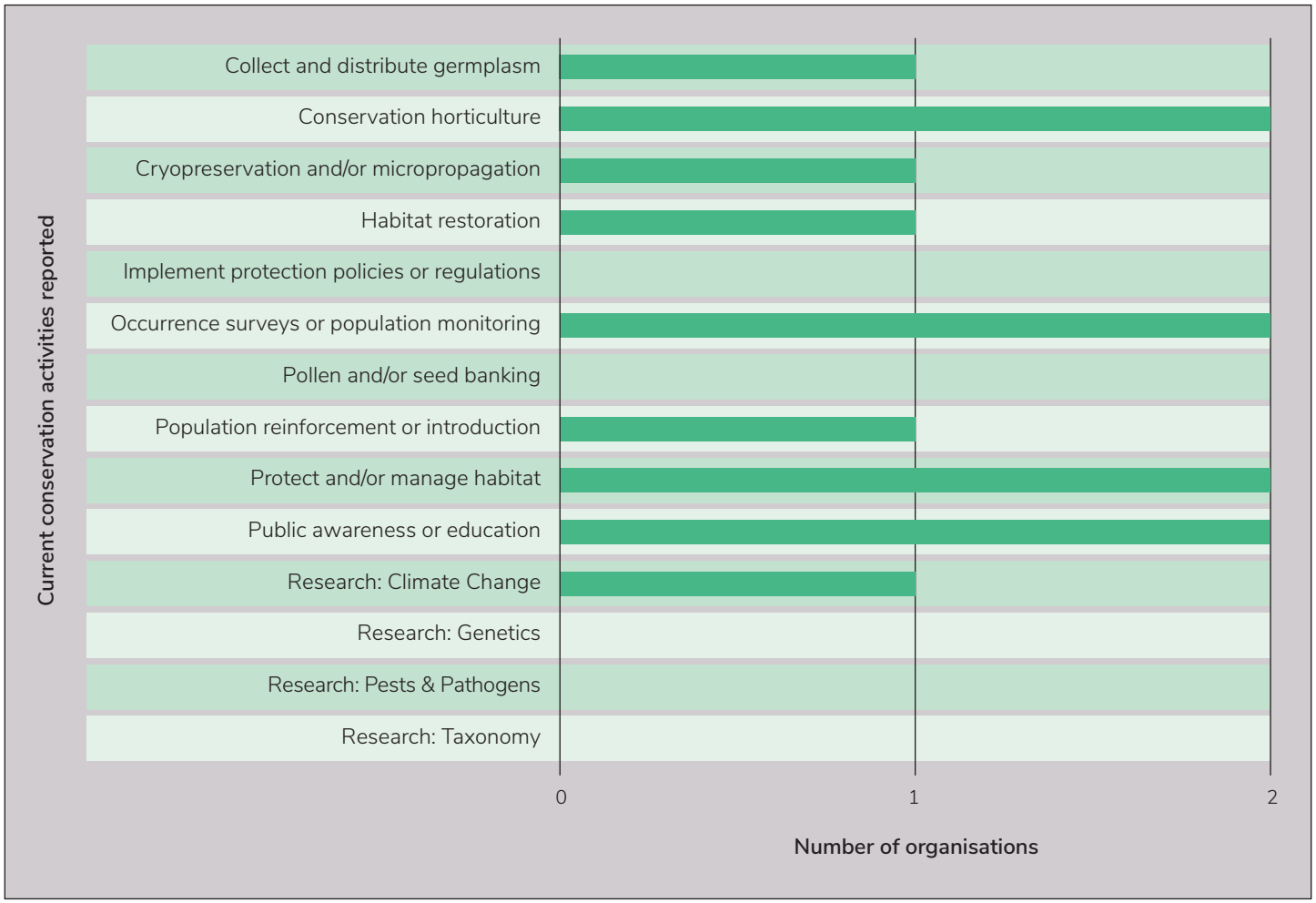

Figure 5. Number of organisations reporting specific conservation activities for *Nothofagus macrocarpa* in the Conservation Activity Questionnaire. Total number of organisations who reported conservation activities for *N. macrocarpa* was four.

Education, outreach and/or training

Public awareness or education was reported as being undertaken by two organisations in the Conservation Activity Questionnaire (Figure 5) . For example, Roblería del Cobre de Loncha National Reserve delivers environmental education programmes about the native forests, including highlighting the importance of *N. macrocarpa* forests (A. Maureira pers. comm., 2022). Whilst Altos de Cantillana Corporation delivers a permanent environmental education programme in two primary schools in the municipalities of Rangue and Pintue, through which they teach students about regional biodiversity including *N. macrocarpa* forests. They also provide an introduction to environmental education and information regarding the presence of *N. macrocarpa* relics to visitors of Altos de Cantillana Reserve (F. Romero pers. comm., 2022).

Species protection policies

In 2020, Chile's Regulations for the Classification of Wild Species (RCE in Spanish) recategorized *N. macrocarpa* as a vulnerable species (Burguer et al., 2020). This category allows the legal protection of *N. macrocarpa* in Chile, forbidding logging and allowing the application of protection regulation through the Environmental Impact Assessment System and Native Forest Law (Droppelmann, 2020). However, more resources need to be made available to convert this theoretical status into conservation action (A. Venegas pers. comm., 2022).

It should also be noted that no activities associated with species protection policies were reported in the Conservation Activity Questionnaire (Figure 5).

Priority Conservation Actions

Results from the Conservation Activity Questionnaire

A Conservation Activity Questionnaire was sent out to identify priority conservation actions that should be undertaken for the future conservation of *N. macrocarpa*. There were five respondents from five organisations. Protection and/or management of habitat, and carrying out occurrence surveys or population monitoring were highlighted most frequently as priority actions needed for the future conservation of the species. (Figure 6).

Conclusion and Recommendations

The following conclusion and recommendations have been compiled by using the research, data and analysis collated in this report, as well as expert consultation.

N. macrocarpa is categorised as Vulnerable by *The Red List of* Nothofagus (Baldwin et al., 2018) and by Chile's Regulations for the Classification of Wild Species (RCE). Wild populations are particularly threatened by land use changes, climate change and forest fires, whilst issues with regeneration are limiting recovery. This species is poorly represented in both *ex situ* living and seed collections and appears to have less conservation activities associated with it than other threatened *Nothofagus* species in Chile. It is therefore essential that existing conservation initiatives are expanded, with significant focus on the following areas to ensure long-term conservation of this species.

Firstly, the current distribution and status of wild populations of *N. macrocarpa* requires reassessment with a view to update distribution maps. In particular, the location and size of the more southerly populations appear to be unclear and warrant further study (A. Gutierrez pers. comm., 2022). Given the reported lack of natural regeneration, the identification, protection, and monitoring of mature trees should be conducted across the entire range of the species. Also, population monitoring should be upscaled to determine the condition of *N. macrocarpa* habitats and the threats to them (A. Maureira pers. comm., 2022). Research into factors impacting natural regeneration is also required, as well as the effects of climate change on the species

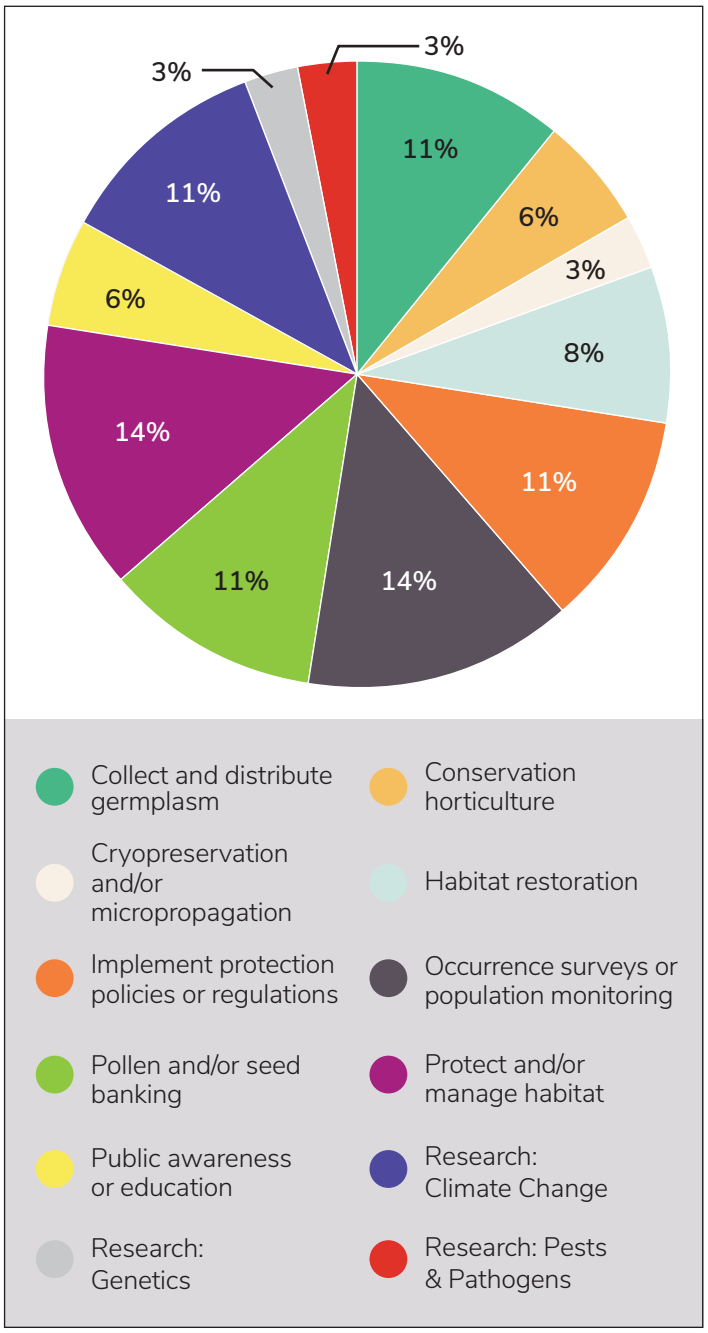

Figure 6. Priority conservation actions needed for the future conservation of *Nothofagus macrocarpa* reported by respondents to the Conservation Activity Questionnaire. Chart shows the proportion of responses identifying conservation actions as a priority. Only action categories that were identified are shown. The total number of respondents was five.

(A. Venegas pers. comm., 2022). Investigations into the soil environment and the species' fungal interactions should also be carried out to better understand their ecological role.

Habitat protection and management are also essential, especially given the limited proportion of populations that currently occur in protected areas (8%). This should include protection from invasive species infiltrating the species' habitat, and protection from land use change (e.g. to plantation).

Given the relatively poor representation of *N. macrocarpa* in *ex situ* collections found in this study (including both seed and living collections), it is recommended that this species is prioritised for wild collecting. To date, collections appear to have been made solely from the northerly populations, so focus should be given to populations further south to improve the genetic representation of *ex situ* collections.

Finally, it should be noted that in 2022 a conservation project funded by Fondation Franklinia was initiated to target the conservation, ecological restoration and capacity building to benefit the three threatened *Nothofagus* species native to South America, including *N. macrocarpa*. The project is led by Universidad de Concepción, working with Chilean institutions Universidad de Chile, Instituto Forestal (INFOR), Universidad Católica del Maule, Universidad de Talca, INIA and Club del Árbol de Talca, with support from BGCI. Some of the recommendations noted here will be actioned as a result of this initiative.

Nothofagus macrocarpa, Cerro El Roble, Chile (Nicolás Lavandero)

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Nothofagus moorei (F.Muell.) Krasser

Synonym(s): *Fagus moorei* F. Muell.; *Lophozonia moorei* (F. Muell.) Heenan & Smissen; *Fagus carronii* C. Moore
Common name(s): Antarctic Beech

IUCN Red List Category and Criteria: Vulnerable A2cd

Species profiles authors: Joanna Wenham, Wakehurst, Royal Botanic Gardens, Kew, UK; Ian Allan, Blue Mountains Botanic Garden Mount Tomah, Australia; Olivia Steed-Mundin, Wakehurst, Royal Botanic Gardens, Kew; Dan Crowley, Westonbirt, The National Arboretum, UK, BGCI; Itxaso Quintana, BGCI.

Suggested citation: Wenham, J., Allan, I., Steed-Mundin, O., Crowley, D., Quintana I. (2024). *Nothofagus moorei* (F.Muell.) Krasser. In Steed-Mundin, O., Crowley, D., Quintana, I., & Wenham, J. *Conservation Gap Analysis of* Nothofagus. Wakehurst, UK: Royal Botanic Gardens, Kew.

Distribution and Ecology

Nothofagus moorei is endemic to east Australia, occurring from Barrington Tops, in north-eastern New South Wales, to Lamington Plateau Macpherson Range, in south-eastern Queensland (Rix & Jackson, 2004) (Figure 1). It has an extent of occurrence (EOO) of 58,000 km² (Baldwin, 2018) and is found in temperate rainforest from 600 m-1550 m a.s.l., occurring most commonly in areas where rainfall exceeds around 1800 mm annually (Read & Brown, 1996). It is the most geographically isolated member of the genus, occurring around 1000 km north of *Nothofagus cunninghamii* and 1500-2000 km from its relatives in New Caledonia and New Guinea (Read & Brown, 1996).

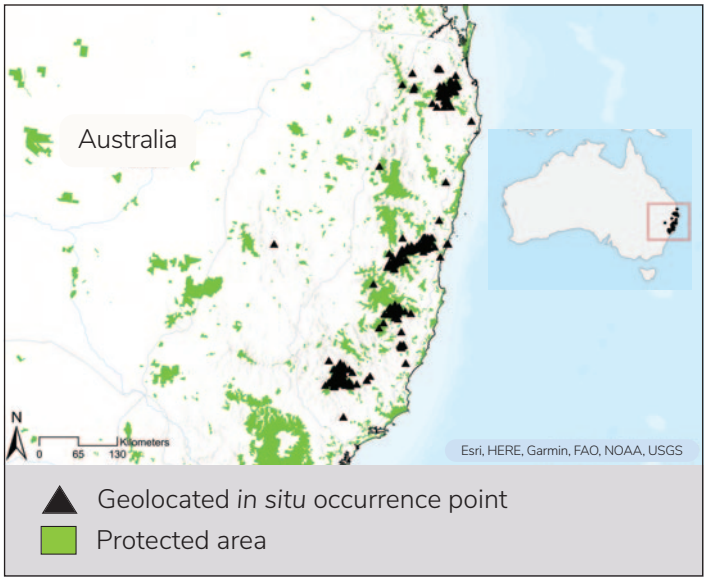

Figure 1. Documented *in situ* occurrence points for *Nothofagus moorei* and Terrestrial Protected Areas in Australia (Terrestrial Protected Areas are from UNEP-WCMC & IUCN 2022, Protected Planet).

On fertile soils, trees can reach over 40 m in height (Read & Brown, 1996), with trunks more than 2 m in diameter, sometimes with coppice growth at the base (Rix & Jackson, 2004). The species can often form almost monospecific stands (particularly at higher elevations), with a closed canopy. These stands can be small, for example along gully watercourses, but have also been found up to 150 ha in size.

N. moorei-dominated forests are commonly bordered by *Eucalyptus* forest, but populations across the geographical range can vary considerably in structure and associated species. At altitude above 1250 m a.s.l *N. moorei* often dominates and communities generally have low species richness; at intermediate altitudes, *N. moorei* usually occurs with many species from warm temperate communities, sometimes as the dominant species; at lower elevations it co-occurs in a more floristically rich warm-temperate community, or it can occur with members of Myrtaceae, Lauraceae, and even with Araucariaceae in some unique assemblages (Read & Brown, 1996).

N. moorei is a monoecious and wind pollinated species, flowering from August to October and fruiting from December to March (Read & Brown 1996). The species exhibits masting and seed dispersal is believed to be poor (Read & Brown 1996). *N. moorei* is also known to regenerate clonally, with new growth commonly sprouting from a basal burl or occasionally from root suckering (Read & Brown, 1996).

Threats to Wild Populations

Threats to wild populations were identified by reviewing *The Red List of* Nothofagus (Baldwin et al., 2018), expert consultation, literature review, and via the Conservation Activity Questionnaire. A comprehensive list of all threats identified for *N. moorei* is available in Appendix C. From the questionnaire, six respondents from a total of six organisations provided threat data for *N. moorei* (Figure 2).

The threats explored below are considered the current most significant threats, categorised into high, medium and low impact. This categorisation has been informed by the sources listed above and have been reviewed by regional experts.

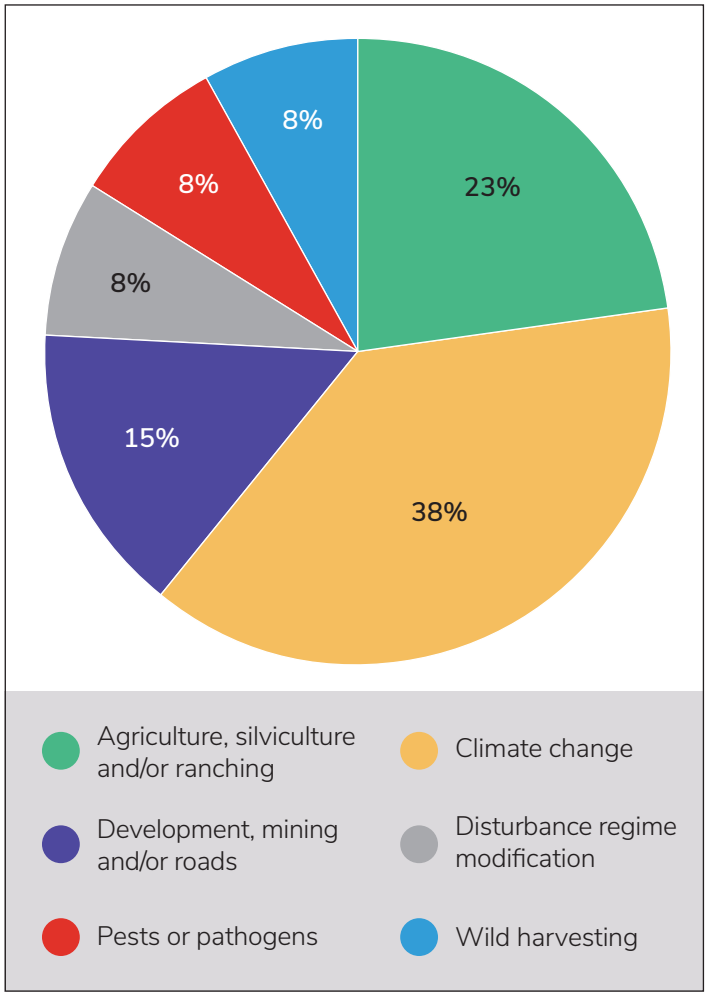

Figure 2. Threats to *Nothofagus moorei* reported by respondents to the Conservation Activity Questionnaire. The chart shows the proportion of responses relating to each threat. Only threat categories that were reported are shown. The total number of respondents was six, from six organisations.

High Impact Threats

Climate change: Climate change was the most commonly identified threat in the Conservation Activity Questionnaire (Figure 2), and climate modelling up to 2050 has predicted a continued contraction of the climatic envelope for *N. moorei* (i.e. cool temperate rainforest) (Mellick et al., 2013). Across much of the species' northern distribution, climatic conditions are predicted to increasingly favour sub-tropical and warm temperate species, which will likely cause a decline in *N. moorei* populations. In the south, although populations of *N. moorei* could potentially expand into eucalypt woodlands as the climate becomes wetter and warmer, it is likely that increased fire frequencies will in fact favour the spread of *Eucalyptus* forest (Schultz, 2008). Fire sensitivity, limited seed dispersal and shade intolerance limit the capacity of *N. moorei* to migrate to other suitable environments, making it particularly vulnerable to anthropogenic climate change (Mellick et al., 2013).

Medium Impact Threats

Land use change - agriculture and/or silviculture: This was the second most common threat identified in the Conservation Activity Questionnaire (Figure 2). Although *N. moorei* has limited desirable timber properties, logging of its associated species such as *Eucalyptus* species and *Ceratopetalum* species can cause root damage, canopy disturbance or expose seedlings (Read & Brown, 1996). It is thought that one third of the species' distribution is within forestry reserves in New South Wales which could make it vulnerable to exploitation from logging (Schultz, 2008).

Disturbance regime modification including fire: Increased fire frequencies across the range of *N. moorei* are predicted to cause a contraction in the natural distribution of the species (Schultz, 2008; Mellick et al., 2013). Significant fires in 2019-20 occurred through one of Australia's largest single tracts of Antarctic Beech forest. Many areas were affected including those with significant populations of *N. moorei* in National Parks such as Barrington tops and Lamington (Department of Agriculture, Water and the Environment, 2020).

Fire also affected populations of *N. moorei* at Blue Mountains Botanic Garden, where subsequent monitoring of regrowth found that individuals affected by a medium-low intensity understory fire were capable of re-sprouting at the base, with some also producing epicormic growth (I. Allan pers. obs., 2021). Further research is required into the potential recovery of *N. moorei* populations after fire.

Extremely restricted populations and/or genetic diversity loss: A number of factors interplay to increase the threat of genetic diversity loss in this species. These include restricted or fragmented extant populations, poor dispersal mechanisms and limited sexual regeneration (reliance on clonal regeneration) (Baldwin et al., 2018; Schultz, 2008; Taylor et al., 2005). In the context of global climate change and environmental instability, the greatest threat is to the northerly populations (Taylor et al., 2005).

Low Impact Threats

Development, mining and/or roads: Although this was the third most common threat identified in the Conservation Activity Questionnaire (Figure 2), it was not a threat identified in the IUCN Red List assessment (Baldwin, 2018). Populations falling within the Gondwana Rainforest of Australia World Heritage site are largely protected from mining (including oil and gas exploitation) and road building (Foley, 2021). However, commercial ground water mining could potentially create a threat in some areas - for example a new groundwater extraction licence for 8 million litres annually has recently been granted in an area adjacent to Springbrook National Park (Environmental Defenders Office, 2023). It is reported that this may negatively affect the ecosystem and species within the world heritage site (Environmental Defenders Office, 2023).

Pests and/or pathogens: This was identified as a threat by one respondent to the Conservation Activity Questionnaire (Figure 2) but was not highlighted on the IUCN Red List assessment (Baldwin, 2018). Indeed, there appears to be limited evidence that pests or pathogens are a direct threat to *N. moorei*. For example, myrtle wilt (*Chalara australis*) which is associated with *N. cunninghamii*, has not been observed to affect *N. moorei* (Read & Brown, 1996). Also, a study into the susceptibility of Australian species to *Phytophthora ramorum* indicated *N. moorei* has low susceptibility (Ireland et al., 2012). That said, several other *Phytophthora* species have been found in the Gondwanan rainforests at Barrington Tops National Park in New South Wales including *P. cinnamomi* and *P. cryptogea*, while *P. multivora* has been found in Lamington National Park (Scarlett et al., 2015). Further research will be needed to establish the susceptibility of *N. moorei* to these species of *Phytophthora*.

In addition, myrtle rust (*Puccinia psidii*), a novel disease in Australia, is posing a significant threat to many of the associated species of *N. moorei*, which could change the eventual floristic composition of regenerating sites and plant communities post-fire (Department of Agriculture, Water and the Environment, 2020).

Nothofagus moorei, Australia (Dan Crowley)

Conservation Activities

In 2021 and 2022 accession data were requested from *ex situ* collections for all *Nothofagus* species that were identified as threatened or Near Threatened in *The Red List for* Nothofagus (i.e. 'target species') (Baldwin et al., 2018). A total of 20 organisations reported having *ex situ* accessions of *N. moorei* (Table 1).

In addition, past, present, planned and future conservation activities for these species were also examined through literature review, expert consultation, and conduction of a questionnaire. Conservation Activity Questionnaires were sent out 2021 and 2022, seven organisations reported being actively involved in several conservation activities associated with *N. moorei* (Figure 5).

Ex situ collections reported 2021-2022

There are 99 *ex situ* accessions including living plants and seeds held at 20 organisations (Table 1). These include around 199 plants in living collections (Figure 3), 706 seeds belonging to 4 seed accessions (Table 2) and 9 plants in nurseries (Table 1). Of the 20 organisations holding *ex situ* collections, eight of them are in the country of origin.

Nothofagus moorei, Cobark, Australia (Dan Crowley)

Table 1. Results from the 2021-2022 *ex situ* survey for *Nothofagus moorei*.

Total	Number of organisations reporting *ex situ* collections	20
	Number of accessions in *ex situ* collections	99
Living collections	Number of accessions in *ex situ* living collections	95
	Number of plants in *ex situ* collections	199 in living collections 9 in nurseries
	Percentage of *ex situ* plants of wild origin	86%
	Percentage of wild origin plants with known locality	99%
Seed collections	Number of accessions in *ex situ* seed collections	4
	Number of seeds in *ex situ* seed collections	706
	Percentage of *ex situ* seed accessions of wild origin	100%
	Percentage of wild origin *ex situ* seed accessions with known locality	100%

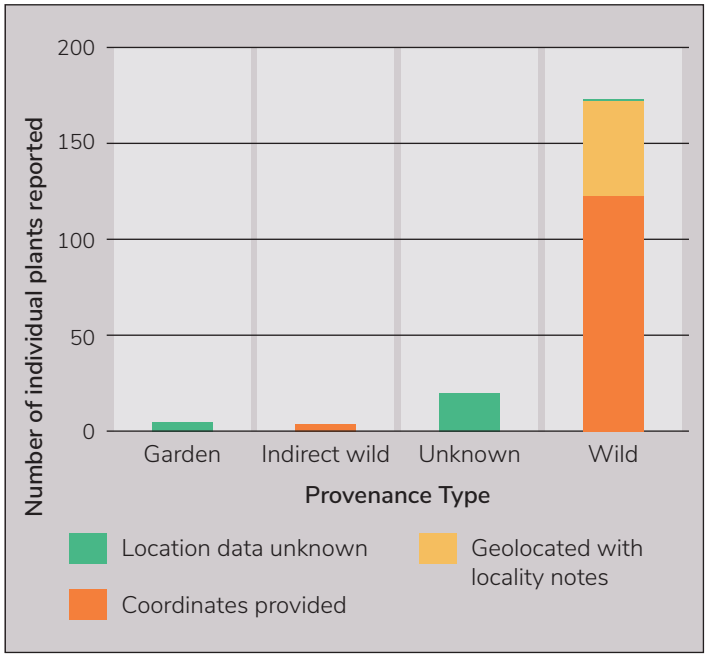

Figure 3. Quantity and origin of *Nothofagus moorei* plants in ex *situ* living collections.

Table 2. Quantity and origin of *Nothofagus moorei* seeds in ex *situ* collections.

Ex situ seed accession	Quantity of seed	Provenance	Locality data
1	94	Wild	Coordinates provided
2	104	Wild	Coordinates provided
3	116	Wild	Coordinates provided
4	392 (estimated from 2.4 grams)	Wild	Coordinates provided

Estimated *ex situ* representation

A spatial analysis was conducted to estimate the geographic and ecological coverage of *ex situ* living and seed collections. Forty, 60 and 80-kilometre buffers were placed around each *in situ* occurrence point and the source locality of each *ex situ* accession (Figure 4). Collectively the *in situ* buffer area serves as the inferred native range of the species or "combined area *in situ*" (CAI40, CAI60, CAI80 respectively). The *ex situ* buffer areas represent the native range "captured" in *ex situ* collections or combined area *ex situ* (CAE40, CAE60, CAE80 respectively). Geographic coverage of *ex situ* collections was estimated by dividing CAE by CAI and ecological coverage was estimated by dividing the number of terrestrial ecoregions present in CAE by the number of ecoregions in CAI. Results are presented in Tables 3 & 4 in km^2 and as a percentage of area covered, and the mean average percentage of coverage of all three buffer sizes is also presented.

The results showed that the 208 *N. moorei* plants in living collections only represent 38% of geographic coverage and 56% of ecological coverage (Table 3). Many of the plants in collections come from three main localities (Figure 4A), hence the low geographical and ecological coverage.

Our research also found four seed accessions for this species, representing 18% of geographic coverage and 44% of ecological coverage (Table 4). The number of seeds in seed banks for *N. moorei* is notably low, with all accessions coming from the southern populations (Figure 4B).

Table 3. Estimated ex *situ* representation of living plant collections for *Nothofagus moorei*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Geographical coverage	21,500 / 73,263 **(29%)**	41,518 / 109,008 **(38%)**	65,661 / 137,834 **(48%)**	**38%**
Ecological coverage	1 / 3 **(33%)**	2 / 3 **(67%)**	2 / 3 **(67%)**	**56%**

Table 4. Estimated ex *situ* representation of seed collections for *Nothofagus moorei*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Geographical coverage	10,090 / 73,263 **(14%)**	20,517 / 109,008 **(19%)**	31,324 / 137,834 **(23%)**	**18%**
Ecological coverage	1 / 3 **(33%)**	1 / 3 **(33%)**	2 / 3 **(67%)**	**44%**

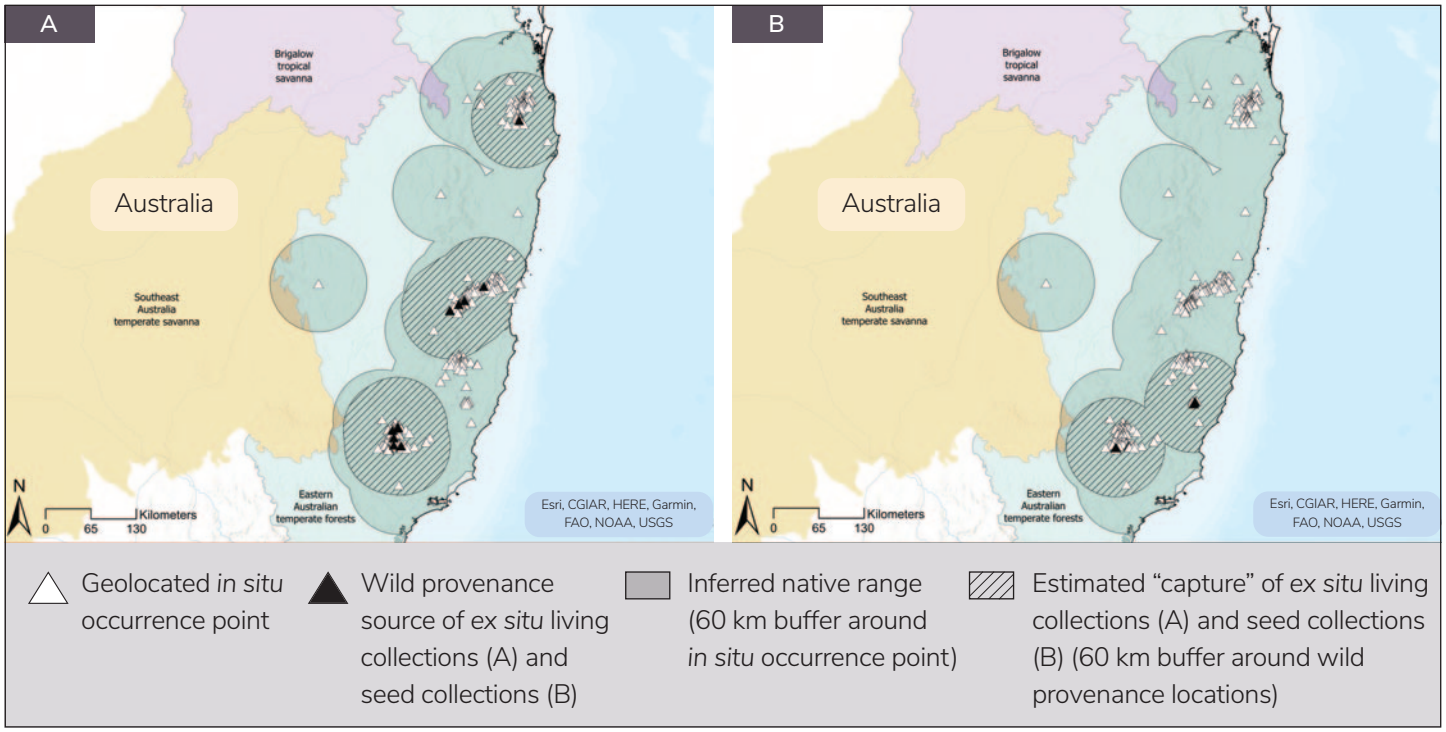

Figure 4. *Nothofagus moorei in situ* occurrence points and *ex situ* source localities for A) living collections and B) seed collections. Terrestrial Ecoregions of the World for Australia (Olson et al., 2001) are coloured and labelled. A 60km buffer has been placed around *in situ* occurrence points to infer the native range of *N. moorei*. A 60km buffer has been placed around the *ex situ* source location to infer the native range captured in *ex situ* collections.

Nothofagus moorei hedge, Blue Mountains Botanic Garden, Australia (Ian Allan)

Wild collecting and/or *ex situ* curation

There were a number of associated activities reported in the Conservation Activity Questionnaire. These included conservation horticulture which was the most common activity reported, as well as collecting and distributing germplasm (two organisations) and pollen and seed banking (one organisation) (Figure 5).

There have been limited studies focused on the seed storage behaviour of *N. moorei*, however a study into Chilean *Nothofagus* species concluded that five species show orthodox seed storage behaviour but the quality of seed lots requires attention and further study (León-Lobos & Ellis, 2005). Initial germination tests carried out by the Millennium Seed Bank (MSB) also suggest that *Nothofagus* seeds have orthodox storage requirements (R. Davies pers. comm., 2021) However, some species in the MSB are showing a small decline in viability, so testing will be undertaken from 2022 - 2023 to collect further data (R. Davies pers. comm., 2021).

Propagation and/or breeding programmes

One organisation reported carrying out micropropagation/cryopreservation in the Conservation Activity Questionnaire (Figure 5). In addition, Inala Jurassic Garden are running small-scale propagation trials of *N. moorei* from seed and cuttings and thus far have been successful with the latter (T. Cochran pers. comm., 2023). Whilst Wakehurst are currently carrying out germination trials of other temperate *Nothofagus* species, the seed collection of *N. moorei* at the MSB is too small to test (J. Wenham pers. obs., 2023).

Reintroduction, reinforcement and/or translocation

There were no activities associated with reintroductions, reinforcements or translocation reported via the questionnaire.

Land protection

A second spatial analysis was conducted to estimate the protected area coverage within the species' range, by finding the spatial intersection of CAI within protected areas. Results are presented in km^2 and percentage of area covered for 40, 60 and 80-kilometre buffers, the mean average percentage of coverage of all three buffer sizes is also presented (Table 5). The protected area coverage should be considered an estimation, as buffers around in situ points are likely to overestimate the distribution range of the target species. Additionally, these buffers might include non-protected habitat where the target species are unlikely to occur.

Within the inferred native range of *N. moorei*, only 17% of the land is covered by protected areas (Table 5). This is the lowest proportion of all the species that occur in Australia.

Sustainable management of land

There were no reports of habitat restoration or protecting and/or managing habitat in the Conservation Activity Questionnaire (Figure 5), however many of the extant populations sit within The Gondwana Rainforest of Australia World Heritage site (Department of Climate Change, Energy, the Environment and Water, 2023). It has a corresponding management plan (Department of the Environment and Heritage, 2000), with active management undertaken by the New South Wales National Parks and Wildlife Service and the Queensland Parks and Wildlife Service (Department of Climate Change, Energy, the Environment and Water, 2023).

Population monitoring and/or occurrences surveys

There were no reports of this activity in the Conservation Activity Questionnaire. However, previously published population-level research has provided insights into the population dynamics (Read & Hill, 1985), floristic composition (Bale & Williams, 1993) and genetic diversity of the species (Taylor et al., 2005).

Research

Four organisations reported to be carrying out research into *N. moorei* in the Conservation Activity Questionnaire (Figure 5). This includes the Research Centre for Ecosystem Resilience (ReCER), at the Botanic Gardens of Sydney, who have been undertaking a large conservation genomics project which includes *N. moorei*. Collaborating with New South Wales Parks and Wildlife Service, they have sampled genetic material across all major extant distributions for the species. Over 370 samples of *N. moorei* have been sequenced using Diversity Arrays Technology (DArT). Additionally, *Nothofagus cunninghamii* and *N. menziesii* are being sequenced as closely related outgroup taxa, to help compare genetic diversity between these species (R. Dimon pers. comm., 2022).

An earlier study which looked at the genetic diversity and regional identity of *N. moorei* concluded that there was significant diversity partitioned between northern and southern populations (Taylor et al., 2005). This study also noted that environmental instability and habitat loss from global climate change are posing a threat to *N. moorei*, particularly populations in the north which hold significant genetic diversity (Taylor et al., 2005). These findings and those of ReCER can be used to inform future conservation strategies.

There have also been previous studies into the threats of global climate change (Schultz, 2008) and work in post glacial spatial dynamics in rainforest biodiversity hotspots (Mellick et al., 2013).

Table 5. Estimated protected area coverage for *Nothofagus moorei*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Protected area coverage	14,206 / 73,263 **(19%)**	18,214 / 109,008 **(17%)**	21,023 / 137,834 **(15%)**	**17%**

Education, outreach, and/or training

Six organisations reported public awareness or education work on *N. moorei* within the Conservation Activity Questionnaire (Figure 5). At the Blue Mountains Botanic Garden there are interpretation panels explaining mass plantings including hedgerows and stands of *N. moorei* throughout the garden (I. Allan pers. comm., 2023). Tours, talks and online blogs at various organisations were also evident in discussions with respondents. In addition, in some national parks, there are interpreted walking trails through *N. moorei* stands which are detailed online by the National Parks Departments (Department of National Parks, Sport and Racing, 2016). In Barrington Tops National Park, NSW, one of these trails is named Antarctic Beech Forest Track.

There are also significant volunteer programmes which involve volunteers and staff from the New South Wales National Parks and Wildlife Service who have been digitising maps of *N. moorei* populations from the 1970s to compare changes over time, assessing patches of *N. moorei* affected by fire in the region, and collecting leaf samples for genetic analysis (Department of Climate Change, Energy, the Environment and Water, 2022).

Species protection policies

No organisations reported to be implementing protection policies or regulations in the Conservation Activity Questionnaire.

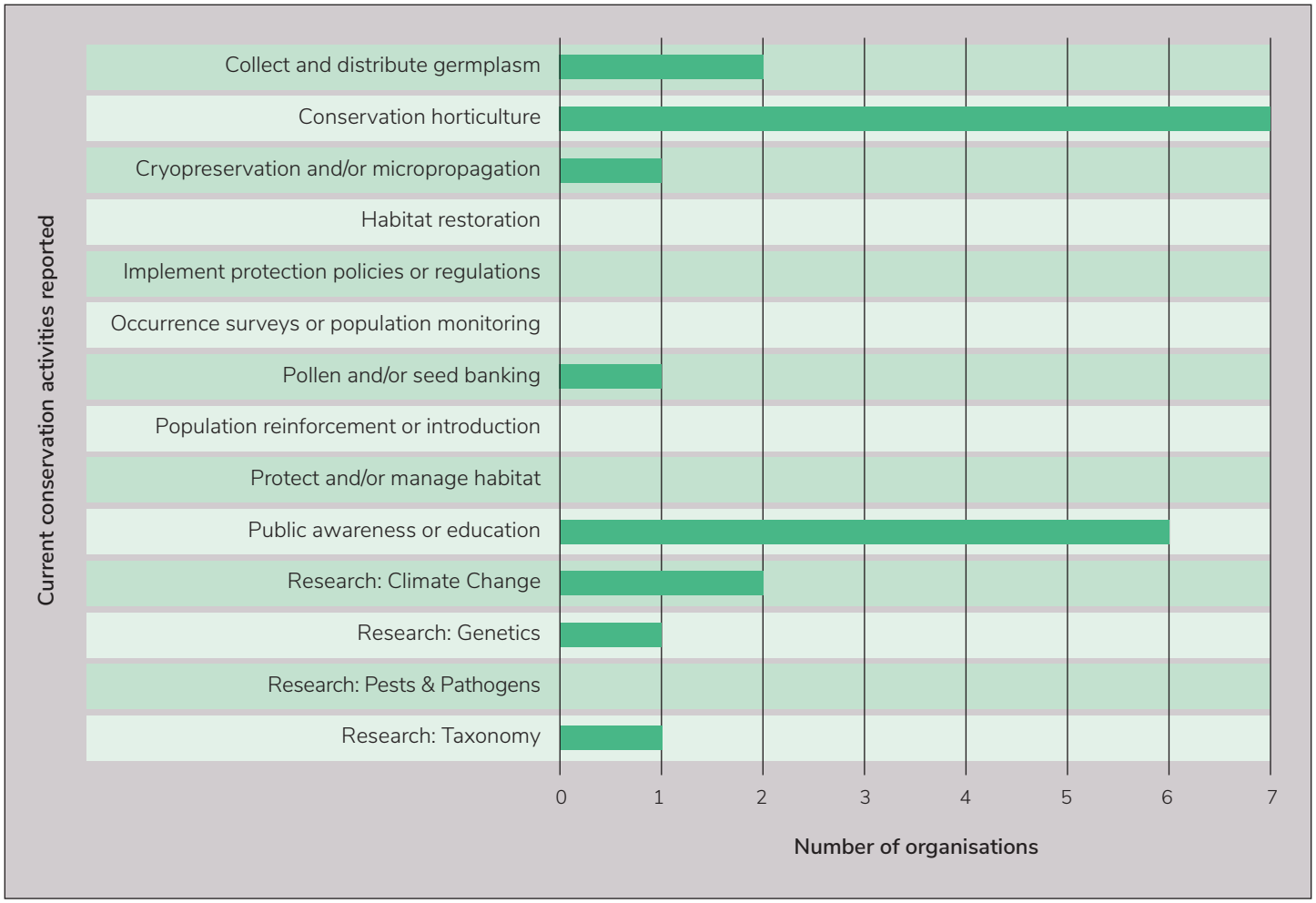

Figure 5. Number of organisations reporting species conservation activities for *Nothofagus moorei* in the Conservation Activity Questionnaire. Total number of organisations who reported conservation activities was 7.

Priority Conservation Actions

Results of the Conservation Activity Questionnaire

A Conservation Activity Questionnaire was sent to identify priority conservation actions that should be undertaken for the future conservation of *N. moorei*. There were seven respondents from seven organisations. Public awareness or education, protect and/or manage habitat and conservation horticulture were highlighted most frequently as priority conservation actions. (Figure 6).

Conclusion and Recommendations

The following conclusion and recommendations have been compiled by using the research, data and analysis collated in this report, as well as expert consultation.

N. moorei is a Vulnerable species (Baldwin et al., 2018). Its fragmented populations are increasingly threatened by the effects of climate change, anthropogenic land use, and fire. Recent fires (2019-2020) have affected extant populations, whilst the predicted contraction of *N. moorei*'s climatic envelope and the absence of suitable habitat for *N. moorei* to migrate to, along with challenges around poor seed dispersal and reliance on clonal reproduction, are all factors that put the species at risk of further fragmentation and genetic diversity loss.

Nothofagus moorei, Blue Mountains Botanic Garden, Australia (Ian Allan)

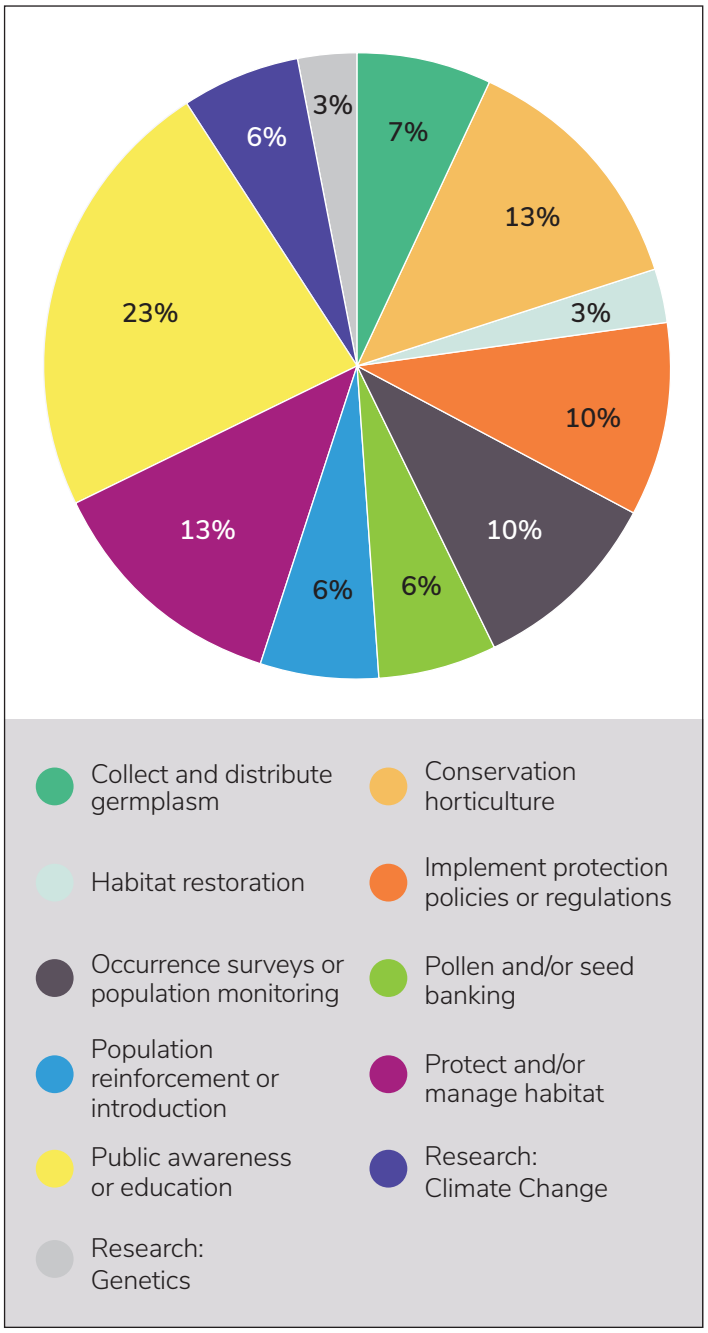

Figure 6. Priority conservation actions needed for the future conservation of *Nothofagus moorei* reported by respondents to the Conservation Activity Questionnaire. Chart shows the proportion of respondents identifying conservation actions as a priority. Only action categories that were identified are shown. The total number of respondents was seven, from seven organisations.

Our research shows *N. moorei* is very poorly represented in *ex situ* seed collections with only four accessions with a total of 706 seeds. These provide very limited geographical coverage (18%) and ecological coverage (44%). Furthermore, although there are c.200 plants in *ex situ* collections, they represent just 38% geographical coverage and 56% ecological coverage.

We would therefore recommend increasing representation in both *ex situ* living and seed collections, particularly the underrepresented northern populations and those most threatened by fire or climate change. The results from the population genomics research being carried out by Research Centre for Ecosystem Resilience (Botanic Gardens of Sydney) provides a very valuable opportunity to use insights from genomics to focus future wild collecting initiatives for *N. moorei*. These data could facilitate the collection of appropriate genetic material to create genetically representative *ex situ* metacollections of *N. moorei*, which could be distributed globally. Indeed, while undertaking this research, Blue Mountains Botanic Garden have indicated that they would like to align the findings of this study with their new Living Collections Strategy. Their relative proximity to the extant populations of *N. moorei* in NSW makes them perfectly positioned to lead collection work and improve genetic representation in *ex situ* collections.

To support this work it is recommended for research into seed storage behaviour to establish seed longevity; germination trials to establish propagation protocols; and research into masting and seed viability to help focus wild collecting efforts and research into the effects of fire and regeneration of populations post-fire.

It is also recommended that the Global Conservation Consortia for *Nothofagus* work with Botanic Gardens generally to enhance interpretation and online information available on this species.

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Nothofagus nuda Steenis

Synonym(s): *Trisyngyne nuda* (Steenis) Heenan & Smissen. **Common name(s):** We-úkwe (Nauti language)

IUCN Red List Category and Criteria: Critically Endangered (CR) B1ab(iii)

Species profiles authors: Olivia Steed-Mundin, Wakehurst, Royal Botanic Gardens, Kew, UK; Dan Crowley, Westonbirt, The National Arboretum, UK, BGCI; Itxaso Quintana, BGCI; Oliver Paul, Papua New Guinea Forest Research Institute, Lae National Herbarium

Suggested citation: Steed-Mundin, O., Crowley, D., Quintana, I., & Paul, O. (2024). *Nothofagus nuda* Steenis. In Steed-Mundin, O., Crowley, D., Quintana, I., & Wenham, J. *Conservation Gap Analysis of* Nothofagus. Wakehurst, UK: Royal Botanic Gardens, Kew.

Distribution and Ecology

There is very little published information on *Nothofagus nuda*. It appears to have an extremely limited distribution, known only from one collection made in 1966 on Upper Wenna Creek, a branch of Tauri River in Gulf District, Papua New Guinea (Baldwin, 2018) (Figure 1). It was found at 1219 m a.s.l., in mixed lower montane forest associated with *Castanopsis* sp. The species reportedly grows to c.20 m tall. (Van Steenis, 1972).

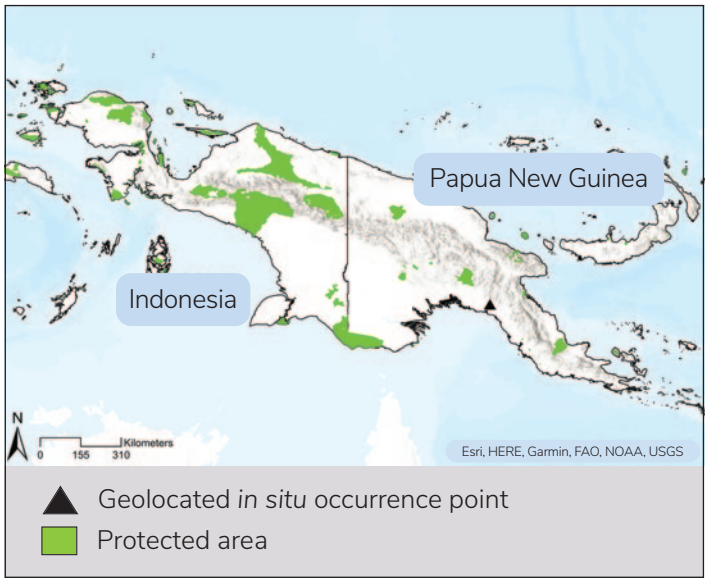
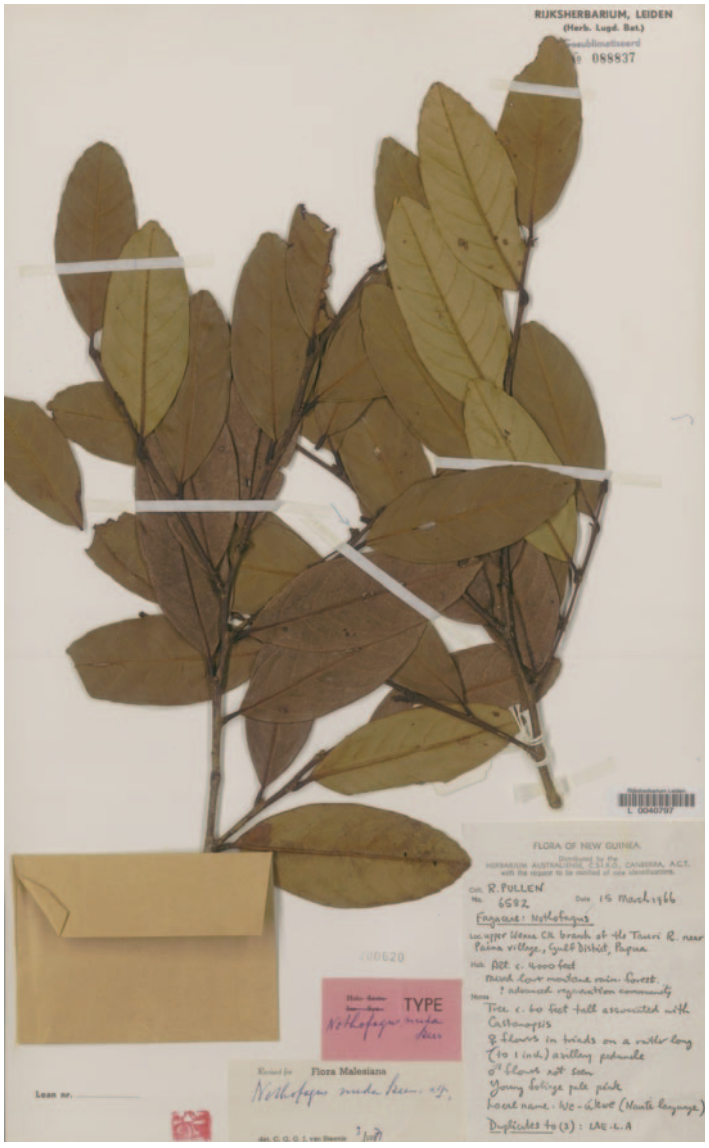


Figure 1. Documented *in situ* occurrence points for *Nothofagus nuda* and Terrestrial Protected Areas in the island of New Guinea (Terrestrial Protected Areas are from UNEP-WCMC & IUCN 2022, Protected Planet).



Nothofagus nuda, Holotype herbarium specimen (Naturalis Biodiversity Center)

Threats to Wild Populations

Threats to wild populations were identified by reviewing *The Red List of* Nothofagus (Baldwin et al., 2018), expert consultation and literature review. Because there is so little information available about this species, the threats below are estimated based on the limited information available. No threats for *N. nuda* were reported via the Conservation Activity Questionnaire.

The threats highlighted below are considered the current most significant threats, categorised into high and medium impact. This categorisation has been informed by the sources listed above and have been reviewed by regional experts.

High Impact Threats

Extremely restricted populations and/or genetic diversity loss: There is only one known population of this species. The survival of the species could be put at critical risk if threats such as fire, logging or climate change have an effect within its range. In addition, if there is only one remaining population comprising few individuals, genetic variability would likely be lost over time through inbreeding and genetic drift, which is likely to reduce reproductive fitness. However, it should be noted that botanical exploration in Papua New Guinea is limited, and there may be extant populations of *N. nuda* that are currently unrecorded.

Land use change - agriculture and/or silviculture & Logging and/or wild harvesting: There has been significant deforestation in Papua New Guinea; 15% of tropical forest have been cleared (1972-2002) and a further 8% degraded by logging (Shearman et al., 2009). As most land is cleared for agricultural purposes, the close proximity of the only known population of this species to a village heightens this threat further (Baldwin, 2018). In addition, the Papuan LNG (Liquid Natural Gas) project, developed by Total Group of Companies, is currently underway in the Gulf area (O. Paul pers. obs., 2022). The only known population could therefore be disturbed as a result of the development that is taking place.

Disturbance regime modification including fire: Seasonal fires are becoming more prevalent especially in logged areas (Baldwin et al., 2018) and fire is considered the most important driver of change in high altitude forest in Papua New Guinea (Shearman et al., 2009), where *N. nuda* occurs.

Medium Impact Threats

Climate change: *Nothofagus* species generally have poorly dispersed seed and those occurring at high altitude such as *N. nuda* have limited ability to migrate (Read & Hope, 1996). The threat of climate change is heightened by the species' restricted range (Baldwin, 2018) and the assumed limited genetic variability, given its single known population.

Conservation Activities

In 2021 and 2022 accession data were requested from *ex situ* collections for all *Nothofagus* species that were identified as threatened or Near Threatened in *The Red List of* Nothofagus (i.e. 'target species' (Baldwin et al., 2018). There were no *ex situ* accessions recorded for this species.

In addition, past, present and planned conservation activities for these species were examined through literature review, expert consultation and conduction of a questionnaire. Conservation Activity Questionnaires were sent out 2021 and 2022. For *N. nuda*, as with all *Nothofagus* species from New Guinea, no conservation activities were reported in the questionnaire. Information on conservation activities for this species has therefore been provided by expert consultation, research papers and other published sources.

Ex situ collections reported 2021–2022

No *ex situ* collections were reported.

Estimated *ex situ* representation

No *ex situ* collections were reported.

Wild collecting and/or *ex situ* curation

There are no known wild collecting initiatives and the species' phenology is poorly understood. It should also be noted that no research appears to have been carried out on the seed storage characteristics of tropical *Nothofagus* species.

Propagation and/or breeding programmes

There are no known population or breeding programmes for this species.

Reintroduction, reinforcement and/or translocation

There are no known reintroduction, reinforcement and/or translocation programmes.

Land protection

This species is not known to occur in any protected areas (Figure 1).

Sustainable management of land

There are no recorded initiatives in the locality of the known population. Furthermore, projects related to LNG extraction in the Gulf area, are posing a threat to the only known population (O. Paul pers. obs., 2022).

Population monitoring and/or occurrence surveys

There have been no recent monitoring or occurrence surveys.

Research

No related published research has been found.

Education, outreach and/ or training

No initiatives for *N. nuda* are known.

Species protection policies

There are no known species protection policies for *N. nuda*.

Priority Conservation Actions

Results of the Conservation Activity Questionnaire

There were no responses related to *N. nuda* in the Conservation Activity Questionnaire.

Conclusion and Recommendations

The following conclusion and recommendations have been compiled by synthesising the research, data and analysis collated in this report, as well as expert consultation.

The Critically Endangered *N. nuda* appears to be an extremely rare species, with just one known population that has not been recorded since 1966 (Baldwin, 2018). Considering there are also no *ex situ* collections, no known conservation activities associated with this species and given the only occurrence is found in a locality which is not within a protected area and which may be affected by LNG extraction, conservation action is urgently required.

Immediate efforts should focus on locating the only recorded population. If found, a population survey should be completed to include a thorough investigation of the area to check for other individuals/sub-populations as well to ascertain more specific threats, particularly associated with the Papuan LNG project. If the population appears to be declining, lacking recruitment or facing threats from human impact, immediate conservation actions will be essential. It is anticipated that this would include seed-collecting for *ex situ* collections and potential reintroductions, as well as land protection. It would require research into phenology, seed storage behaviour, propagation protocols and seedling establishment, which appear to be poorly understood for any of the threatened or Near Threatened *Nothofagus* species from New Guinea. Some related work has been carried out for *Nothofagus grandis* from Papua New Guinea, which could potentially be expanded to include this species (T. Kuria pers. comm., 2022). Research focused on climate change modelling would also be welcomed.

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Nothofagus pseudoresinosa Steenis

Synonym(s): *Trisyngyne pseudoresinosa* (Steenis) Heenan & Smissen; *Nothofagus pseudoresinosa* var. *microphylla* Steenis. **Common name(s):** Tart, Poio, Mépa

IUCN Red List Category and Criteria: Near Threatened (NT) B1ab(iii,v).

Species profiles authors: Olivia Steed-Mundin, Wakehurst, Royal Botanic Gardens, Kew, UK; Dan Crowley, Westonbirt, The National Arboretum, UK, BGCI; Itxaso Quintana, BGCI ; Oliver Paul, Papua New Guinea Forest Research Institute, LAE National Herbarium

Suggested citation: Steed-Mundin, O., Crowley, D., Quintana, I., & Paul, O. (2024). *Nothofagus pseudoresinosa* Steenis. In Steed-Mundin, O., Crowley, D., Quintana, I., & Wenham, J. *Conservation Gap Analysis of* Nothofagus. Wakehurst, UK: Royal Botanic Gardens, Kew.

Distribution and Ecology

Nothofagus pseudoresinosa occurs in a number of disjunct populations, largely in the highlands of central and eastern Papua New Guinea (Figure 1), at elevations from c.2400 -3150 m a.s.l. (Bijmoer et al., 2022a; Bijmoer et al., 2022b). A single occurrence has also been recorded in the Arafak Mountains in Western Papua, Indonesian New Guinea (Kennedy, 2022). However, this record is disputed and was not included in the species' IUCN Red List assessment (Baldwin, 2018), and has not been included in this analysis.

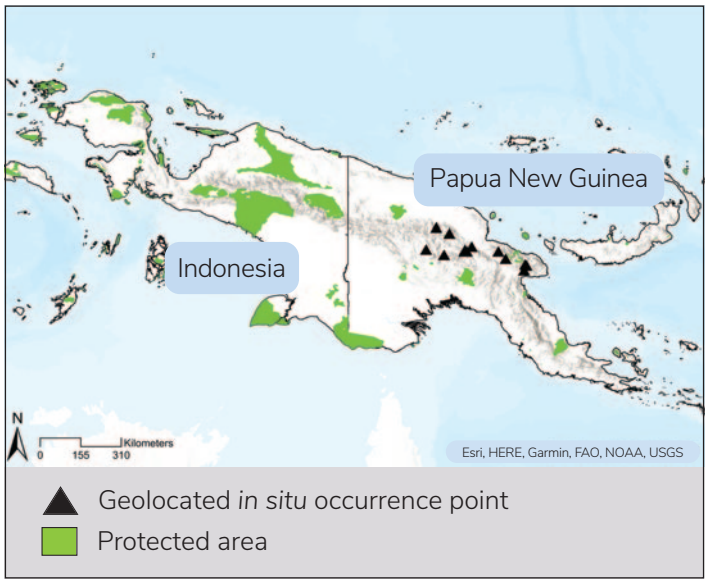

Figure 1. Documented *in situ* occurrence points for *Nothofagus pseudoresonisa* and Terrestrial Protected Areas for the island of New Guinea (Terrestrial Protected Areas are from UNEP-WCMC & IUCN 2022, Protected Planet).

N. pseudoresinosa is a large tree reaching 40-45 m tall, with a trunk up to 150 cm in diameter (Orrel Informatics Office, 2022; Bijmoer et al., 2022b). It usually occurs in stands on mountain ridges (Orrel Informatics Office, 2022; Read et al., 1990), but is also recorded as occurring in meadow swamp on forest margins (Royal Botanic Gardens, Kew, 2021). It is often the dominant species in the forest's upper canopy, sometimes forming a sparse canopy allowing for a relatively rich understory, though sometimes forms a dense canopy, with a less developed understory (Read et al., 1990). Co-occurring woody species commonly include members of the families Cunoniaceae and Myrtaceae (Read et al., 1990). Other known associates include *Pandanus* species (Bijmoer et al., 2022a) and *Widjajachloa producta* (Read et al., 1990). Large-scale but infrequent disturbance appears to play a role in initiating and maintaining *Nothofagus* stands in Papua New Guinea (Read et al., 1990).

Threats to Wild Populations

Threats to wild populations were identified by reviewing *The Red List of* Nothofagus (Baldwin et al., 2018), expert consultation and literature review. Because there is limited published research on threats to *N. pseudoresinosa* specifically, the information below largely refers to *Nothofagus* species in Papua New Guinea in general.

The threats explored below are considered the current most significant threats, categorised into medium and low impact. This categorisation has been informed by the sources listed above and have been reviewed by regional experts.

Medium Impact Threats

Land use change: agriculture and/or silviculture & Logging and/or wild harvesting: The size of this tree makes it more likely to be specifically logged for timber (Baldwin, 2018). In addition, there has been significant deforestation in Papua New Guinea: 15% of tropical forest has been cleared (1972-2002) and a further 8% degraded by logging (Shearman et al., 2009).

Low Impact Threats

Disturbance regime modification including fire: Fire is considered the most important driver of change in high altitude forest in Papua New Guinea (Shearman et al., 2009), where *N. pseudoresinosa* occurs. Seasonal fires are becoming more prevalent especially in logged areas (Baldwin, 2018).

Nothofagus pseudoresinosa, Isotype herbarium specimen (Naturalis Biodiversity Center)

Conservation Activities

In 2021 and 2022 accession data were requested from *ex situ* collections for all *Nothofagus* species that were identified as threatened or Near Threatened in *The Red List of* Nothofagus (i.e. 'target species') (Baldwin el al., 2018). There were no *ex situ* accessions recorded for this species.

In addition, past, present and planned conservation activities for these species were examined through literature review, expert consultation and conduction of a questionnaire. Conservation Activity Questionnaires were sent out 2021 and 2022. For *N. pseudoresinosa*, as with all *Nothofagus* species from New Guinea, no conservation activities were reported in the questionnaire. Information on conservation activities for this species has therefore been provided by expert consultation, research papers and other published sources.

Ex situ collections reported 2021–2022

No *ex situ* collections were reported.

Estimated *ex situ* representation

No *ex situ* collections were reported.

Wild collecting and/or *ex situ* curation

There are no known wild collecting initiatives and the phenology is poorly understood. It should also be noted, no research appears to have been carried out into whether tropical *Nothofagus* species have orthodox seed storage characteristics.

Propagation and/or breeding programmes

There are no known population or breeding programmes for this species.

Reintroduction, reinforcement and/or translocation

There are no known reintroduction programmes.

Land protection

A spatial analysis was conducted to estimate the protected area coverage within the species' range. Forty, 60 and 80-kilometre buffers were placed around each *in situ* occurrence point. Collectively the *in situ* buffer area serves as the inferred native range of the species or "combined area *in situ*" (CAI40, CAI60, CAI80 respectively). By finding the spatial intersection of CAI within protected areas, protected area coverage could be estimated. Results are presented in km^2 and percentage of area covered for 40, 60 and 80-kilometre buffers, the mean average percentage of coverage of all three buffer sizes is also presented (Table 1). The protected area coverage should be considered an estimation, as buffers around *in situ* points are likely to overestimate the distribution range of the target species. Additionally, these buffers might include non-protected habitat where the target species are unlikely to occur.

Within the inferred native range of *N. pseudoresinosa*, 1.5% of the land is covered by protected areas (Table 1). Known occurrence points are close to Mount Wilhelm National Park (Figure 1).

Sustainable management of land

Although there are not any recorded initiatives in the locality of the known populations, Mount Wilhelm National Park is conserved and used purposely for conservation, tourism and sustainable management of the environment. However, there are also threats in this area, including from the introduction of pests and invasive weeds by the movement of tourists both nationally and internationally (O. Paul pers. obs., 2022). Fire could also be a threat here, as experienced during the last El Niño in 1997 (O. Paul pers. obs., 2022).

Table 1. Estimated protected area coverage for *Nothofagus pseudoresinosa*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Protected area coverage	577 / 40,993 **(1.4%)**	946 / 66,659 **(1.4%)**	1,510 / 88,166 **(1.7%)**	**(1.5%)**

Population monitoring and/or occurrence surveys

A study in 1990 looking at the population dynamics of *Nothofagus* forests in Papua New Guinea included one study site dominated by *N. pseudoresinosa* at Iwam Pass. The population structure at this site is disjunct, with one group comprising trees with larger stems, and another with smaller stems. The differences in growth rates showed evidence of successful regeneration over a relatively short period, followed by a long period of unsuccessful regeneration (Read et al., 1990). There do not appear to be any follow up studies at this site and no other monitoring or occurrence surveys.

Research

There is limited published research focused on *N. pseudoresinosa*. A study into the population dynamics of *Nothofagus* forest in Papua New Guinea, which included *N. pseudoresinosa*, suggests that large-scale but infrequent disturbance plays a role in maintaining *Nothofagus* stands in Papua New Guinea Highlands (Read et al., 1990). Another study looking at foliar-frost resistance, suggests that this species has some, albeit limited, resistance to frost, similar to that recorded in warm temperate or sub-tropical tree species (Read & Hope, 1989). This information will be useful if *ex situ* living collections are to be established in temperate environments.

Education, outreach and/or training

There are no known initiatives in place for *N. pseudoresinosa*.

Species protection policies

There are no known species protection policies for *N. pseudoresinosa*.

Priority Conservation Actions

Results of the Conservation Activity Questionnaire

There were no responses related to *N. pseudoresinosa* in the Conservation Activity Questionnaire.

Conclusion and Recommendations

The following conclusion and recommendations have been compiled using the research, data and analysis collated in this report, as well as via expert consultation.

Given that *N. pseudoresinosa* occurs in a number of localities across Papua New Guinea and has been assessed as Near Threatened (Baldwin, 2018), the priority conservation actions are considered less urgent than for the other *Nothofagus* species from Papua New Guinea included in this study. However, given that most of the occurrence details were reported over 50 years ago and little is known about current populations, it is recommended that population surveys are carried out at recorded occurrence sites to assess current populations and determine if they appear to be declining, lacking recruitment or facing specific threats. It would be particularly useful to revisit the population monitoring sites at Iwam Pass to assess if any regeneration has taken place since 1990. It is also recommended that the disputed occurrence point in Indonesian New Guinea is visited to ascertain if a population exists here.

Once more is known about current populations and specific threats, it is likely that the species' IUCN Red List assessment will need updating. Further conservation actions may be recommended at this point, which would likely include seed-collecting for *ex situ* collections and associated research into phenology, seed storage behaviour, propagation protocols and seedling establishment, all of which appear to be poorly understood for any of the threatened or Near Threatened species from New Guinea.

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Nothofagus stylosa Steenis

Synonym(s): *Trisyngyne stylosa* (Steenis) Heenan & Smissen. **Common name(s):** unknown

IUCN Red List Category and Criteria: Critically Endangered (CR) B2ab(iii)

Species profiles authors: Olivia Steed-Mundin, Wakehurst, Royal Botanic Gardens, Kew, UK; Dan Crowley, Westonbirt, The National Arboretum, UK, BGCI; Itxaso Quintana, BGCI; Reza Saputra, West Papua Natural Resources Conservation Agency (Balai Besar KSDA Papua Barat), Ministry of Environment and Forestry.

Suggested citation: Steed-Mundin, O., Crowley, D., Quintana I., & Saputra, R. (2024). *Nothofagus stylosa* Steenis. In Steed-Mundin, O., Crowley, D., Quintana, I., & Wenham, J. *Conservation Gap Analysis of* Nothofagus. Wakehurst, UK: Royal Botanic Gardens, Kew.

Distribution and Ecology

Nothofagus stylosa is endemic to Indonesian New Guinea, where it is only known from the Type locality on Mt Trikora, at 2500-3050 m a.s.l., from material collected in 1982 (Figure 1). Very little is recorded about this species, hence the information that follows is limited. The population appears to occur across both the lower and upper montane zones of Mt Trikora (Mangen, 1993), reaching 3050 m a.s.l., close to the upper altitudinal limit for *Nothofagus* from New Guinea.

The species is dominant in the upper canopy, forming pure stands, 20-30 m tall (Mangen, 1993). In the lower montane zone, it forms relatively open forests, which have both a rich understory and shrub layer, co-occurring with genera including *Cryptocarya, Saurauia, Elaeocarpus, Tetractomia* and *Pandanus* (Mangen, 1993). In the upper mountain zone, it forms closed forests where only an understorey is present, including taxa such as *Tasmannia piperita, Acronychia murina, Vaccinium* species and *Gaultheria* species (Mangen, 1993).

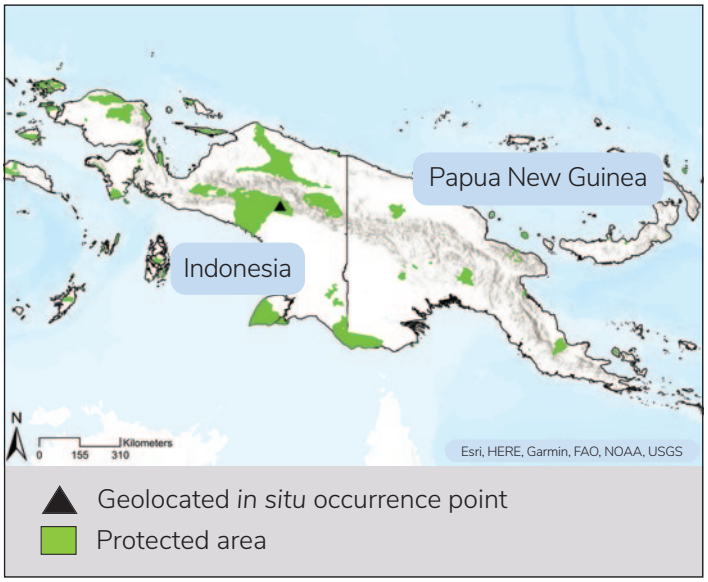

Figure 1. Documented *in situ* occurrence points for *Nothofagus stylosa* and Terrestrial Protected Areas in the island of New Guinea (Terrestrial Protected Areas are from UNEP-WCMC & IUCN 2022, Protected Planet).

Threats to Wild Populations

Threats to wild populations were identified by reviewing *The Red List of* Nothofagus (Baldwin et al., 2018), expert consultation and literature review. Because there is limited published data relating to threats to *N. stylosa* specifically, the information below largely refers to *Nothofagus* species in Indonesian New Guinea in general. No threats for *N. stylosa* were reported via Conservation Activity Questionnaire.

The threats explored below are considered the current most significant threats, categorised into high, medium and low impact. This categorisation has been informed by the sources listed above and have been reviewed by regional experts.

High Impact Threats

Extremely restricted population and/or genetic diversity loss: There is only one known population of this species. The survival of the species could be put at critical risk if threats such as logging, fire or climate change have an impact on this population. In addition, it is likely to have limited genetic variability, which may limit its reproductive fitness and its ability to adapt to climatic change.

Land use change- agriculture and/or silviculture & Logging and/or wild harvesting: The sole recorded population occurs close to *Nothofagus flaviramea*, an important timber species, which puts it at higher risk of logging (Baldwin, 2018). There has been significant deforestation in Indonesian New Guinea: 0.75 million hectares of old-growth forest were cleared from 2001-2019 (Gaveau et al., 2021).

Disturbance regime modification including fire: Seasonal fires are becoming more prevalent, especially in logged areas (Baldwin, 2018). Mt Trikora area was affected by widespread fire during the 1997–1998 El Niño event (Hope, 2014). It is therefore possible that the species has already been affected by seasonal fires (Baldwin, 2018).

Medium Impact Threats

Climate change: *Nothofagus* species in general have poorly dispersed seeds and specialist soil requirements which limits their ability to migrate as the climate changes (Read & Hope, 1996). This species is at increased risk from climate change because it occurs at high altitude and is only known from one location, which limits its ability to migrate further (Read & Hope, 1996).

Low Impact Threats

Development, mining, development and/or roads: A road built in 1988 on Mt Trikora has led to greater visitation, including exploitation of the forest here (Hope, 2014).

Pests and/or pathogens: Large patches of dieback have been observed for some time in evenly-aged *Nothofagus* forests in the Lorentz National Park, in which Mt Trikora is situated, however, it is not known if *N. stylosa* is impacted. The contributing factors to the dieback are also not well understood. It is possible that a fungal pathogen such as *Phytophthora cinnamomi* (which has been isolated from soil samples) is involved, however research to date is inconclusive (Arentz, 1988; R. Saputra pers. comm., 2022). Abundant regeneration in the diseased stands has, until recently, suggested it is not limiting the distribution or regeneration of *Nothofagus* species (Read & Hope, 1996). However, the dieback appears to be worsening with climate change and since the construction of the Trans Papua highway through Lorentz National Park (UNESCO, 2017).

Conservation Activities

In 2021 and 2022 accession data were requested from *ex situ* collections for all *Nothofagus* species that were identified as threatened or Near Threatened in *The Red List of* Nothofagus (i.e. 'target species' (Baldwin et al., 2018)). There were no *ex situ* accessions recorded for this species.

In addition, past, present and planned conservation activities for these species were examined through literature review, expert consultation and conduction of a questionnaire. Conservation Activity Questionnaires were sent out 2021 and 2022. For *N. stylosa*, as with all *Nothofagus* species from New Guinea, no conservation activities were reported in the questionnaire. Information on conservation activities for this species has therefore been provided by expert consultation, research papers and other published sources.

Ex situ collections reported 2021- 2022

No *ex situ* collections were reported.

Estimated *ex situ* representation

No *ex situ* collections were reported.

Wild collecting and/or *ex situ* curation

There are no known wild collecting initiatives. The species' phenology is poorly understood and no research appears to have been carried out into the seed storage behaviour of tropical *Nothofagus* species.

Propagation and/or breeding programmes

There are no known population or breeding programmes for this species.

Reintroduction, reinforcement and/or translocation

There are no known reintroduction, reinforcement and/or translocation programmes

Land protection

A spatial analysis was conducted to estimate the protected area coverage within the species' range. Forty, 60 and 80-kilometre buffers were placed around each in situ occurrence point. Collectively the *in situ* buffer area serves as the inferred native range of the species or "combined area *in situ*" (CAI40, CAI60, CAI80 respectively). By finding the spatial intersection of CAI within protected areas, protected area coverage could be estimated. Results are presented in km^2 and percentage of area covered for 40, 60 and 80-kilometre buffers; the mean average percentage of coverage of all three buffer sizes is also presented (Table 1). The protected area coverage should be considered an estimation, as buffers around *in situ* points are likely to overestimate the distribution range of the target species. Additionally, these buffers might include non-protected habitat where the target species are unlikely to occur.

Within the inferred native range of *N. stylosa*, 56% of the land is covered by protected areas (Table 1). The only known population occurs on Mt Trikora, which falls within the Lorentz National Park (Figure 1).

Table 1. Estimated protected area coverage for *Nothofagus stylosa*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Protected area coverage	3,786 / 5,006 **(76%)**	5,898 / 11,263 **(52%)**	7,838 / 20,024 **(39%)**	**56%**

Sustainable management of land

Lorentz National Park is a UNESCO World Heritage Site (UNESCO, 2017). It is administered by the Indonesian Park Service for the Directorate for Nature Conservation and a draft management plan has been drawn up. However, monitoring and management is hindered by limited funding and a limited number of staff and there are continued threats including road building and illegal logging (IUCN & UNEP-WCMC, 2017). In addition, Trikora is becoming a popular destination for trekking.

Population monitoring and/or occurrence surveys

There have been no monitoring or occurrence surveys and the population has not been recorded since 1982. In 2018 a survey of *Nothofagus* in Lorentz National park found 10 *Nothofagus* species, but it did not record *N. stylosa* (R. Saputra pers. comm., 2022).

Research

No related published research has been found.

Education, outreach and/or training

No initiatives for *N. stylosa* are known.

Species protection policies

There are no known species protection policies for *N. stylosa*.

Priority Conservation Actions

Results of the Conservation Activity Questionnaire

There were no responses related to *N. stylosa* in the Conservation Activity Questionnaire.

Conclusion and Recommendations

The following conclusion and recommendations have been compiled by synthesising the research, data and analysis collated in this report, as well as expert consultation.

The Critically Endangered *N. stylosa* (Baldwin, 2018), appears to be an extremely rare tree, reported from a single population which has not been formally recorded since 1982. The threats to this species, including logging and fire, are amplified by the small population size. Considering there are also no *ex situ* collections and no known conservation actions associated with this species, it is recommended to undertake focused conservation action as soon as possible.

There is an urgent need to locate the recorded population and carry out a population survey to ascertain if it has been affected by fire and/or logging and to identify any other specific threats. A thorough exploration of the Mt Trikora area to check for other sub-populations is also recommended.

If the population appears to be declining, lacking recruitment or facing threats from human impact, targeted conservation actions will be essential. This would likely include seed-collecting for *ex situ* collections and potential *in situ* reintroductions. It would require research into phenology, propagation protocols, seedling establishment, and seed storage behaviour which appear to be poorly understood for any of the threatened or Near Threatened species from New Guinea. Research focused on climate change modelling would also be welcomed.

An updated IUCN Red List assessment should also be undertaken once the population has been surveyed.

Finally, it is recommended that *N. stylosa* is proposed as a conservation priority species in Indonesian New Guinea.

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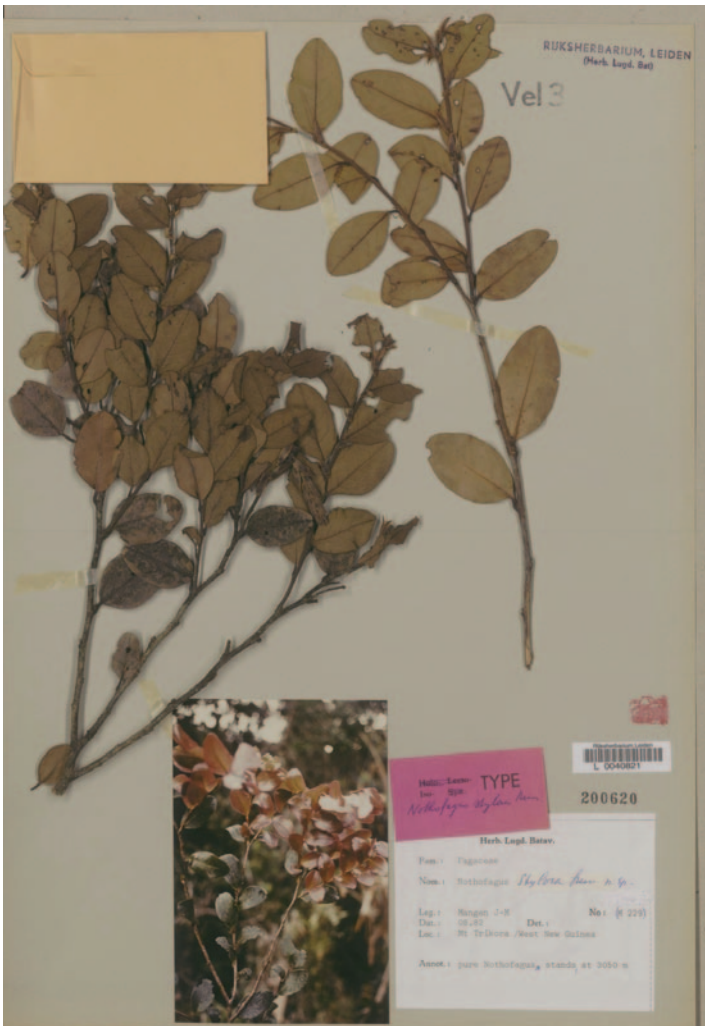

Nothofagus stylosa, isotype herbarium specimen (Naturalis Biodiversity Center)

Nothofagus womersleyi Steenis

Synonym(s): *Trisyngyne womersleyi* (Steenis) Heenan & Smissen. **Common name(s):** lew

IUCN Red List Category and Criteria: Critically Endangered (CR) B1ab(i,ii,v)+2ab(i,ii,v).

Species profiles authors: Olivia Steed-Mundin, Wakehurst, Royal Botanic Gardens, Kew, UK; Dan Crowley, Westonbirt, The National Arboretum, UK, BGCI; Itxaso Quintana, BGCI; Oliver Paul, Papua New Guinea Forest Research Institute, Lae, National Herbarium; Reza Saputra, West Papua Natural Resources Conservation Agency (Balai Besar KSDA Papua Barat), Ministry of Forestry and Environment

Suggested citation: Steed-Mundin, O., Crowley, D., Quintana, I., Paul, O., & Saputra, R. (2024). *Nothofagus* womersleyi Steenis. In Steed-Mundin, O., Crowley, C., Quintana, I., & Wenham, J. *Conservation Gap Analysis of* Nothofagus. Wakehurst, UK: Royal Botanic Gardens, Kew.

Distribution and Ecology

Nothofagus womersleyi has a restricted distribution, known from three localities on the island of New Guinea. One locality is in Indonesian New Guinea in the Kebar Valley, Watjetoni Mountains, West Papua; the second is c.1,300 km away in Papua New Guinea in the Southern Highlands, near Lake Kutubu; the third in Mt Wilhelm National Park, Papua New Guinea (Figure 1). The populations in Papua New Guinea were not included in the IUCN Red List assessment (Baldwin et al., 2018), but they have been confirmed as present (O. Paul pers. comm., 2022), and the occurrence at Lake Kutubu has an herbarium voucher associated with it at RBG Kew (Royal Botanic Gardens Kew, 1975).

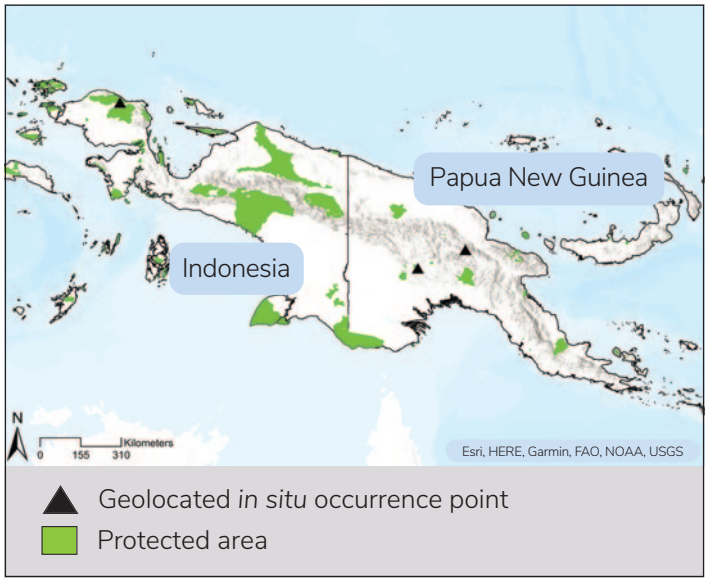

Figure 1. Documented *in situ* occurrence points for *Nothofagus womersleyi* and Terrestrial Protected Areas in the island of New Guinea (Terrestrial Protected Areas are from UNEP-WCMC & IUCN 2022, Protected Planet).

This species has only ever been collected twice, hence the information that follows is limited.

N. womersleyi is an evergreen tree growing to 20 m tall, with a trunk diameter of 40 cm. It grows within primary rainforest in peaty soils (Royal Botanic Gardens, Kew, 2021). It has a reported altitudinal range of 950-1200 m a.s.l. A 1960 collection in West Papua recorded it as locally 'common' (Royal Botanic Gardens, Kew, 2021). Little is reported about co-occurring species.

Threats to Wild Populations

Threats to wild populations were identified by reviewing *The Red List of* Nothofagus (Baldwin et al., 2018), expert consultation and a literature review. Because there is limited published data relating to threats to *N. womersleyi* specifically, the information below largely refers to *Nothofagus* species on the island of New Guinea in general. No threats for *N. womersleyi* were reported in the Conservation Activity Questionnaire.

The threats explored below are considered the current most significant threats, categorised into high and medium impact. This categorisation has been informed by the sources listed above and have been reviewed by regional experts.

High Impact Threats

Extremely restricted population and/or genetic diversity loss: This species is considered to be in a particularly precarious state because of its restricted occurrence and likely narrow genetic base (Baldwin, 2018). However, it should be noted that this is based on the presence of known populations which may be an under-representation of the species' true state in the wild.

Land use change: agriculture and/or silviculture & Logging and/or wild harvesting: This species occurs alongside *Nothofagus flaviramea*, an important timber species, which puts it at higher risk of logging (Baldwin, 2018). In addition, there has been significant deforestation on the island of New Guinea. In Papua New Guinea 15% of tropical forest have been cleared (1972-2002) and a further 8% degraded by logging (Shearman et al., 2009). In Indonesian New Guinea, 0.75 million hectares of old growth forest were cleared from 2001-2019 (Gaveau et al., 2021). For a species with such a small number of populations, deforestation in one location would have a significant impact on population size and genetic variation.

Medium Impact Threats

Disturbance regime modification including fire: Seasonal fires are becoming more prevalent especially in logged areas (Baldwin, 2018) and fire is considered the most important driver of change in high altitude forest in Papua New Guinea (Shearman et al., 2009), where two populations of *N. womersleyi* occur. The limited number of populations make it particularly vulnerable to the threat of fire.

Development, mining, and/or roads: The *N. womersleyi* population in the Kebar Valley is located near the Trans Papua Highway, which has a high risk of human disturbance.

Conservation Activities

In 2021 and 2022 accession data were requested from *ex situ* collections for all *Nothofagus* species that were identified as threatened or Near Threatened in *The Red List of* Nothofagus (i.e. 'target species') (Baldwin et al., 2018). There were no *ex situ* accessions recorded for this species.

In addition, past, present and planned conservation activities for these species were examined through literature review, expert consultation and conduction of a questionnaire. Conservation Activity Questionnaires were sent out 2021 and 2022. For *N. womersleyi*, as with all *Nothofagus* species from the island of New Guinea, no conservation activities were reported in the questionnaire. Information on conservation activities for this species has therefore been provided by expert consultation, research papers and other published sources.

Ex situ collections reported 2021- 2022

No *ex situ* collections were reported.

Estimated *ex situ* representation

No *ex situ* collections were reported.

Wild collecting and/or *ex situ* curation

There are no known wild collecting initiatives. The phenology of fruit production is poorly understood and no research appears to have been carried out into the seed storage behaviour of tropical *Nothofagus* species.

Propagation and/or breeding programmes

There are no known population or breeding programmes for this species.

Reintroduction, reinforcement and/or translocation

There are no known reintroduction, reinforcement or translocation programmes.

Land protection

A spatial analysis was conducted to estimate the protected area coverage within the species' range. Forty, 60 and 80-kilometre buffers were placed around each *in situ* occurrence point. Collectively the *in situ* buffer area serves as the inferred native range of the species or "combined area *in situ*" (CAI40, CAI60, CAI80 respectively). By finding the spatial intersection of CAI within protected areas, protected area coverage could be estimated. Results are presented in km^2 and percentage of area covered for 40, 60 and 80-kilometre buffers; the mean average percentage of coverage of all three buffer sizes is also presented (Table 1). The protected area coverage should be considered an estimation, as buffers around *in situ* points are likely to overestimate the distribution range of the target species. Additionally, these buffers might include non-protected habitat where the target species are unlikely to occur.

Within the inferred native range of *N. womersleyi*, only 2.1% of the land is covered by protected areas (Table 1), even though the reported occurrences are all located within protected areas (Figure 1). However the protected areas have a small area when compared to the chosen buffers (40, 60 and 80-km): Mount Wilhelm National Park, Papua New Guinea (8.17 km^2); a Wildlife Management Area present at Lake Kutubu, Papua New Guinea (49.24 km^2); and the core zone at the south-east of Tamrau Utara Nature Reserve, West Papua, Indonesian New Guinea (Figure 1). In Indonesia, Nature Reserve is the highest level of protected area, functioning primarily for conservation. There are also customary lands which are protected by the local Mpur tribe in Tambrauw.

Table 1. Estimated protected area coverage for *Nothofagus womersleyi*.

	40 km buffer	60 km buffer	80 km buffer	Mean average of all three buffer sizes
Protected area coverage	243 / 13,771 **(1.8%)**	557 / 30,108 **(1.9%)**	1,368 / 52,841 **(2.6%)**	**2.1%**

Sustainable management of land

In Indonesian New Guinea, The Manokwari Declaration committed to conserve 70% of forest in the region of West Papua, where one population of *N. womersleyi* occurs (Cámara-Leret et al., 2019). Furthermore, the Tambrauw Regency has also been declared as a Conservation Regency (Asem et al., 2013). These two regulations aim to ensure sustainable development of the regency and the province where *N. womersleyi* occurs.

In Papua New Guinea, Mount Bosavi Conservation area (situated around the Kutubu area) is committed to conserving the flora and fauna in the area. However, funding is a hindrance. A number of companies including Oil Search Limited, and Papua New Guinea(PNG) ExxonMobil are involved in LNG (liquid natural gas) projects in the Tari and Kutubu area. PNG ExxonMobil has made commitments to preserve biodiversity through their Biodiversity Strategy (PNG Exxon Mobil, 2019), hence it may be possible to seek collaborations focused on conservation and sustainable land management.

Population monitoring and/or occurrence surveys

There have been no recent monitoring or occurrence surveys for the species and there are only three reported occurrences of this species and only one since 1975. An exploration is currently being planned by the West Papua Natural Resources Conservation Agency and other stakeholders to locate the population in Kebar Valley, West Papua (R. Saputra pers. comm., 2022).

Research

No related published research has been found.

Education, outreach and/ or training

No initiatives for *N. womersleyi* are known.

Species protection policies

In West Papua Province, Indonesia, *N. womersleyi* has recently been accepted as a conservation priority species (R. Saputra pers. comm., 2022). There are no known species protection policies for *N. womersleyi* in Papua New Guinea.

Priority Conservation Actions

Results of the Conservation Activity Questionnaire

There were no responses related to *N. womersleyi* in the Conservation Activity Questionnaire.

Conclusion and Recommendations

The following conclusion and recommendations have been compiled by using the research, data and analysis collated in this report, as well as expert consultation.

The Critically Endangered *N. womersleyi* appears to be a very rare tree, limited to just three known populations, two of which have not been recorded since 1975. Considering there are also no *ex situ* collections and limited conservation actions associated with this species specifically, conservation actions are a high priority.

There is a pressing need to locate the recorded populations and to carry out population surveys. This should include thorough investigations of the area to check for other individuals/subpopulations as well to ascertain more specific threats. If populations appear to be declining, lacking recruitment or facing threats from human impact, immediate conservation actions will be essential. Given the limited information available, it is currently only possible to speculate about specific actions, but these would likely include genetically representative seed-collecting for *ex situ* collections and potential reintroductions. Research into phenology, propagation protocols, seed storage behaviour and seedling establishment, would likely also be required. Some related work into phenology has been carried out for *Nothofagus grandis* from Papua New Guinea, which could potentially be expanded to include this species (T. Kuria pers. comm., 2022).

An updated IUCN Red List assessment should also be undertaken once populations have been surveyed.

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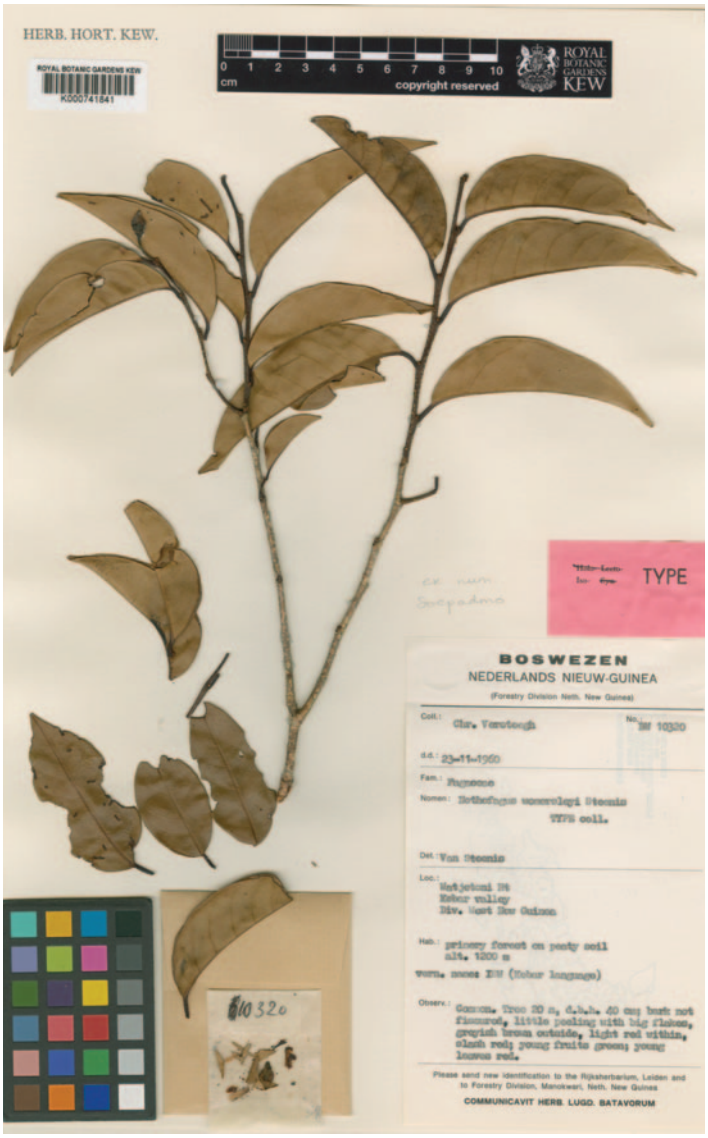

Nothofagus womersleyi, Isotype herbarium specimen (RBG Kew, 2021)

Appendix B: List of organisational contributors to the Conservation Activity Questionnaire for target *Nothofagus* species

Conservation Activity Questionnaires were sent out to 82 organisations from 2021 to 2022. A total of 24 organisations replied to at least one section of the questionnaire.

Thank you to the below organisations who provided data. Some organisations opted to remain anonymous.

Organisation	Country	Threats	Current conservation activities	Priority conservation actions
Bioforest	Chile	✓	✓	✓
Blue Mountains Botanic Garden Mount Tomah	Australia	✓	✓	✓
Château Pérouse Botanical Garden	France	✓	✓	✓
Corporación Nacional Forestal (CONAF) (Centro de Semillas)	Chile	✓	✓	✓
Corporación Nacional Forestal (CONAF)	Chile	✓	✓	✓
Howick Arboretum	UK	✓	✓	✓
Forestal Mininco S.A.	Chile	✓	✓	✓
Inala Jurassic Garden	Australia	✓	✓	✓
Jardín Botánico Nacional	Chile	✓	✓	✓
Jardin des Plantes	France	✓	✓	✓
National Botanic Garden of Wales	UK	✓	✓	✓
Royal Botanic Gardens Kew	UK	✓	✓	✓
Royal Tasmanian Botanical Gardens	Australia	✓	✓	✓
Tasmanian Arboretum	Australia	✓	✓	✓
Universidad Católica del Maule	Chile	✓	✓	✓
Universidad de Concepción	Chile	✓	✓	✓
Universidad de Talca	Chile	✓	✓	✓
Karwarra Australian Native Botanic Garden	Australia	✓	✓	✓
Anonymous organisation 1	Chile	✓	✓	✓
Anonymous organisation 2	Chile	✓	✓	✓
Anonymous organisation 3	Chile	✓	✓	
Anonymous organisation 4	UK		✓	✓

Appendix C: Threats to wild populations listed by species and region

Threat data was gathered from *The Red List of* Nothofagus (Baldwin et al., 2018), Conservation Activity Questionnaire, literature review, and expert consultation. The results were merged as appropriate under the categories presented.

	Land use change - agriculture and/or silviculture	Development, mining and/or roads	Logging and/or wild harvesting	Disturbance regime modification including fire	Climate change	Extremely restricted populations and/or genetic diversity loss	Invasive species	Pests and/or pathogens	Natural regeneration issues	Tourism and/or recreation	Unknown	Other
Australia												
Nothofagus cunninghamii	✓	✓	✓	✓	✓			✓			✓	✓
Nothofagus gunnii				✓	✓			✓			✓	
Nothofagus moorei	✓	✓	✓	✓	✓	✓		✓				
Chile												
Nothofagus alessandrii	✓		✓	✓	✓	✓	✓			✓	✓	✓
Nothofagus glauca	✓	✓	✓	✓	✓		✓	✓		✓	✓	
Nothofagus macrocarpa	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	
New Caledonia												
Nothofagus aequilateralis		✓		✓	✓							✓
Nothofagus baumanniae		✓		✓	✓							
Nothofagus codonandra		✓		✓	✓						✓	
Nothofagus discoidea		✓		✓	✓						✓	
New Guinea (Papua New Guinea and Indonesian New Guinea)												
Nothofagus crenata	✓	✓	✓	✓		✓		✓				
Nothofagus nuda	✓	✓	✓	✓	✓	✓						
Nothofagus pseudoresinosa	✓		✓	✓								
Nothofagus stylosa	✓	✓	✓	✓	✓	✓		✓				
Nothofagus womersleyi	✓	✓	✓	✓		✓						✓

Appendix D: List of organisational contributors to the *ex situ* survey of target *Nothofagus* species

Data was gathered from 2021 to 2022. A total of 48 organisations from nine countries provided accession level data for the target species.

Thank you to the organisations who provided data.

Organisation	Country
Arboretum Bokrijk	Belgium
Arboretum Wespelaar	Belgium
Australian National Botanic Gardens	Australia
Australian Plant Bank	Australia
Balmacara Estate	UK
Bedgebury National Pinetum and Forest	UK
Benmore Botanic Garden	UK
Bicton Park Botanical Gardens	UK
Blue Mountains Botanic Garden Mount Tomah	Australia
Booderee National Park	Australia
Botanic Gardens of South Australia	Australia
Botanical Garden, University of Talca	Chile
Brodick Castle	UK
Cambridge University Botanic Garden	UK
Château Pérouse Botanical Garden	France
Corporación Nacional Forestal (CONAF) (Centro de Semillas)	Chile
Crarae Garden	UK
Crathes Castle	UK
Dunedin Botanic Garden	New Zealand
Eastwoodhill National Arboretum of New Zealand	New Zealand
Exbury Gardens	UK
Forestal Mininco	Chile
Inala Jurassic Garden	Australia
INIA	Chile
Instituto Forestal	Chile
Jardin des Plantes	France
John F Kennedy Arboretum	Ireland
Logan Botanic Garden	UK
Millennium Seedbank, Royal Botanic Gardens Kew	UK
National Arboretum Canberra	Australia
National Botanic Garden of Wales	UK
National Botanical Garden, Valdivian Forest Collection	Chile
Reserva Nacional Laguna Torca	Chile
RHS Garden, Rosemoor	UK
RHS Garden, Wisley	UK
Royal Botanic Garden, Edinburgh	UK
Royal Botanic Garden, Sydney	Australia
Royal Botanic Gardens, Kew	UK
Royal Botanic Gardens, Victoria	Australia
Royal Tasmanian Botanical Gardens	Australia
San Francisco Botanical Garden	USA
Sir Harold Hiller Gardens	UK
Stavanger Botanic Garden	Norway
Tasmanian Arboretum	Australia
Tregrehan Garden	UK
Victorian Conservation Seed bank	Australia
Wakehurst, Royal Botanic Gardens Kew	UK
Westonbirt, The National Arboretum	UK

Nothofagus glauca, Cerro Poqui, Chile (Nicolás Lavandero)

Appendix E: Results from the *ex situ* collections survey of the target *Nothofagus* species

The ex *situ* collections survey was sent out from 2021 to 2022. 48 organisations from nine countries provided accession level data. See Appendix D for a list of participating organisations.

	No. of organisations with ex situ collections (inc. plants, seedlings and/or seed)	No. of accessions in ex situ living collections (plants and seedlings)	No. of individual plants in ex situ living collections	No. of plants marked as wild origin in ex situ living collections	No. of plants ex situ with given or geolocated wild origin	No. of wild origin seedlings in ex situ nurseries	No. of accessions in ex situ seedbanks	No. of seeds in ex situ seed banks	No. of seeds marked as wild origin in ex situ seed banks	No. of seeds ex situ with given or geolocated wild origin
Nothofagus aequilateralis	0	0	0	0	0	0	0	0	0	0
Nothofagus alessandrii	21	50	150	127	125	4047	3	2115	2115	2115
Nothofagus baumanniae	0	0	0	0	0	0	0	0	0	0
Nothofagus codonandra	1	1	1	1	1	0	0	0	0	0
Nothofagus crenata	0	0	0	0	0	0	0	0	0	0
Nothofagus cunninghamii	30	202	409	220	203	0	10	255,354	255,354	255,354
Nothofagus discoidea	0	0	0	0	0	0	0	0	0	0
Nothofagus glauca	24	70	102	74	60	15,535	8	22,558	20,919	20,919
Nothofagus gunnii	6	11	27	27	18	4	7	26,079	26,079	26,079
Nothofagus macrocarpa	9	10	23	17	16	1	2	22,369	22,369	22,369
Nothofagus moorei	20	95	199	172	171	2	4	706	706	706
Nothofagus nuda	0	0	0	0	0	0	0	0	0	0
Nothofagus pseudoresinosa	0	0	0	0	0	0	0	0	0	0
Nothofagus stylosa	0	0	0	0	0	0	0	0	0	0
Nothofagus womersleyi	0	0	0	0	0	0	0	0	0	0

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