BGCI and IABG's

Species Recovery Manual

BOTANIC GARDENS CONSERVATION INTERNATIONAL

IABG International Association of Botanic Gardens

Botanic Gardens Conservation International (BGCI)

BGCI is a membership organisation representing a network of 800 botanic gardens in more than 100 countries. Our members include the largest, most renowned gardens on the planet but they also include many smaller gardens situated in the world's plant diversity hotspots. All of these member gardens share a commitment to making sure that no plant species becomes extinct, and a combined workforce of many thousands of horticulturalists and scientists is working towards that end. BGCI is the largest plant conservation network in the world, and our vision is a world in which plant diversity is valued, secure and supporting all life. To create this world our mission is:

"To mobilise botanic gardens and engage partners in securing plant diversity for the well-being of people and the planet".

BGCI has offices in Europe, North America, Asia and Africa, and is in a prime position to promote an efficient, cost-effective and rational approach to plant conservation in botanic gardens. We do this in four ways by:

1. **Leading and advocacy**. We provide leadership for the botanic garden sector, promoting the role of botanic gardens to policymakers and funders in delivering the Global Strategy for Plant Conservation.
2. **Leading innovative and strategic projects achieving outcomes in plant conservation policy, practice and education**. BGCI leads projects and networks delivering Global Strategy for Plant Conservation targets.
3. **Co-ordinating efforts and building plant conservation capacity in botanic gardens and broader society**. We build technical capacity in the botanic garden sector and beyond by acting as a knowledge hub and a clearing house for best practice, training, resources and expertise.
4. **Providing funding**. We mobilise funding to deliver plant conservation projects and outcomes in the botanic garden community and wider society.

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Ecological Restoration Alliance of Botanic Gardens (ERA)

BGCI coordinates the Ecological Restoration Alliance of Botanic Gardens (ERA), a global consortium of botanic gardens actively engaged in ecological restoration. ERA members are carrying out restoration of a diverse range of ecosystems around the world. Members are committed to partnering with other restoration practitioners and using their skills and knowledge to support and improve restoration, specifically focusing on incorporation of a wide range of indigenous species for biodiversity conservation and restoration for species conservation.

International Association of Botanic Gardens (IABG)

For over 60 years, the International Association of Botanic Gardens (IABG) has been the official umbrella organisation for botanic gardens and arboreta all over the world. Founded in 1954 at the 8th International Botanical Congress held in Paris, IABG is a scientific member of the International Union of Biological Sciences (IUBS) to which it reports. The main aims of IABG are:

- To promote international cooperation among botanic gardens, arboreta and other similar institutes and organisations maintaining scientific collections of living plants; and work with and foster cooperation between botanic garden organisations at national and regional levels.
- To promote the documentation and exchange of information, plants and specimens of mutual interest among botanic gardens, arboreta and other similar institutes.
- To promote the study of plants, especially those that are of scientific, economic or cultural interest, through their cultivation within botanic gardens, arboreta and similar institutes and organisations, and through research on the taxonomy, physiology, reproductive biology and phenology of plants, both wild and cultivated.
- To foster the role of botanic gardens, arboreta and other appropriate organisations in habitat and species conservation, recovery and restoration and to promote cooperation in these fields between IABG and such organisations.
- To promote the science and technology of horticulture, including the study and the practice of plant introduction, adaptation, selection and breeding, and develop cooperation with horticultural institutions and associations.
- To promote awareness of the risks posed by invasive alien species and adopt precautionary measures to prevent their introduction and spread as well as those with invasive potential.
- To strengthen the role and recognition of botanic gardens as major scientific and cultural organisations in addressing a wide range of environmental and social issues, at the national, regional and global levels.

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Magnolia ventii, South China Botanical Garden (Image: Yang Keming).

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Seed storage at the millenium seedbank. With strict controls over humidty and with the temperature at -20C the seeds are preserved for research and restoration. Wakehurst Place, Royal Botanic Gardens, Kew (Image: Barney Wilczak).

Preface

Tissue culture of orchid species at the Xishuangbanna Tropical Botanic Gardens (Image: Barney Wilczak).

In the light of recent assessments which confirm that biodiversity continues to decline in every region of the world, significantly reducing nature's capacity to contribute to people's well-being, it is incumbent on us to redouble our efforts to plan and implement conservation actions in the most efficient and effective ways possible. Plant conservation is largely dependent in most countries on the creation of a system of protected areas, complemented by both *in situ* and *ex situ* actions at the species and population level, notably species recovery actions, reintroductions and conservation translocations and the creation of genebanks for storing germplasm such as seed, pollen, cell and tissue cultures.

Conservation of threatened species involves both protection of the habitats and areas in which they grow and actions directed at the species and population level. While enormous advances have been made in developing and managing protected areas, the effective conservation of threatened species very often requires more than their simple presence in such areas and needs to be supplemented by various forms of management intervention through species recovery programmes. While a few countries have well developed species recovery systems most have not and the situation is quite acute in the tropics where comparatively little action is undertaken. Moreover, most threatened species occur outside protected areas and so far efforts to address their conservation have been largely neglected.

It is evident that species recovery is not well understood. It is a complex process involving many different disciplines and actors, and responsibility for it at a national level is often unclear, given that it cuts across different ministries and agencies. After various consultations, it was felt by BGCI and IABG that it would be valuable to produce a manual that would clarify the aims and purpose of species recovery, set out the various steps and processes involved, propose the necessary guidelines and indicate good practice. Given the lack of resources, both human and financial, currently available for comprehensive species recovery plans, the manual also indicates various ways in which *in situ* conservation actions that fall short of full recovery may be undertaken, thus providing an interim solution until more ambitious approaches are possible.

This manual is aimed specifically at conservation practitioners but also includes comprehensive bibliographic references, which enable more in depth reading on the topics covered in this publication. Our hope is that this manual will be particularly useful for botanic garden staff working on integrated plant conservation projects that encompass both *ex situ* and *in situ* conservation. Encouraging botanic garden personnel to share their data, knowledge and skills outside their garden walls, particularly for species recovery, is an important objective for BGCI and IABG.

The preparation of the manual has benefitted from the participation of several conservation biology experts who have prepared the text of some of the chapters. Many others have provided advice, comments and photos.

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Paul Smith BGCI

Vernon Heywood IABG

Introduction and Scope

Globally the loss of biodiversity shows little sign of decreasing, despite our efforts to arrest this trend. The biggest threats facing plants are habitat loss, biological resource use, residential and commercial development, natural system modifications, pollution and invasive species. The predicted impacts of climate change present a scenario in which the effectiveness of our conservation approaches is being questioned. Given the limited resources available for conservation, it is essential that we focus our efforts on actions that are likely to produce successful conservation outcomes.

The development of a system of protected areas or reserves is the underpinning of most countries' conservation strategy although increasingly the effectiveness of protected areas in protecting biodiversity is being questioned, especially in the light of climate change. Targeted actions, including recovery programmes, are being undertaken to address the growing number of threatened species, but to date such actions are only in place for a limited number of species in a small number of countries and scarcely at all in most tropical countries.

One of the reasons for this neglect of recovery actions is a lack of clarity and consistency about the aims and methods to be employed, coupled with a lack of critical empirical evaluation of the effectiveness of the interventions that have been carried out. No standardised format exists for developing or implementing a species recovery plan, although many countries use plans based on those developed under the United States Endangered Species Act of 1972[1] as a reference and source of guidance.

This manual aims to address issues that have hindered the widespread application of recovery programmes by providing guidance on planning and implementing species recovery projects.

Scope

A broad introduction to conservation approaches is provided in the opening chapters of this manual, but the focus of guidance provided is on species recovery. The manual does not deal with reintroduction which is undertaken when parts or all of a species' natural range has been lost and aims to introduce a new population(s) within it. Good practice and guidelines for reintroductions already exist such as those of the Center for Plant Conservation[2].

Tetradium ruticarpum growing within a pilot restoration site in Gongcheng County, China.

Content

Chapter 1 provides an introduction to species recovery, outlining context and definitions. Chapter 2 provides an overview of current species recovery planning and actions, identifying who is doing what and where.

Chapters 3 - 5 focus on the need for species recovery as part of effective conservation strategies and in the face of threats to plants. Chapter 3 provides an overview of the process of *in situ* conservation and where species recovery fits in. Chapter 4 analyses the shortcomings of protected areas and why species-focused measures within protected areas are required alongside broader site management. Chapter 5 discusses the nature of threats that face plants, a clear understanding of which is important for successful species recovery.

As funds and resources available for conservation are limited, Chapter 6 helps practitioners to prioritise which species should be included in recovery programmes.

Chapters 7 – 12 provide guidance on planning, developing and implementing species recovery plans and actions. Chapter 7 provides guidance on eco-geographical surveying to gain a full understanding of a target species before designing a species recovery plan. Chapter 8 provides guidance on how to develop a species recovery plan. Guidance is provided on determining how many individuals and populations to include in species recovery (Chapter 9), how to involve communities and other stakeholders in species recovery (Chapter 10), management interventions (Chapter 11) and how to monitor species recovery (Chapter 12). Chapter 13 concludes the manual by looking at this guidance and the need for species recovery in the longer-term.

Case studies are included in this manual to provide an additional source of guidance for the preparation of recovery plans. Further reading and references is provided at the end of each chapter.

Audiences

This manual is aimed at helping conservation policy makers and practitioners to appreciate the need for effective species recovery and provide guidance on how to undertake effective species recovery programmes. The manual also aims to encourage more botanic gardens and arboreta to actively use their *ex situ* collections, skills and knowledge for species recovery programmes. The guidance also aims to help protected area managers, other land managers and communities to appreciate the important role that they can play in species recovery.

Endnotes

[1] Endangered Species Act (1973). www.fws.gov/endangered/laws-policies/
[2] Maschinski, J., Albrecht, M.A., Monks, L.T. and Haskins, K.E. (2012). Center for Plant Conservation. Best Reintroduction Practice Guidelines. In: Maschinski, J. and Haskins, K.E. (Eds.). *Plant Reintroduction in a Changing Climate: Promises and Perils. The Science and Practice of Ecological Restoration*. Island Press, Washington D.C., United States.

Chapter 1.
Context and definitions

Aim of this chapter

This chapter provides an introduction to species recovery and outlines the mandate and policy context for species recovery programmes. The chapter also aims to clarify terms used related to species recovery, by providing an explanation of different conservation approaches and providing definitions of key terms.

1.1 What is species recovery?

Species recovery refers to the procedures whereby species as a whole, or targeted populations of species that have become threatened, for example through loss of habitat, decrease in population size, or loss of genetic variability, are recovered to a state where they are able to maintain themselves without further human intervention.

Species recovery is essentially an *in situ* process although *ex situ* material is often required for population reinforcement (augmentation). It is a multidisciplinary approach and involves many different actors. Species recovery should not be a stand-alone action, but should be seen as part of an overall integrated conservation strategy (see Section 1.3 Conservation approaches).

1.2 Mandate and policy context

The international mandate for species recovery derives from the United Nations Convention on Biological Diversity (CBD) and subsequent decisions adopted by the Parties to the Convention, such as the Global Strategy for Plant Conservation, the Strategic Plan for Biodiversity 2011-2020, including the Aichi Biodiversity Targets, and from the Second Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture which includes *in situ* conservation and management as the first of its priority actions.

Clauses (d) of the CBD Article 8 *In Situ Conservation* 'Promote the protection of ecosystems, natural habitats and the maintenance of viable populations of species in natural surroundings'; and (f): 'Promote the recovery of threatened species, inter alia, through the development and implementation of plans or other management strategies' are quite explicit in addressing conservation at the species level. In addition, Article 9 *Ex Situ Conservation*, clause (d): 'Adopt measures for the recovery and rehabilitation of threatened species and for their reintroduction into their natural habitats under appropriate conditions' specifically refers to recovery.

Demonstrating a clear understanding of the policy context for species recovery in funding applications will increase chances of success.

Following the failure to meet the 2010 Biodiversity Targets, Parties to the CBD adopted a revised Strategic Plan for Biodiversity, including 20 'Aichi Biodiversity Targets' for the period 2011–2020, Target 12 being 'By 2020 the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained'. Moreover, Goal C of the Strategic Plan is 'Improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity' which would be achieved in part through species and habitat recovery actions.

The revised Global Strategy for Plant Conservation adopted by the CBD includes two key targets for species level conservation, to be achieved by 2020:

GSPC Target 7: 'At least 75% of known threatened plant species conserved *in situ*', and
GSPC Target 8: 'At least 75% of threatened plant species in *ex situ* collections, preferably in the country of origin, and at least 20% available for recovery and restoration programmes'.

There is therefore, a strong international mandate for species recovery programmes.

In some instances, there are regional treaties relevant to species conservation and recovery such as the European Union's Habitats Directive and the Council of Europe's Bern Convention, both of which have compiled lists of species requiring conservation action (see further detail in Chapter 2).

In addition to these international and regional commitments, countries may have their own national mandate or policy for species conservation and recovery. In all cases, recovery actions have to take place in accordance with the relevant legislation of the countries concerned.

1.3 Conservation approaches

Traditionally, plant conservation is undertaken *in situ* for ecosystems and areas and for species and populations; and *ex situ* for species and populations. Box 1.1 provides a summary of conservation approaches.

Box 1.1 Conservation approaches

***In situ* conservation**

The practice of *in situ* conservation of plant diversity essentially comprises of two approaches:

(1) At the habitat level: Creating protected areas of various types for the conservation of ecosystem diversity and biological diversity or important/significant species diversity; and
(2) At the species/population level: Conserving individual target species or small groups of target species (threatened or not) through *in situ* management and monitoring.

Most countries have developed a system of protected areas to address the conservation of areas, ecosystems and habitats and the biodiversity within them. These areas range from strictly protected reserves to multi-use areas, and consequently their role in conserving individual species varies greatly, as is discussed in Chapter 4. Many species/populations receive some degree of protection if situated in protected areas but are often not effectively conserved solely by being present in a protected area. Usually, some form of direct **species conservation**, **management or recovery** will also be required. In the case of threatened species this will include actions directed at containing or removing the threat(s) to which they are subject. Species conservation, management or recovery is often required for successful conservation of threatened species, both within and outside of protected areas.

***Ex situ* conservation**

Many countries have *ex situ* conservation facilities such as seed banks, pollen banks, field genebanks (living collections), and tissue/cell culture laboratories for short, medium or long-term storage of germplasm. Such collections should aim to capture the genetic diversity of the target species, and hold sufficient material for the implementation of recovery and restoration programmes as required.

The *in situ* conservation, management or recovery of a species, by definition essentially takes place in nature (*in situ*), but may also involve *ex situ* actions such as growing or storing material that may be used for population reinforcement (augmentation).

Royal Botanic Gardens, Kew Millennium Seed Bank contains more than 85,800 seed collections, representing over 38,500 species (Image: Barney Wilczak).

1.4 Intermediate conservation approaches

The separation between *in situ* and *ex situ* conservation is no longer clear cut and increasingly conservation approaches that fall between or combine the two are being introduced. Some of the approaches have not yet been tested on a wide scale but are included in Box 1.2 as they are relevant to recovery programmes.

Box 1.2 Intermediate conservation approaches

Quasi in situ

The terms 'complex *ex situ-in situ* … conservation' and '*quasi in situ* conservation were introduced by Volis and Blecher[1] to describe their approach as a bridge between *ex situ* and *in situ* conservation whereby *ex situ* collections are maintained in a natural or semi-natural environment while preserving both neutral and adaptive genetic diversity. It was applied to populations of *Iris atrofusca* in the Northern Negev, Israel. A modified version of this *quasi in situ* approach whereby growing *in situ* seedlings of diverse origins aimed at enriching the diversity of an existing population was attempted with apparently considerable success in the woody climber *Embelia ribes* in the Western Ghats, India[2].

Quasi in situ should be considered as a possible alternative to conventional recovery approaches.

Circa situm

The term '*circa situm*' has been used to refer to the special circumstances of conservation within altered agricultural landscapes (e.g. agroforestry systems, home gardens) that are outside natural habitats but within a species' native geographical range[3]. It is usually applied to tree species and is described as 'the preservation of planted and/or remnant trees and wildings in farmland where natural forest or woodland containing the same trees was once found, but this has been lost or modified significantly through agricultural expansion'. It is sometimes referred to as 'conservation through use'[4].

Circa situm can contribute to the conservation of tree species in highly modified agricultural landscapes, facilitate pollination between populations, and provide seed sources to support recovery programmes.

Seed (genetic) plots

The practice of selecting plots or stands of target species of trees and woody plants for seed production for use in plant breeding is a form of conservation that may be carried out both *in situ* in natural forests or planted *ex situ*. Various terms are used, including seed plots, genetic plots, gene conservation stands, seed stands, seed collection areas or seed stands, and most are applied in forestry[5].

Seed plots provide a good source of material for recovery programmes for trees.

→ → →

Dynamic conservation units
Dynamic conservation of forest genetic resources means maintaining the genetic diversity of trees within an evolutionary process and allowing generation turnover in the forest. The conservation units may consist of either natural or planted stands. A pan-European network of selected genetic conservation units for various tree species has been created according to pan-European minimum requirements and data standards of these units[6].

This approach is specifically aimed at the *in situ* conservation of genetic resources of forest trees (See Box 6.8) and can provide a source of seed for recovery programmes.

Plant Micro-Reserves (PMRs)
In an ideal world, nature reserves should be as large as possible but this is becoming increasingly unachievable as fragmentation of ecosystems has become a global phenomenon. The use of vegetation fragments as small scale reserves for attempting to conserve populations of endangered species has been practised in several countries. A particular model is the Plant Micro-Reserve (PMR) pioneered in Spain and also adopted in Central and Eastern Europe[7] and less formally in many other countries. Small reserves are inherently unstable and difficult to maintain and manage but can be worthwhile, at least in the short-term, especially for target species of high importance[8].

PMRs may provide an alternative form of conservation for species with small populations where large formal protected areas are not possible.

Source: Modified from Heywood[9]

Above: Home gardens in Tengchong County, China growing socio-economically important native plant species.
Below: Home gardens in Tengchong County, China have been designed to include native plants with ornamental, medicinal and economic functions.

1.4 Integrated conservation strategies

There is a growing acceptance of the need for collaboration between *in situ* and *ex situ* conservation practitioners, and adoption of a combination of *in situ*, *ex situ* and intermediate conservation approaches. At the same time, it is being increasingly recognised that much more attention should be paid to seeking ways of conserving species that occur outside protected areas and involving a wider range of land managers as well as local communities. This is of particular relevance to species recovery programmes as they rely on a combination of *in situ* and *ex situ* conservation approaches and many threatened species' ranges do not occur within protected areas.

1.5 Terminology

The terminology associated with species recovery is often complex. In the absence of an internationally agreed framework and terminology for species recovery, this section provides an explanation of the source of confusion and guidance on the use of the term 'recovery' and other related terms. We have also included a Glossary (Appendix 1) providing a broader set of definitions that align with common practice.

When applied to species, the terms 'recovery' and 'recovery plans' tend to be used as a general description for any actions to protect or conserve threatened species. However, the terms 'recovery' and 'recovery plans' derive from the US Endangered Species Act, where they have a quite specific meaning[10]. As the ultimate goal of all *in situ* interventions is to 'recover' species so they no longer need conservation action, the general use of the terms 'recovery' or 'recovery plans' to refer to actions to protect or conserve threatened species is therefore acceptable, provided it is clear what actions are covered.

Furthermore, there is no agreement in the conservation community as to what the concepts of 'recovery' and 'recovered state' actually mean or involve and they are poorly defined and often confused, both in the conservation literature and in legislation. As a consequence, each country may propose its own definitions and criteria and different levels of detail, both qualitative and quantitative, about the process and the end-state may be included in the definitions[11]. This is one of the contributory factors to the lack of success of many recovery programmes and failure to meet targets. It also makes it difficult to evaluate and compare the outcomes of recovery programmes given that each adopts its own criteria and many papers do not provide clear definitions of the terminology used.

'...defining what recovery should mean for a population or species involves more than scientific analysis. In particular, the risk of partial or complete failure (i.e. extinction) that we as a society are willing to accept and the degree to which we try to restore species to former numbers, distributions, and ecological functions blend into matters legal and ethical'.[12]

IUCN has proposed a set of Guidelines for Reintroductions and Other Conservation Translocations[13]. These guidelines do not deal directly with species recovery in the broad sense but only those cases where population reinforcement (augmentation) is required.

Some definitions of key terms are provided in Box 1.3.

Box 1.3 Definitions

Recovery is the process whereby a species or population is restored to a viable state in which it is self-sustaining without further intervention. The term is also used for the outcome or recovered end-state of the process (also known as **recovered state**). The terms **recovery goal**, **recovery criteria**, **recovery actions** are also used.

Reintroduction is the intentional movement and release of an organism inside its indigenous range from which it has disappeared.

Translocation is the human-mediated movement of living organisms from one area, with release in another. The IUCN reintroduction guidelines use the term **conservation translocation** and when the release is within the indigenous range, they call this **population restoration** and if conspecifics are present in the release, this is termed **reinforcement** [augmentation] and if not, reintroduction.

Note: This manual focuses on species recovery, not reintroduction.

Protection versus conservation. A distinction is sometimes made between the processes of 'protection', which has been defined as 'determining and implementing the short-term measures necessary to halt a species' slide to extinction', and 'recovery', defined as 'determining and implementing the longer-term measures necessary to rebuild the population of the species to the point at which it is no longer in danger of extinction'[14]. We recommend maintaining a distinction between 'protection' and 'conservation': For example, protected areas and micro-reserves may afford some degree of protection to individual species but not complete conservation which would require the implementation of further measures that are aimed at addressing the specific threats to which the species is subjected. Further measures can include recovery actions.

Protection versus persistence. It is not just presence of a species/population in a protected area but its persistence there that is important to qualify as effective conservation. The persistence of a species may rely on recovery actions.

Restoration. The use of the term restoration without qualification, e.g. ecological restoration, habitat restoration, species restoration, population restoration, etc., is best avoided.

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Species-rich dry grasslands restored after removal of exotic conifer plantations in southern Belgium (Image: Sandrine Godefroid).

Chapter 2.
Who is doing what and where?

Aim of this chapter

This chapter provides an overview of what is being done in terms of plant species recovery around the world and by which bodies, and highlights good reference sources for developing species recovery plans. This chapter also highlights the desirability of countries preparing a national strategy for species recovery.

2.0 Introduction

When planning conservation of plant species, it is important to be aware of what is already being done nationally since a country or state framework or guidelines may exist and should be followed when appropriate. It is also useful to know how issues are tackled in other countries, especially those with a long-standing tradition of preparing and implementing recovery plans, so that valuable lessons can be learned.

2.1 Implementing partners

In practice, *in situ* actions such as the preparation and implementation of recovery, conservation, management or monitoring plans are carried out by a diversity of organisations and agencies, reflecting the interdisciplinary nature of the topic. These include:

- Government departments
- National or regional environment agencies
- Forestry institutes
- University departments
- Botanic gardens and arboreta
- National or local environment or conservation associations
- Intergovernmental agencies
- Nongovernmental organisations (NGOs)
- The armed forces, and
- Civil society

Such a wide range of actors makes it difficult to access information on the recovery actions being undertaken by individual countries, especially as many countries appear to have no mechanism for gathering the data and have a poor record of reporting it, even though they are required to do so under various treaties to which they are party.

'In the regional workshops, countries reported that species conservation management plans helped improve the conservation status of species. Yet, data on how many threatened species have conservation management plans is reported only sporadically'. CBD SBSTTA Updated Assessment of Progress Towards Selected Aichi Biodiversity Targets[1]

2.2 Legal basis

Endangered species legislation is a major framework for the delivery of science advice to conservation policy.[2]

Evidence suggests that species recovery efforts benefit considerably when:

i) They are undertaken by or under the auspices of specialised governmental or state agencies
ii) National legislation is in place that provides the legal framework for protection and the necessary resources[3]
iii) They have a legal basis

Even so, the existence of legislation is no guarantee of action on the ground.

Countries such as Australia, Canada, Japan, the USA and New Zealand have adopted a formal national legal structure for species recovery. More information on the approaches of some of these countries is provided in this chapter. Many countries have adopted a looser and less organised approach and of these many appear to have little or no evident action or policy.

In addition to national requirements, the legal framework may also derive from an intergovernmental treaty or agreement to which individual governments are parties. For example, the European Union Habitats Directive and the Council of Europe's Bern Convention. More information on their impact on species recovery planning in Europe is provided in this chapter.

In some countries such as Italy, the protection of the flora is addressed only through the ratification of international agreements or EU Directives and not through national measures[4].

2.3 National inventories of recovery actions.

While most countries have prepared, or are preparing, a list of threatened species, only a few of them, such as Australia and the USA for example, have compiled a national list of recovery plans. For most countries, it can be difficult to access information about who is doing what since the relevant data is widely dispersed, and there is no compilation or database of actions being undertaken for recovery or management plans for *in situ* conservation of target species either at a global or regional level.

An overall assessment for individual countries, albeit somewhat out of date, can be obtained from the 4th National Reports to the CBD (submitted from 2009-2014) which include as an annex Progress towards Targets of the Global Strategy for Plant Conservation (GSPC) and from the 5th National Reports (submitted from 2014 to date) which report on progress towards the implementation of the Strategic Plan for Biodiversity 2011-2020 and progress towards the Aichi Biodiversity Targets. However, many countries have not submitted a report and for others that have prepared reports little or no precise information about *in situ* conservation or recovery planning for plant species is included[5].

It should be noted that the publication of recovery plans does not necessarily indicate that the plans have been agreed, let alone implemented. For example, Bermuda has prepared a recovery plan for eight species of flowering plants in accordance with the Bermuda Protected Species Act 2003. The plan lists in detail the actions proposed but only represent the official position once they have been signed and approved by the Director of Conservation Services[6]. Likewise, a recovery plan for the Yellow wood tree, *Zanthozylum flavum*[7], outlines the actions needed for its recovery but as noted in the foreword by the director of the Department of Environment and Natural Resources of Bermuda, 'Objectives of the recovery plan will be attained and necessary funds made available subject to budgetary and other constraints affecting the parties involved'.

The majority of species recovery plans are being developed, and actions are being implemented, in Australia, Canada, China, New Zealand, South Africa, the USA and Europe. More detail about the experiences of some of these countries is provided below and links to national recovery plans are provided as further reading at the end of this chapter.

Box 2.1 Links to national recovery plans and related topics

Australia
- Australian Government Department of Environment and Energy
- Species Profile and Threats Database
  www.environment.gov.au/cgi-bin/sprat/public/sprat.pl
- Recovery Plans made or adopted
  www.environment.gov.au/biodiversity/threatened/recovery-plans/made-or-adopted
- The Australian Government's Threatened Species Strategy
  www.environment.gov.au/ts-strategy
- New South Wales Department of Environment & Heritage Recovery Plans
  www.environment.nsw.gov.au/threatenedspecies/RecoveryPlans.htm

Brazil
- Brazilian National Centre for Flora Conservation (CNCFlora)
  cncflora.jbrj.gov.br/portal

Canada
- Species at risk Public Registry A to Z Species Index
  www.registrelep-sararegistry.gc.ca/sar/index/default_e.cfm

China
- Plant species with extremely small populations (PSESP) and their significance in China's national plant conservation strategy[8].
  www.biodiversity-science.net/EN/10.17520/biods.2014183

Europe
- EIONET. European Environment Information and Observation Network
  www.eionet.europa.eu
- The Biodiversity Information System for Europe (BISE):
  biodiversity.europa.eu//
  www.eea.europa.eu/publications/state-of-nature-in-the-eu

Spain
- Estrategia Española de Conservación Vegetal 2014–2020
  www.mapama.gob.es/es/biodiversidad/planes-y-estrategias/estrategia_ce_vegetal_2014-2020_tcm30-197338.pdf

Mediterranean region
- An overview of *in situ* conservation of plant species in the Mediterranean. Heywood (2014)[9]
  www1.unipa.it/herbmed/flora/24-005.pdf

United Kingdom
- UK BAP priority vascular plant species
  jncc.defra.gov.uk/page-5171

United States
- U.S. Fish & Wildlife Service (USFWS)
- Environmental Conservation Online System (ECOS)
  ecos.fws.gov/ecp0/reports/box-score-report#recPlans
- Find Endangered Species
  www.fws.gov/endangered/
- Endangered Species Recovery Plans Search
  www.fws.gov/endangered/species/recovery-plans.html
- Endangered Species Recovery | Overview
  www.fws.gov/endangered/what-we-do/recovery-overview.html

New Zealand
- Government of New Zealand Department of Conservation
- Threatened Species Recovery Plans
  www.doc.govt.nz/about-us/science-publications/series/threatened-species-recovery-plans/

2.3.1 Australia

In Australia, national recovery planning instruments were originally provided for in the Commonwealth's Endangered Species Protection Act 1992 and are now provided for by its successor, the Environment Protection and Biodiversity Conservation (EPBC) Act 1999 which is the main legislative pillar for national threatened species protection. Recovery planning also occurs at the state and territory level. Recovery plans are binding on the government – 'once a recovery plan is in place, Australian Government agencies must act in accordance with that plan'[10] although there is no mechanism in the Act to enforce this[11].

The Department of the Environment's **Species Profile and Threats Database**[12] lists the Recovery Plans adopted under the EPBC Act. This includes recovery plans for more than 600 plant species, plus a number of plans that address all of the threatened species and ecological communities within a given region. The website allows access to the detailed recovery plans and so is a valuable resource for those contemplating species recovery actions.

A recent review[13] suggests that there is a shift taking place at the federal level away from recovery plans towards less robust instruments. For example, less detailed conservation advices under the EPBC Act that are not binding on decision makers, are increasingly being relied upon for species that have been identified by the Australian Government as having 'simple' protection needs.

The Australian Government **Threatened Species Strategy**[14] includes the following goals for plants by 2020:

- 100% of Australia's known threatened plant species stored in one or more of Australia's conservation seed banks
- Recovery actions underway for at least 50 plants and at least 60 threatened ecological community sites
- At least 30 priority plant species have improved trajectories
- At least 80% of projects funded through the 20 Million Trees and Green Army programmes support recovery of threatened plants and animals.

Another important initiative is the Australian Government's **Threatened Species Recovery Hub** which is a collaborative research programme on threatened species management. This AU$60 million initiative is supported by funding through the Australian Government's National Environmental Science Programme (NESP), and matched by contributions from ten of the country's leading academic institutions and the Australian Wildlife Conservancy. It works closely with more than two dozen collaborating organisations, including management agencies and conservation groups, to ensure its research has an on-ground impact in threatened species management. The Threatened Species Recovery Hub was established in 2015 and will conclude in 2021[15].

In addition, at a state level, recovery plans have been written specifically for state populations of target species. An example is the state of New South Wales (NSW) where, under the NSW Threatened Species Conservation Act 1995, recovery plans may be prepared for a species, a group of species, or for part of the range of a species. Some 60 recovery plans for endangered or vulnerable plant species have been prepared[16] but since 2007, the preparation of **Priorities Action Statements** have largely replaced the development of full recovery plans.

The NSW Office of Environment and Heritage is responsible for running a conservation programme for threatened species called *Saving our Species*. Under this programme, a conservation project has been prepared for most of the 650 listed threatened plant species in NSW. Each project includes a set of management actions that have been considered by an expert panel for each species to be important to implement to ensure at least one population survives in 100 years' time. In 2016, the NSW government announced funding of AU$100 million over the next five years for the *Saving our Species* programme. In year one of the programme, 262 entities will receive implementation funding, most of which are plant species[17].

2.3.2 Canada

In Canada, the Species at Risk Act (SARA) 2003 is one part of the Government of Canada's strategy for the protection of wildlife species at risk. The strategy also includes commitments under the Accord for the Protection of Species at Risk under which federal, provincial and territorial ministers responsible for wildlife, commit to a national approach for the protection of species at risk and activities under the Habitat Stewardship Program. This programme is a partnership-based conservation initiative sponsored by the Government of Canada, administered by Environment Canada and managed cooperatively with Parks Canada Agency and Fisheries and Oceans Canada.

The purposes of SARA are to prevent Canadian indigenous species, subspecies, and distinct populations from becoming extirpated or extinct, to provide for the recovery of endangered or threatened species, and encourage the management of other species to prevent them from becoming at risk. The Act established the **Species at Risk Public Registry** which includes Schedule 1 as the official list of wildlife species at risk and lists 221 species of vascular plants of which 46 are species of special concern and 22 are not at risk, together with links to information about the species and recovery initiatives[18].

Once a species is listed as extirpated, endangered or threatened, individuals of that species are automatically protected on federal land and the competent minister must prepare a strategy for its recovery. In practice, the preparation of recovery strategies for listed species has been slow and practically none has a legally accepted recovery action plan so action on the ground is also lacking[19].

Recovery planning also occurs outside the auspices of SARA, for example recovery strategies and action plans produced by individual jurisdictions, or national recovery plans that were published prior to SARA.

2.3.4 China

Conservation at the species level in China, which houses about 10% of the world flora, has focused mainly on *ex situ* approaches, largely through the efforts of botanic gardens that belong to the Academy of Science's Chinese Union of Botanical Gardens (CUBG).

In China, *in situ* conservation of plant species is addressed primarily by the c. 3000 nature reserves, covering c. 16% of the land surface of the country, that have been established since 1956 and the large number of forest parks and small reserves. These provide a basis for the development of a network of *in situ* conservation areas for wild plants[20]. The reserves house a large number of plant species and a high percentage of the Chinese flora, although the exact number of plant species conserved *in situ* in the nature reserves is not known nor is it known how many of these species are effectively conserved. The total number of species for which conservation or recovery plans have been prepared or implemented in China is not known although a programme for the conservation and restoration of Plant Species with Extremely Small Populations (PSESP) was launched in 2010 by the State Forestry Administration (SFA), the lead conservation agency in China (see Case study 1). This programme involved initially 120 very rare species, covering all ecosystem types occurring in China[21].

A detailed analysis of plant 'conservation translocations' undertaken in China identified 222 projects, involving 154 species; of these 87 were Chinese endemic species and 101 (78%) were listed as threatened on the Chinese Species Red List. 60 (27%) of these translocations were [population] augmentations, 16 (7%) were reintroductions in the strict sense, 89 (40%) were within-range introductions, and 57 (26%) were conservation introductions[22]. Examples of Chinese plant recovery programmes are given by Huang *et al*. (2015)[23]

Botanic gardens in China, supported by international partners and BGCI, have been assisting in the implementation of a number of recovery programmes for threatened plant species. To date, these have involved over 30 threatened species including some of the rarest trees known from only a few locations and occurring in very low numbers.

Case study 1 The Chinese Plant Species with Extremely Small Populations (PSESP) programme

The Chinese Plant Species with Extremely Small Populations (PSESP) programme was developed to rescue the most globally threatened plant species in China. Since the project launched in 2005, reintroduction and reinforcement of three model PSESP, namely *Manglietiastrum sinicum*, *Quercus sichourensis* and *Paphiopedilum armeniacum*, has been supported by China's State Forestry Administration (SFA) and the Yunnan Forestry Department (YFD) as a demonstration programme for the rescue and conservation of PSESP.

In March 2010, the Yunnan Government approved the *Planning Outline (2010–2020) and Emergency Action Plan (2010–2015) for Wild Species with Extremely Small Populations*, which designates 62 PSESP for rescue before 2020 of which 20 required urgent action by 2015, and are therefore given the highest priority. Following the development and distribution of guidelines on conserving and rescuing PSESP in China, c. 120 PSESP have been targeted nationally for action.

PSESP are characterised by small remaining populations (lower than the Minimum Viable Population (MVP)), restricted habitat, extremely high risk of extinction, and exposure to serious human disturbance. Given there is limited scientific basis for a MVP threshold for plant species, a review of literature addressing global MVP and conservation practices in China was considered. Species with fewer than 500 mature individuals in each isolated subpopulation and with an overall population size not exceeding 5000 mature individuals were proposed as PSESP in China.

During the past five years, with financial support from a special government fund, national and regional-level actions to rescue PSESP (including field surveys, creating *in situ* conservation sites, propagation for both *ex situ* conservation and recovery programmes, as well as germplasm banking) have resulted in significant progress in several parts of China. Training programmes run by the central and local governments at both national and provincial levels, as well as education and public awareness campaigns about the concept of PSESP have also been implemented. Over the next five years, the authorities hope that China's PSESP conservation programme can create a high-impact template for direct action and for the focus of financial and human resources on the species most in need of support. The Ministry of Science and Technology of China has already announced several national key projects for PSESP rescue programmes.

Source: Sun, W.[24]

Left and above: Planted PSESP at a *near situ* restoration site in the Zhibenshan Mountains, West Yunnan, China.

2.3.5 United States

The United States Endangered Species Act (1973) is the world's leading legislation for the protection of species at risk of extinction. No action can be taken to protect a species until it has been listed, a process that takes on average over 12 years from first consideration to listed status and often longer in the case of plants[25].

A summary of Listed Species and Recovery Plans[26], taken from the U.S. Fish & Wildlife Service (USFWS) Environmental Conservation Online System (ECOS) shows that as at 2018, out of a total of 949 conifers, ferns and fern allies and flowering plants listed as endangered or threatened, 675 have draft or finalised recovery plans. Some recovery plans cover more than one species, and a few species have separate plans covering different parts of their ranges. These figures include only plans generated by the USFWS (or jointly by the USFWS and National Marine Fisheries Service (NMFS), and only listed species that occur in the United States.

The USFWS Endangered Species website[27] also provides information about and links to consultation and recovery programmes and the policies and tools used to work with their partners to conserve and recover at-risk and listed species. Recovery plans that have been revised or finalised since 1978 can be accessed electronically from the lists of species with recovery plans[28].

The USFWS works in partnership with Federal, State, and local agencies, Tribal governments, conservation organisations, the private sector, landowners, and other concerned citizens and stresses that collaborative efforts are critical to recovery success[29]. An excellent example is the collaborative Plant Extinction Prevention Program in the state of Hawai'i (See Case study 2).

In addition to the work carried out under the auspices of the Endangered Species Act, conservation and recovery actions for species are carried out by NGOs and other bodies, but no complete listing of these actions is available.

Case study 2 Hawai'i's Plant Extinction Prevention Program: 'Preserving Hawai'i's rarest plants through teamwork'

The Hawaiian Islands are home to extraordinary array of unique plants: some 1,400 vascular plant taxa (including species, subspecies, and varieties) native to the State of Hawai'i, and nearly 90% of these are endemic.

The Plant Extinction Prevention (PEP) Program operates as a project of the Pacific Cooperative Studies Unit of the University of Hawai'i at Manoa and is supported by State and Federal funds, grants, and donations from public and private institutions. Its mission is to protect Hawai'i's rarest native plants from extinction and is committed to reversing the trend toward extinction by managing wild plants, collecting seeds, and establishing new populations. It carries out recovery actions for over 190 Threatened and Endangered plant species each year. These include:

- **Focusing** on the 238 PEP species with fewer than 50 wild individuals remaining
- **Collecting** fruit, seeds, and cuttings for long-term storage, research, propagation, and return to the wild. 177 PEP species have been collected, stored and grown at partner facilities
- **Protecting** wild plants, including 8,500m of fencing protecting 64 PEP species
- **Surveying** for new plants, with more than 12 new species discovered
- **Outplanting** in the wild, with 51,000 outplants made, representing 116 rare species
- **Monitoring** populations of source and translocated plants.

Since the initiative began, it claims that Hawai'i has experienced no plant extinctions.

Source: Plant Extinction Prevention Program[30]

Hymenophyllum tunbrigense, an incredibly delicate and rare fern whose leaves are only one cell thick. Wakehurst Place, Royal Botanic Gardens, Kew (image: Barney Wilczak).

Box 2.2 Species protected under the European Union Habitats Directive

In order to ensure the survival of Europe's most endangered and vulnerable species, EU governments adopted the Habitats Directive in 1992 (Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora). Species and subspecies listed under the EU Habitats Directive are protected in various ways:

- For species listed in Annex II of the Habitats Directive (c. 900 in total) core areas of their habitat – designated as Sites of Community Importance – must be protected under the Natura 2000 Network and the sites managed in accordance with the ecological requirements of the species
- For species and sub-species listed in Annex IV (over 400, including many that are also listed in Annex II) a strict protection regime must be applied across their entire natural range within the EU, both within and outside of Natura 2000 sites
- For species and sub-species listed in Annex V (over 90) member states shall, if deemed necessary as a result of surveillance work, take measures to ensure that their exploitation and use in the wild is compatible with maintaining them in a favourable conservation status.

Source: The Habitats Directive[31]

2.3.6 Europe and the Mediterranean region

The European Union Habitats Directive (92/43/ECC) mainly focuses on the conservation of natural habitats through the creation of NATURA 2000, the largest network of protected sites in the world, but also requires the protection of species listed in its Annexes (see Box 2.1). The central concept of the Habitats Directive is to maintain, or when necessary restore, both habitats and species to what is termed 'Favourable Conservation Status' (FCS)[32], a concept that is still evolving.

The Council of Europe's Bern Convention[33], aims to conserve wild flora and fauna and their natural habitats, giving particular attention to endangered and vulnerable species, and has set up the Emerald Network, an ecological network made up of Areas of Special Conservation Interest (ASCIs)[34].

Together, these provide what has been described as one the most advanced and effective intergovernmental policy instruments[35]. Yet even so, they have so far proved insufficient to ensure an acceptable conservation status for many of the species legally protected[36], emphasising the need for better coordination between species-based and area-based conservation.

The total number of European species for which recovery plans have been prepared is difficult to ascertain as there is no single source that can be consulted. A major information source on the range, habitat, population status, and prospects for the species listed in Annexes II, IV and V of the Habitats Directive is the Eionet database of the European Topic Centre on Biological Diversity[37].

Amygdalus georgica in the wild in Sveneti, Eastern Georgia.

EU biodiversity factsheets for EU Member States are available from the Biodiversity Information System for Europe (BISE)[38], a single entry point for data and information on biodiversity in the EU.

Also, the report *State of nature in the EU*[39] gives some information on conservation measures from the recent reports under Article 17 of the Habitats Directive for the plants which are listed on the annexes of the Directive. For vascular plants, 842 assessments are reported and their conservation status and trends are:

Favourable	28.6 %
Unfavourable-improving	4.6%
Unfavourable-unknown-trend	13.3%
Unknown	17.0%
Unfavourable-stable	19.6%
Unfavourable-declining	16.9%

Information from individual European countries on recovery plans for plant species is incomplete and few countries have compiled a comprehensive national list.

A recent survey of *in situ* conservation of plant species in the Mediterranean region suggests that based on available country figures, of the 2–3000 threatened plants species in the region, fewer than 10% have conservation or recovery plans[40].

In Spain, the Strategy for Plant Conservation (*Estrategia Española de Conservación Vegetal*)[41] which provides the most up to date official summary of *in situ* conservation action in Spain states that up to 2013, 48 action plans have been approved (37 species recovery plans, three conservation plans, three habitat conservation plans, and five habitat management plans). There are also a number of draft plans awaiting approval. The regionalisation of conservation in Spain through the autonomous communities makes it more difficult to get a complete overview. However, a subsequent gap analysis undertaken to assess the percentage of threatened plants effectively conserved *in situ* in Spain revealed that 140 taxa are managed *in situ* through legal recovery or conservation plans in force in one or more autonomous regions, while 581 threatened plant species (36.1%) were found to have at least one population living in a national park in Spain and 70 threatened taxa are present in at least one micro-reserve[42].

Box 2.3 Species recovery actions in tropical countries

Mexico

In Mexico, conservation at the species level has been orientated towards establishing the degree of threat to which species are exposed, with a view to including them in the national list of threatened species (NOM-059-SEMARNAT-2010)[43], and at developing and implementing programmes such as Projects for Recovery of Priority Species (PREP) and the Programme for Conservation of Threatened Species (PROCER). Of the 16 current PREP projects, only two are for plants, while for the 30 threatened species PROCER considered for the preparation of action programmes only one, *Diospyros zolocotzii*, is a plant[44].

The Mexican Association of Botanic Gardens is actively engaged in species recovery projects, both within and outside of the grounds of the gardens. For example, the Botanic Garden of the Biology Department of the Autonomous University of Mexico (UNAM), manages a reserve area on campus, where a successful recovery programme for *Bletia urbana* has been implemented, an orchid species listed as threatened (A) on NOM-059-SEMARNAT-2010. The UNAM Botanic Garden also manages a large scale recovery programme in the Sierra de Tehuacan-Cuicatlan for threatened succulent species, including *Echeveria laui*, listed as at risk of extinction (P) on NOM-059-SEMARNAT-2010.

Brazil

In Brazil, with a flora of some 46,000 species, the Brazilian National Centre for Flora Conservation (CNCFlora) is responsible, at the national level, for assessing the conservation status of the Brazilian flora and developing recovery plans for species threatened with extinction. Efforts are being made to address this situation, but with only just over 11% of the native flora so far assessed for their extinction risk, the challenges are huge. Of the estimated 8,058 native tree species in Brazil, CNCFlora has evaluated the extinction risk for 1,125 species (13.9% of the total of Brazilian tree species), resulting in 420 tree species being assigned to a given threat category (66 CR; 224 EN and 130 VU). To date only one of them (*Dimorphandra wilsonii*) has an officially published recovery plan[45].

332 CNCFLora Action Plans have been developed to date. These mainly address the identification of priority areas for species threatened with extinction[46] and assessment of the threats to the species and areas but do not include species conservation or recovery plans. A number of National Action Plans have been published for certain regions such as the Serra do Espinhaço Meridional and the Grão Mogol - Francisco Sá[47] and these contain detailed information on the morphology, ecology, distribution, demography and threats to the threatened species in these areas but the conservation and management actions rarely go beyond noting their presence in a protected area. This is, however, work in progress.

India

In India, the Ministry of Environment, Forest and Climate Change has a Special Programme for Recovery of Critically Endangered Species. Initially 17 species have been identified and of these, eight, have received funding based on proposals received from various State/Union Territory Governments but none of these are for plants[48].

In 2016, BGCI led a seed collection training course for 27 participants from 16 institutions across India. Following the training course, a challenge fund was launched for participants to collect seed from threatened plant species, preparing for future recovery efforts.

Kenya

As part of a Global Trees Campaign project, the Eastern Africa Herbarium developed a list of 65 priority tree species for Kenya. One of the criteria when developing the list was species with limited or no conservation action underway. Collecting guides were prepared and seed collection training delivered by BGCI and the Kenya Forestry Research Institute to enable collection of seed from priority tree species, for *ex situ* conservation and future recovery programmes.

Brackenhurst Botanic Garden in Tigoni, Kenya is restoring a 40 hectare area of indigenous forest which incorporates more than 500 woody plant species, many of which are threatened. The forest provides a safe area to initiate species recovery programmes, including for *Embelia keniensis*, a Critically Endangered woody climber that used to be present in larger numbers in the area but the population has been reduced dramatically as a result of urbanisation and agricultural expansion.

Highlighting the different variety of seeds at a BGCI seed conservation training course in Kerala, India.

BGCI seed conservation training in Kerala India in collaboration with Jawaharlal Nerhu Tropical Botanic Garden and Research Institute.

2.3.6 Tropical countries

'To date, Brazil has only one officially published recovery plan for a tree species'[49]

In most tropical countries, few recovery plans or actions have been reported. The reasons for this neglect of species recovery in the tropics include a lack of infrastructure and capacity, over reliance on protected areas as a conservation strategy, and the absence of a tradition or a legal framework for undertaking recovery programmes.

On the other hand, many tropical countries have a tradition of protecting individual species or habitats for social, religious or cultural reasons, for example in sacred forests or groves, and although the number of species involved is small, these systems could serve as models for developing a wider approach to plant species recovery in tropical countries.

Increasing the number of species recovery programmes in tropical countries should be a conservation priority given that a large proportion of tropical plant species are at risk as a result of habitat loss or degradation caused largely by agricultural development, overexploitation and urbanisation. This needs to be coupled with support, in terms of finance, but also infrastructure and expertise, particularly from countries with more experience carrying out species recovery programmes. Such support could include providing training, storing material that is available for future recovery programmes, carrying out propagation trials or genetic analyses. For example, the Royal Botanic Gardens, Kew Millennium Seed Bank holds seed collections from tropical countries, and most collections are stored under an agreement that the material will be returned to the source country if a request is made, to enable recovery and restoration programmes.

A number of botanic gardens in tropical countries are actively engaged in species recovery projects, or contain areas of natural vegetation that contain significant numbers of threatened species. Such natural areas provide scope for effective *in situ* conservation action and recovery programmes[50]. Some examples are provided in Box 2.3. These examples can be replicated for other species and used as models for scaling up species recovery in tropical countries.

2.4 Strategic planning

It is evident from the examples provided above that strategic planning greatly benefits the implementation of *in situ* species conservation and recovery actions. Whilst the targets of the Global Strategy for Plant Conservation (GSPC) and the Aichi Biodiversity Targets of the Strategic Plan for Biodiversity 2011-2020 provide a useful framework for action, increased guidance on implementation of *in situ* conservation of plant species is needed to improve efforts at the national level, as well as improved reporting systems. Lessons can be taken from the substantial progress towards a global strategy for the conservation of Crop Wild Relatives, whose importance has only come to be acknowledged in the past 15-20 years[51].

Countries would benefit from the preparation of a national strategy for species recovery, either as a stand-alone strategy, or as part of its National Biodiversity Strategy and Action Plan (NBSAP). National strategies should aim to:

- Ensure coordination of planning and implementation of species conservation so that collaboration can occur and activities are harmonised between the relevant stakeholders and actors involved
- Institutionalise the practice of species recovery by embedding it in national planning mechanisms supported by relevant policy, legislative and financial measures
- Promote the public awareness and understanding of the importance of species recovery, and
- Provide a mechanism for reporting on progress towards targets and plans agreed under other agreements – such as the CBD.

Aidia shweliensis in China.

2.5 Conclusions

Progress towards the implementation of recovery plans for plant species presents a very mixed picture, with few countries meeting the globally or nationally set targets. At the policy level, progress could be encouraged through:

- Improved strategic planning at the global level
- Improved strategic planning at national / subnational level
- Increased obligation to implement actions following conservation assessments and development of recovery plans. This is even necessary in countries with a strong existing legal framework
- Increased obligation to monitor recovery actions
- Increased mobilisation of funds for recovery actions.

While it is the responsibility of governments to ensure that the necessary strategic planning and legislation is put in place, the conservation community and civil society have a major role to play, for example by:

- Presenting strong arguments for the necessary infrastructure and resources to be put in place when required and explaining the consequences of inaction
- Providing critical assessments of the effectiveness or otherwise of the legal frameworks, national and global policies that are in place
- Ensuring that conservation and recovery plans that have been funded are well planned, have clearly stated objectives
- Ensuring that conservation and recovery plans are implemented, species recovery actions are carried out as appropriate and the success or otherwise of actions are monitored
- Exploring innovative or alternative methods for providing *in situ* protection for the large number of species for which conventional approaches are not possible in the short-term
- Ensuring plans, reports and project case studies are made publicly available to guide the development of other recovery plans
- Increasing collaboration between organisations and sharing of infrastructure and expertise, particularly with tropical countries.

Propagation trials of *Magnolia omeiensis* at Emeishan Botanical Garden, China.

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Chapter 3.
In situ conservation of species – an overview of the process

Aim of this chapter

This chapter aims to provide an overview of the whole process of species recovery and outlines the essential components of successful recovery plans. Further detail is provided on each component in subsequent chapters. It also enables practitioners to choose the type and level of actions required for their target species.

3.0 Introduction

The main general aim and long-term goal of *in situ* conservation of target species is to **protect**, **manage** and **monitor** selected populations **in their natural habitats**. This enables **natural evolutionary processes to be maintained**, thereby allowing **new variation to be generated in the gene pool** that will allow the species to adapt to changing environmental conditions.

For many species, successful *in situ* conservation will be achieved by:

- Maintaining and protecting the habitats in which they occur
- Identifying any threats to the species
- Taking steps to remove or contain these threats, and
- Monitoring the results.

If the above actions are insufficient for natural evolutionary processes to be maintained (i.e. if the species has already declined to a point where these processes are no longer occurring), species recovery actions will be required in addition to removal of threats.

3.1 Conservation options

The conservation options available for a particular species will depend on a variety of factors, including population status, population size, and nature and degree of threats.

Protected areas have been and still are widely regarded as the main strategy for *in situ* conservation of biodiversity. However, recorded presence of a species in a protected area should not be taken as evidence of its effective conservation. Protected areas only offer a degree of protection for species within them. Relying simply on the occurrence of a species in a protected area is known as a **hands-off** approach or **passive conservation** in that no species-specific action is taken. It should be noted that the majority of species do not occur in protected areas.

Ensuring that the target species has viable populations that are able to persist over time and continue to evolve, within or outside of a protected area, will usually require targeted actions and monitoring, known as **active conservation**. Prior to implementing conservation actions, a plan is often written.

It is useful to distinguish between **species management plans**, **species conservation plans** and **species recovery plans**. Table 3.1 identifies the type of plan and conservation actions required for species, depending on the scale and degree of threat facing them. The difference between species conservation/action/management plans and recovery plans is a matter of scale and degree, and reflects the extent of management intervention needed.

- For species not known to be currently threatened or are otherwise considered to have a low probability of extinction, a species conservation or action plan will not normally be proposed. In such cases, a general assessment of their status and conservation requirements may be prepared such as the species accounts of the UK Biodiversity Action Plan priority species[1]. If, however, the species is regarded for other reasons (scientific, economic, social) to be of high priority, a conservation plan may be prepared while the species still maintains its full range of genetic variability.

Monitoring growth of *Erica verticillata* plants reintroduced at Rondevlei, South Africa (Image: Adam Harrover).

Table 3.1 Species management plan, conservation plan or recovery plan?

Scale and degree of threat	Action required			
	Type of action required	**Management plan and monitoring of habitats and populations**	**Species conservation plan and actions**	**Species recovery plan and actions**
Species that are **not currently threatened** and have a **low probability of extinction** (IUCN Red List category Least Concern)	**Monitoring**	**Yes** – so further action can be taken if the situation changes	**No** – Unless the species is regarded as high priority for scientific, economic or social concern or importance	**No**
Species that are **threatened to some extent** (IUCN Red List category Near Threatened or Vulnerable).	**Conservation action**	**Yes**	**Yes**	**No** – Unless the species is regarded as high priority for scientific, economic or social concern or importance
Species that are **currently threatened** and **have already suffered severe population loss**, are **in rapid decline** and **partial or total extinction is likely within decades** (IUCN Red List category Endangered or Critically Endangered)	**Conservation action and species recovery**			**Yes**

Adapted from: Hunter and Heywood[2]

- For species that are threatened to some extent but are not currently endangered, the removal, mitigation or containment of the factors causing the threat means that some form of intervention is necessary. In such cases a species conservation plan will be appropriate, including the setting up of a reserve or some off-site arrangement if the species does not occur in a protected area (see Chapter 11).

- For species that are currently endangered and have already suffered severe population loss or are in rapid decline so that partial or total extinction is likely within decades, a species recovery plan is the appropriate action.

Further guidance on the steps involved in the preparation of a recovery strategy and action plan are given in subsequent chapters.

3.2 Single-species versus multi-species plans

For groups of species that co-occur in a particular ecosystem and apparently share common threats, **multi-species plans**, involving a multi-species approach to conservation or recovery, are sometimes recommended.

Plant species conservation and recovery, as practised so far, has tended to focus more on single target species areas rather than on groups of species occurring together. However, a multi-species approach has been increasingly adopted in recent years for recovery programmes by Australia, Canada, the USA (through the introduction of the Endangered Species Act's Habitat Conservation Plan – HCP) and some European Union countries (through the EU Habitats Directive), partly on the grounds of better facilitating the protection of biodiversity and ecosystems and thereby covering the needs of more species[3].

It has also been argued that the increasing emphasis on the multispecies approach was largely motivated by economic considerations and was more cost-effective, given that the number of target species is likely to exceed available resources for a species-by-species approach. A landscape approach, which in effect involves a range of species, is also being adopted in some cases.

The main scientific rationale behind the use of multi-species plans is the assumption that several target species will share the same or similar threats within an ecosystem whose protection will lead to the conservation of each of the species and even provide some degree of protection for other species that are not specifically targeted at the time. On the other hand, the multi-species approach is not without risks and can be very complex, time-consuming and expensive[4]. In addition, the effectiveness of multi-species plans may be limited because less money and effort is spent per species and they are often poorly resourced as compared with single-species plans.

'As the scale of planning widens, the scope deepens, and the duration lengthens, the uncertainties, funding challenges, and difficulties of interjurisdictional problem solving accelerate[5]

The effectiveness of multi-species recovery conservation programmes has been reviewed in surveys of multi-species plans undertaken in Australia, Canada and the US[6]. An in-depth study of recovery plans conducted by the Society for Conservation Biology (SCB) concluded that the multi-species plans approved under the ESA as of 2000, paid less attention to the individual listed species included in each plan compared with single-species plans[7]. It found that individual target species in multi-species plans, had less robust scientific underpinning, objectives and recommendations, and that trends in status for individual species tended to be less positive than those for species with single-species recovery plans.

The issue is not clear cut, however, partly due to the insufficient or inadequate data available to allow recovery success to be assessed. There is, however, evidence from the various surveys that often, insufficient attention to detail is given to individual species within multi-species plans. It would appear that, for these plans to be effective, as much effort must be given to each species as in a series of single-species plans. One report found that nearly half of the multi-species plans failed to display threat similarity greater than that for randomly selected groups of species and concluded that, as currently practised, multi-species recovery plans are less effective management tools than single-species plans[8].

The advantages of multi-species approaches are summarised in Box 3.1. Some of the main problems in implementing multi-species plans are:

- They are less likely than single-species plans to include species-specific biological and ecological information, and adaptive management criteria
- The lumping together of species does not appear to be based on any biologically logical criteria (i.e. similarity of habitats or threats)
- Multi-species plans have fewer recovery tasks implemented during the life of the plan
- Species included in multi-species plans have been found to be four times less likely to exhibit positive status trends.

Box 3.1 Strengths of multi-species approaches

Multi-species approaches can:

- Address common threats in a concise and focused manner;
- Streamline the public consultation process
- Reduce duplication of effort in describing the habitats of, and threats to, each species
- Provide a good format for environmental impact statements;
- Promote thinking on a broader scale
- Reduce conflicts between listed species occurring in the same area
- Benefit other species not at risk
- Provide an approach that can restore, reconstruct or rehabilitate the structure, distribution, connectivity and function upon which a group of species depends.

Source: Canadian Wildlife Service[9]

During the past 10-15 years an extensive series of publications have been produced on the conservation of Crop Wild Relatives and on forestry species (Box 3.2). These include a series of recommendations for developing genetic conservation management plans, and protocols for *in situ* (genetic) conservation and *ex situ* conservation. The guidance is also relevant to wild plant species in general.

Box 3.2 Publications relevant to genetic resource conservation of forest trees and Crop Wild Relatives

Maxted, N., Ford-Lloyd, B.V. and Hawkes, J.G. (Eds.). (1997). *Plant Genetic Conservation, The* In Situ *Approach*. Chapman and Hall, London, United Kingdom.

FAO, DFSC and IPGRI. (2001). Forest genetic resources conservation and management. Vol. 2. In: *Managed natural forests and protected areas (in situ)*. International Plant Genetic Resources Institute, Rome, Italy.

FAO, FLD and IPGRI. (2004). *Forest genetic resources conservation and management. Vol. 1. Overview, concepts and some systematic approaches.* International Plant Genetic Resources Institute, Rome, Italy

Heywood, V.H. and Dulloo, M.E. (2005). *In Situ* Conservation of Wild Plant Species. A Critical Global Review of Good Practices. IPGRI Technical Bulletin No. 11. FAO and IPGRI. IPGRI, Rome, Italy.

Hunter, D. and Heywood, V. (Eds.). (2011). *Crop Wild Relatives. A manual of* in situ *conservation*. Earthscan, London, United Kingdom.

Maxted, N., Ford-Lloyd, B.V., Kell, S.P., Iriondo, J., Dulloo, E. and Turok, J. (Eds.). (2008). *Crop Wild Relative Conservation and Use.* CAB International, Wallingford, United Kingdom.

Maxted, N., Avagyan, A., Frese, L., Iriondo, J.M., Magos Brehm, J., Singer, A. and Kell, S.P. (2013). Preserving Diversity: A Concept for *In situ* Conservation of Crop Wild Relatives in Europe. Rome, Italy: *In Situ* and On-farm Conservation Network, European Cooperative Program for Plant Genetic Resources.

Maxted, N., Ehsan Dulloo, M. and Ford-Lloyd, B.V. (Eds.). *Enhancing Crop Genepool Use: Capturing Wild Relative and Landrace Diversity for Crop Improvement*. CAB International, Wallingford, United Kingdom.

Iriondo, J.M., Dulloo, E. and Maxted, N. (Eds.). (2008). *Conserving plant genetic diversity in protected areas: population management of Crop Wild Relatives.* CAB International Publishing, Wallingford, United Kingdom.

3.3 The process of *in situ* conservation and species recovery

The process of *in situ* conservation and recovery of species involves a series of steps which are given in Table 3.2. These steps can be grouped under the following headings:

- Inventory and status assessment
- Initial protection and monitoring
- Establishing which species are of priority for conservation or recovery
- Conservation and recovery planning
- Selection of area and habitat
- Monitoring strategy and plan
- Consultation and review
- Implementation
- Aftercare

It should be stressed that the process outlined in Table 3.2 is meant for guidance and in practice, each *in situ* species conservation project is unique and so the sequence followed and amount of emphasis given to the various components will vary on a case by case basis and additional steps may need to be taken. In continuation, a summary of the key points of the main stages is given while subsequent chapters will provide the details.

3.3.1 Inventory and status assessment

The first step is to prepare an **inventory** of the species that might require some form of *in situ* conservation action by carrying out a **status assessment**. This will normally be undertaken at a national or subnational scale. The assessment of the status of the species will be knowledge-based, using science-based data such as distribution, ecology, demography (when known), population trends and known threats to the habitats in which the species occurs and to the populations of the species. Local traditional or community knowledge should also be taken into account in the assessment. The outcome of this process is a **status assessment or report and will provide a first inventory of species that will serve as basis for further selection and action.**

Ideally, the assessments should be undertaken by independent scientific bodies and in a transparent manner so as to avoid any chance of undue external influence by interested parties. In Canada, for example, the species assessment process is conducted by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Based on the status report, they use a committee of experts to conduct a species assessment and assign the status of a wildlife species believed to be at some degree of risk nationally.

3.3.2 Initial protection and monitoring

For those species determined to be at risk, appropriate measures need to be put in place as soon as possible to protect the species *in situ* and ensure that its habitat is safeguarded, such as habitat weeding, population enhancement, so as to prevent any further decline in their status while any further conservation measures as may be needed are planned. In addition, *ex situ* collections should be made if this is possible without causing harm to the remaining populations.

Table 3.2 The process of *in situ* conservation

The conservation of species *in situ* involves a series of procedures and actions which ideally should be undertaken in a logical sequence, for example:

Inventory and assessment

- Prepare an inventory of the species that might require some form of *in situ* conservation action by carrying out a status assessment.
- Monitor the population trends of these species and examine the nature and degree of risk so as to establish which of them are in need of immediate protection or other conservation action.

Initial protection and monitoring

- For those species determined to be at risk, appropriate measures need to be implemented as soon as possible to protect the species *in situ* and ensure that its habitat is safeguarded, to prevent any further decline in their status while any further conservation measures that are needed or full scale recovery are planned.

Establishing which species are of priority for conservation or recovery

- Determine the nature and level of long-term protection and actions needed (Box 3.1).

Conservation and recovery planning

For those species that are selected as priority/target species for recovery action:

- Verification of taxonomic identity
- Assessment of their geographical distribution, ecology, microclimate and soil preferences
- Assessment of their demography and population structure
- Assessment of their phenology, reproductive biology and breeding systems
- Assessment of their conservation status and threat analysis
- Assessment of their genetic variation
- Selection of the target populations to be conserved
- Selection of the area(s) in which the target species are to be conserved
- Selection of critical habitat
- Determination of the spatial scale of conservation needed – location, number and size of populations to be conserved; decision on whether to adopt a single-species or multi-species approach
- Identification of aims of conservation and the appropriate conservation measures

→ → →

- Preparation of a conservation or recovery management plan for the target populations, if threatened, or monitoring plan if not currently threatened
- Organisation and planning of specific conservation activities
- Identification and involvement of interested parties
- If the target area is already protected, assessment of the management status of the protected areas in which the target populations occur; and proposals for modification of management guidelines as appropriate
- Consultation with protected area managers, local communities and other interested parties
- If the area or reserve/genetic reserve/gene management zone has to be created from scratch, design of the reserve including boundaries, zoning and protection, and development of a management plan and guidelines
- Determine statutory and legal requirements involved and arrange for necessary legislative approval (e.g. publication of a management plan, gazetting new protected area/reserve) or legislative changes (e.g. modification of a management plan of protected area) to be submitted to competent authorities

Monitoring strategy and plan

- Development of a monitoring strategy for the area(s)
- Development of a monitoring plan for assessing the effectiveness of the management interventions on the target populations and their conditions, genetic variability and needs
- Development of a monitoring plan for assessing the impacts of human activities

Consultation and review

- Submit the management and monitoring plans and the whole conservation strategy to consultation review by all interested and affected parties.
- Invite public comment on the plans
- Prepare outreach and publicity materials
- Preparation of a budget
- Development of a timeline
- Risk assessment

Implementation

- Build a project team
- Field implementation
- Evaluation of outcome and independent assessment
- Planning, costing and implementation of post-recovery actions if needed

Aftercare

- Monitoring
- Further intervention

Modified from Heywood[10]

The *ex situ* material may be stored in a genebank, field genebank, botanic garden or arboretum living collections, cell or tissue culture and cryopreservation.

Decisions on the nature and level of **initial protection** and actions and short-term goals will be commensurate with the initial assessment of the level of risk or urgency and may range from simply continued vigilance and ensuring effective habitat protection to various levels of management intervention.

In addition, **a monitoring and reporting system** should be put in place for those species at risk. This will monitor population trends and any deterioration in status or increase in the intensity of threatening factor and will serve as an early warning system. The sooner threats are detected and addressed, the better are the chances of successful conservation or recovery.

3.3.3 Establishing which species are of priority for conservation or recovery

The initial inventory of species at risk will now need to be reviewed and decisions made about the kinds of action that are needed **to ensure their long-term survival**. Effective action to achieve *in situ* conservation of threatened species usually involves some kind of action plan (See Table 3.1). These may be conservation plans or recovery plans, or simply a general assessment of their status and conservation requirements (such as the Species Statements of the UK Biodiversity Action Plan), depending the degree and nature of the threats to the species. Each country may have its own terminology and procedures. The plans will usually involve a range of actions, often including both *in situ* and *ex situ* techniques. They may be for single species or for multiple species in a particular area.

Leionema hillebrandii (Image: Paul Smith).

Native species being maintained within a pilot restoration site in Gongcheng County, China.

3.3.4 Conservation and recovery planning

Once a decision is made about the nature and level of actions needed to ensure the conservation or recovery of a target species, a structured strategy and action plan should be prepared. This will normally involve a series of steps as detailed in Chapter 8 and will depend on the nature and extent of the threats to the species and or the habitat. The actions proposed may include a series of interventions needed to counter or contain the threats to the species' populations so as to avoid further deterioration in the status of the species' populations and help restore them to a viable condition, as well as actions needed to ensure the effective protection of the habitat.

3.3.5 Selection of area and critical habitat

Protection of the habitat is a key requirement in the conservation of biodiversity. Many of the target species selected for recovery or other conservation action will be found to occur wholly or partly in protected areas. Presence of a population(s) of a target species in an already existing protected area is an obvious advantage and if it occurs in more than one such area, a choice will have to be made as to which of them should be selected. It is important to ascertain the details of the management plans for any areas that are likely to be selected.

It is also essential to establish which areas contain habitat that is considered essential for the effective conservation of the species: this is known as **critical habitat** (see Chapter 6).

Where target species do not occur within a protected area and a decision is made to establish a new protected area or reserve, the selection of an area is of course determined by the presence of the target species in it. The main issues to be addressed are identifying the subset of critical habitat (Box 6.1) necessary for the survival and recovery of the species, deciding how many populations are to be included, how much genetic variation should be captured, design of the reserve including boundaries, zoning and protection, whether the proposed area is ecologically viable and whether it will be possible to maintain it securely, and development of a management plan and guidelines. The details of the criteria that may be taken into account are discussed in Chapters 6, 7 and 8.

Given that many endangered species occur outside existing protected areas, conservation strategies and management for species/populations occurring off-reserve/outside protected areas, such as negotiating easements, covenants, trusts and partnerships, need to be developed, as discussed in Chapter 10. This is the case with most forest trees where 'most *in situ* conservation of forest genetic resources happens outside protected areas on lands in a range of public, private and traditional ownerships, especially in multiple-use forests and those used primarily for wood production'[11].

3.3.6 Development of a monitoring strategy and action plan

The development of a monitoring strategy and action plan is an important part of the species recovery process. Monitoring may be required at all or any stages of the conservation or recovery process. Thus, the following are commonly required:

- Development of a monitoring plan for target species to follow changes in the status of the species' populations
- Development of a monitoring strategy for the area(s) in which the target species occur
- Development of a monitoring plan for assessing the effectiveness of the management interventions on the target populations and their conditions, genetic variability and needs.

Details of monitoring approaches and methodologies are discussed in Chapter 12.

3.3.7 Consultation and review

It is important that relevant experts and all interested parties, including those who will be responsible for implementing proposed actions and the local communities or indigenous peoples on whose lands the species are sited, should be involved in the preparation of a species conservation or recovery plan. In some countries, there is a legal requirement for the plans to be made available for public comment. In Australia, for example, the plans are placed on public exhibition for three months, except where this has already been undertaken by States/Territories[12].

Collecting *Phyllodoce caerulea* (Image: Natacha Frachon).

3.3.8 Implementation

While every effort should be taken to make the conservation or recovery action plans as clear and comprehensive as possible, it has to be stressed that they are a means to an end and of no value unless they are implemented. Too many plans sit on the shelves awaiting action. The implementation process, however carefully planned, will often throw up problems that have not been anticipated and may require modification of the plan. The implementation also needs to be carefully monitored to ensure that it is being undertaken effectively and in a timely manner.

3.3.9 Aftercare

The effective implementation of a conservation/action plan may take 5-10 or more years to achieve and if successful, regular monitoring should be undertaken to ensure that the 'restored status' is maintained. Although it is often assumed that once the conservation/recovery goals have been met, no further management will be needed, evidence suggests that many species will still need continuing intervention to maintain viable populations. Such species are termed 'conservation-reliant'.

3.3.10 Checklist

As is very evident, the processes of conservation and recovery planning is highly complex and it is good practice for countries to prepare a checklist of actions that need to be taken at each stage. An example is the Australian government's 'Recovery Planning – Compliance Checklist for Legislative and Process Requirements' which guides assessment of a recovery plan against the legal requirements of the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) and Regulations[13], and policy requirements of the Department of the Environment, to be provided with recovery plans for terrestrial threatened species and ecological communities.

3.4 Conclusions

- By definition, *in situ* conservation of species takes place in nature and requires that the habitat of the species whether it be a reserve or not is adequately protected. Off-site conservation of species has been seriously neglected and much greater attention needs to be paid to devising effective methodologies.
- It is important that all conservation or recovery plans should have clearly stated objectives against which the effectiveness of the outcome can be evaluated.
- The objectives cannot be set until a proper evaluation of the biological status of the species has been carried out. This requires as detailed an eco-geographical survey as possible to determine the full distribution of the species' populations and its ecological requirements and ascertain whether the population(s) is stable, decreasing or increasing.
- While published information on the biological/conservation situation of a species (including threat status) is important, it is no substitute for field survey. Many published conservation assessments are incomplete, incorrect or simply out of date.
- If the species is reported to be threatened, the detailed nature and impact of the threat(s) must be ascertained and if appropriate the necessary actions required to eliminate, reduce or contain the threats included in the conservation/recovery strategy.
- It should be made clear how the threats to the species/areas are addressed by the recovery actions.
- The better and more comprehensive a conservation or recovery plan is, the better is the chance of its success. On the other hand, circumstances may not permit this and some conservation action is better than nothing and may buy time until more effective procedures can be implemented.
- Extensive consultation will all interested partied should take place during the planning of a conservation or recovery strategy and action plan and the process should be as open and public as possible.
- It is essential to recognise the rights and interests of local communities in the lands where protected areas are sited and their involvement and participation in developing and implementing actions plans is essential.
- *In situ* conservation of a species should be supplemented by the conservation storage of *ex situ* material in a genebank, field genebank, botanic garden or arboretum living collections, cell or tissue culture and cryopreservation.
- *Ex situ* material may be needed as part of a conservation or recovery plan.

While the most effective conservation action possible should always be the aim, there will often be a trade-off between what is ideal and what is possible with the resources available. Realistically, it has to be accepted that some conservation action is better than none at all, although failure to undertake all the actions necessary to prevent the further deterioration of threatened species/populations will store up problems for the future, at which time even more drastic actions may be needed to save the species.

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Chapter 4.
The role of protected areas in species protection and recovery

Aim of this chapter

This chapter outlines the diversity of protected areas and their strengths and weaknesses in protecting biodiversity. It explains the links between species and area management and highlights that presence in protected areas will not necessarily result in recovery for threatened species without additional specific conservation measures. This chapter also identifies actions that can be taken to improve the management of protected areas in order to benefit species conservation and recovery.

4.0 Introduction

...the focus on endangered species management should be as much on the ecosystems within which these species reside as on the populations themselves. Also, the focus should be on restoring resilience of the populations, rather than stabilization of the populations[1].

Species management and area management are both involved in species conservation and recovery and there is a necessary interplay between them. Species recovery is dependent on the maintenance of healthy, functioning and resilient ecosystems and conversely healthy and resilient ecosystems will depend on the maintenance of viable populations of the species they house. It is therefore, essential that in approaching species conservation and recovery that the closest possible cooperation be maintained between the relevant protected area managers and landowners or managers outside of protected areas.

Some advocate that conservation of endangered species should be viewed through a lens of resilience, that management strategies should be shifted from a species-centred to a systems-based approach and argue that 'moving from a focus on specific species or even particular habitats to one that seeks to understand and better support system dynamics will allow our efforts to better capture the complexity associated with the challenges of biodiversity'[2]. On the other hand, relying on protected areas as they are currently managed has not been effective in allowing many threatened species to survive and recover. The challenge is as much one for protected area managers as for species conservation biologists. Focusing our efforts on protected areas will risk neglecting many endangered species that exist outside of these areas.

This manual recommends that, whilst establishing and maintaining protected areas is an important component of biodiversity conservation, in most cases, specific measures are also required to ensure the conservation and recovery of threatened species within these areas.

4.1 Important issues to note about protected areas and species recovery

4.1.1 Protected areas are extremely diverse

Protected areas may be defined in many different ways, for, example, by the CBD and other international conventions, by regional treaties, and nationally. What is regarded as a protected area in one country may not be regarded as such in another country. The IUCN definition is *'A clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values'*. Ten categories of protected area recognised by IUCN, according to their management objectives, are given in Box 4.1.

It should be noted that although many countries have adopted the IUCN area categories, there is still a wide variation in the way the terms are used, with the designation National Park, for example, being applied to areas in all the IUCN categories[3].

The rationale behind protected areas has widened to include a range of functions, including:

- Biodiversity conservation: ecosystem- and species-orientated
- Maintenance of ecosystem services
- Genetic conservation of target species of economic importance
- Sustainable development
- Ensuring ecosystem health
- Poverty alleviation
- Respecting rights of indigenous peoples

These functions are reflected in the way the areas are managed and the degree of protection. It follows, therefore, that their suitability and effectiveness in providing protection to a target species varies considerably.

Box 4.1 IUCN protected areas categories system

Ia Strict Nature Reserve
Category Ia are strictly protected areas set aside to protect biodiversity and also possibly geological/geomorphical features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values. Such protected areas can serve as indispensable reference areas for scientific research and monitoring.

Ib Wilderness Area
Category Ib protected areas are usually large unmodified or slightly modified areas, retaining their natural character and influence without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition.

II National Park
Category II protected areas are large natural or near natural areas set aside to protect large scale ecological processes, along with the complement of species and ecosystems characteristics of the area, which also provide a foundation for environmentally and culturally compatible, spiritual, scientific, educational, recreational and visitor opportunities.

III Natural Monument or Feature
Category III protected areas are set aside to protect a specific natural monument, which can be a landform, sea mount, submarine cavern, geological feature such as a cave or even a living feature such as an ancient grove. They are generally quite small protected areas and often have high visitor value.

IV Habitat/Species Management Area
Category IV protected areas aim to protect particular species or habitats and management reflects this priority. Many Category IV protected areas will need regular, active interventions to address the requirements of particular species or to maintain habitats, but this is not a requirement of the category.

V Protected Landscape/Seascape
A protected area where the interaction of people and nature over time has produced an area of distinct character with significant, ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values.

VI Protected area with sustainable use of natural resources
Category VI protected areas conserve ecosystems and habitats together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where low-level non-industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area.

Source: IUCN[4]

Box 4.2 Mismatch between protected land and biodiversity priorities in the USA

An assessment of the USA protected area portfolio for biodiversity shows that although the total area under protection is substantial, 'its geographic configuration is nearly the opposite of patterns of endemism within the country'. Most protected lands are in the West, whereas the vulnerable species are largely in the Southeast. The authors of this study comment that while the USA has one of the oldest and most sophisticated systems of protected areas in the world, possesses a large amount of information about the country's biodiversity, and has substantial resources available, it does not do well in protecting biodiversity. They make recommendations to improve the coverage, map priorities for multiple taxa and recommend specific areas for immediate, conservation attention, including both public and private land.

Source: Jenkins *et al*.[5]

4.1.2 Not all protected areas are effective in maintaining biodiversity

Because of their diverse functions, there are various ways in which the effectiveness of protected areas can be measured, for example by looking at different outcomes – economic, social, and conservation of habitat and biodiversity. It should not be assumed therefore that biodiversity conservation is a primary management aim for all protected areas.

Several surveys indicate that there is growing evidence that many protected areas do not in fact provide adequate protection against threats to the biodiversity they house[6]. The reasons for this include[7]

- Lack of management plans
- Inadequate management (between 20% and 50% of those that have been assessed are inadequately protected or managed)
- Lack of or incomplete biodiversity inventories
- Failure to manage areas for biodiversity
- Failure to undertake proper threat assessments of key biodiversity such as target species and the necessary actions to contain or eliminate these threats
- Declining support and lack of adequate finance, and
- The vagaries of political commitment and control, corruption, downgrading, downsizing and degazettement (PADDD), so the survival of any particular species or group of species within their bounds is by no means guaranteed.

4.1.3 Effectiveness of protected areas in conserving species diversity

It is possible to achieve effective conservation in protected areas, but fundamentally this depends upon appropriate implementation and funding of protected areas worldwide, and hard decisions will need to be made, as given the limited resources and capacity for conservation, it will be impossible to make all protected areas effective in conserving all species of wildlife[8].

Despite the substantial expansion in the number and coverage of protected areas, high rates of biodiversity loss still persist[9]. Two major reasons for this are that the coverage of protected areas is still inadequate and that there is a common mismatch between the location of protected areas and the distribution of threatened species[10], resulting in most threatened species occurring outside them (See Box 4.2). Part of the explanation for the continuing loss of biodiversity within existing protected areas is the multitude of threats to which they are exposed[11], the lack of adequate management and insufficient support both financial and political[12]. It follows, therefore, that they do not necessarily provide sufficient protection to habitats and species.

A review of Australia's Commonwealth National Parks, using available information from 41 endangered or significant species that occur in them revealed that:

- A large proportion of these species are only found in national parks, highlighting the significant role and responsibilities that these parks play in their conservation and management
- Very few of the species are held in *ex situ* collections (living or seed bank) and collections that do exist are small indicating that opportunities to re-establish populations following extinction events are extremely limited
- Very few of the species are regularly monitored and population trajectories are unclear
- Too little information on the impacts of threats or species biology exists, limiting our ability to secure these species against further loss[13].

The effectiveness of protected areas in conserving threatened species will normally depend on:

- The degree and quality of protection of the areas and their habitats
- The amount of effort and investment in actions to mitigate or abate threats within the protected area, such as changes in disturbance regime (e.g. fire frequency), visitor pressure, invasive alien species
- The amount of effort and investment in the specific management needs of the target species within the protected area, such as steps to mitigate or remove threats to the species
- Ongoing monitoring of the state of management and protection of the areas.

It is generally assumed that the presence of a species in a protected area indicates that it will receive some degree of protection and it has been claimed that they are our best hope for meeting global targets such as preventing species extinctions[14]. It must be stressed, however, that **protection alone is not sufficient to achieve conservation or recovery of a threatened species: what we need to aim for is persistence and recovery over time.**

Transporting *Magnolia omeiensis* seedlings to reinforce populations *in situ* on Mount Emei, Sichuan, China.

- Without monitoring and active management of individual species within protected areas, the genetic diversity within and between target populations could be eroded over time and entire populations could even go extinct
- If the target species are threatened, they are unlikely to survive long-term within protected areas unless the threats are contained, mitigated or removed.

It is also widely believed that protected areas are more effective in maintaining biodiversity or biomass than non-protected areas, and indeed this has been one of the main justifications for expanding the protected area estate. Yet there is in fact surprisingly little evidence for this, both generally for species richness and population densities, and for plants in particular. What data we have are far from conclusive[15], some of which suggest populations fare no better within protected areas compared to outside. Much of the information reported is for animal species not plants which may show different results[16].

Using the Living Planet Index (LPI) to assess the impact of protected areas for species globally, a Zoological Society of London report showed that 'increases in populations are evident in many protected areas but there are also many cases of population declines'. The report found that:

'The establishment of protected areas should protect against some threats to the populations within them. Populations of species that are recorded as threatened (at the population level) are declining even inside protected areas with an average decline of 12%. Populations of species with no recorded threats increase up until 2009 (154% increase) after which there is a sharp decline resulting in an average increase since 1970 of 124%. The remaining populations (classified as unknown) have experienced overall a 61% increase'.

Determining the presence of target species in protected areas is widely regarded as the main criterion for meeting the requirements of Target 7 of the Global Strategy for Plant Conservation (GSPC) ('At least 75% of known threatened plant species conserved *in situ*'), 'Conserved *in situ*' is understood to mean that biologically viable populations of these species occur in at least one protected area or the species is effectively managed outside the protected area network, through other *in situ* management measures'[17].

Case study 3 Species recovery in a protected area – Saving the Yuanbaoshan fir in southern China

The Critically Endangered Yuanbaoshan fir (*Abies yuanbaoshanensis*) is one of the most highly threatened tree species in China. It only occurs within Yuanbaoshan National Nature Reserve (NNR) in Guangxi province and has a global population of fewer than 300 individuals. It is threatened by habitat degradation, limited natural regeneration and climate change.

The Global Trees Campaign in collaboration with Guangxi Institute of Botany has built capacity for tree conservation within the nature reserve by offering its staff training courses, mentoring and opportunities to exchange experiences and knowledge with other nature reserves in Southern China.

NNR staff have successful implemented a number of management interventions including; patrolling, monitoring and controlling pioneers species that inhibit the natural regeneration of the Yuanbaoshan fir. Low levels of natural regeneration were also tackled through propagation and planting of Yuanbaoshan seedlings. In 2016, 100 seedlings were planted and after seven months survival rate remained at an impressive 100%.

Above: *Abies yuanbaoshanensis* (Image: Ding Tao/Guangxi Institute of Botany).

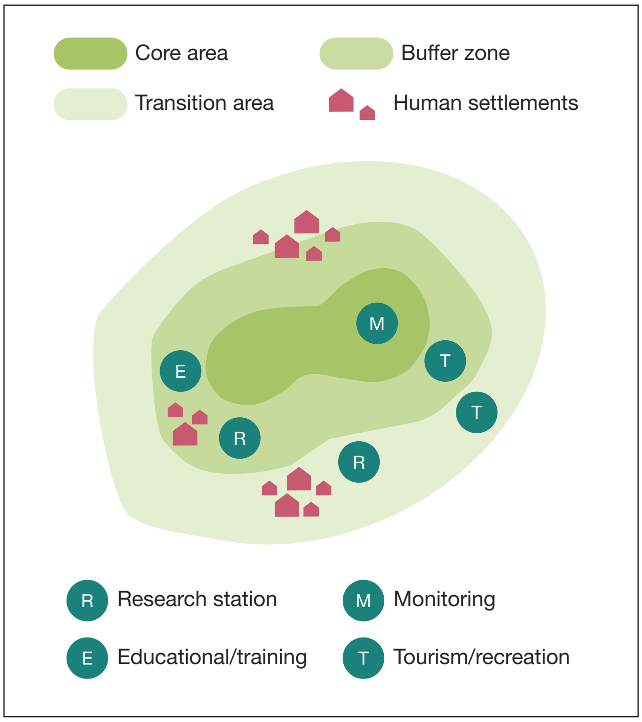

Fig. 4.1 UNESCO Biosphere Reserve zonation

However, the first part of such a rationale is essentially non-operational: either a species occurs in a protected area or it does not. There is no action that can be taken that will alter this, other than to extend an existing area or create a new one that contains the target species, but that of course is the concern of Targets 4 and 5 of the GSPC[18]. Moreover, the aim is not, of course, to increase the number of threatened species that are found in protected areas (to 75% or whatever number one choses), but to reduce it by effective conservation in protected areas and of course elsewhere in the wild. Presence in a protected area should be seen as a means to an end, not an end in itself. The aim of *in situ* conservation of target species is to *remove* the threats that cause them to be endangered. If a species in a protected area is threatened, and the area is properly protected, then action needs to be taken to eliminate or contain the factors that threaten the species other than loss of habitat.

'We must continually monitor whether protected areas are benefiting biodiversity, in terms of representation and persistence or improvement of species populations'

4.1.4 Conservation of target species may conflict with current protected area management aims

Protected area design and management practices that focus on the landscape level, community level or species level may conflict with one another. Moreover, management interventions in protected areas for other species, such as burning, erosion control, increasing tree cover and productivity (in the case of forest reserves) and other habitat disturbance may not be suitable or may even be detrimental to the survival of the populations of target species for recovery that occur there. This stresses the need for an integrated approach to conservation that includes both area-based and species-based needs and actions.

4.2 Biosphere reserves

UNESCO's Man and Biosphere (MAB) programme, initiated in 1974, is an international network, of some 669 sites across 120 countries (as at 2018) dedicated to conserving biodiversity, demonstrating sustainable development, and conducting research and education. The original aim was that each site would have a strictly protected area at their core with zones of increasing human influence (see Fig. 4.1). The concept has evolved over the years and now covers three official functions: biodiversity conservation, sustainable development, and logistical support for research and capacity building[19].

MAB Reserves protect landscapes, ecosystems and biodiversity such as the Sunderban Biosphere Reserve in India which includes a large number of mangrove species. In addition, a number of reserves provide protection for individual plant species such as the Shouf Biosphere Reserve in the Lebanon, whose core zone is the Al-Shouf Cedar Nature Reserve for the Lebanon Cedar (*Cedrus libani*), the Araganeraie Biosphere Reserve in Morocco which includes extensive forests of the Argan tree (*Argania spinosa*), the Grazalema Biosphere Reserve in Spain which includes large stands of the Pinsapo fir (*Abies pinsapo*), the Podocarpus-El Condor Biosphere reserve in Ecuador which houses forests of Romerillo (*Podocarpus glomeratus*) which gives the park its name. Such reserves are an important, if somewhat, neglected tool for plant species conservation and recovery.

4.3 Genetic Reserves

Genetic reserves, also known as Gene Conservation Areas, Gene Management Zones (GMZs), or Gene Parks/Sanctuaries, are essentially protected areas which are managed in such a way as to maintain suitable ecological conditions for the management of the genetic diversity of wild populations of one or more target species. Target species include Crop Wild Relatives, medicinal and aromatic plants, timber and fruit trees and other species of socio-economic importance. They may be independent areas or included within existing protected areas. The main focus is on the conservation and utilisation of genetic diversity[20]. Of course, the maintenance of the genetic diversity of species populations to ensure their survival and continued evolution is key to all species conservation and recovery programmes but in the case of, for example a crop wild relative, the aim is also to maintain the genetic diversity needed for crop plant breeding and the continual development of new cultivars adapted to changing conditions. For examples of genetic reserves see Box 4.3.

Box 4.3 Examples of genetic reserves

Costa Rica – Corcovado National Park; genetic reserve for avocado (*Persea americana*), nance (*Byrsonima crassifolia*) and sonzapote (*Licania platypus*).

India – National Citrus Gene Sanctuary, Nokrek Biosphere Reserve, Garo, Meghalayas; known for preserving a rich diversity of indigenous citrus varieties including Indian wild oranges (*Citrus indica and C. macroptera*).

Palestine – Wadi Sair Genetic Reserve, Hebron; for legumes and fruit trees.

Syria – Sale-Rsheida Reserve; for *Triticum dicoccoides, Hordeum* spp.

Turkey – Ceylanpinar State Farm; includes seven genetic reserves for wild wheat relatives *Aegilops* spp., *Triticum* spp.
Kasdagi National Park; includes ten genetic reserves for wild plum (*Prunus divaricata*), Chestnut (*Castanea sativa*), *Pinus brutia, P. nigra* and *Abies equi-trojani*.
Bolkar Mountains; includes five genetic reserves for *Pinus brutia, Pinus nigra* subsp. *pallasiana, Cedrus libani, Abies equi-trojani, Juniperus excelsa* and *Castanea sativa*.

Vietnam – Gene Management Zone in Huu Lien Nature Reserve, Lang Son Province; for *Colocasia* (Taro), litchi, longan, rice, citrus spp. and rice bean.

Uzbekistan – Nurata State Reserve for walnut (*Juglans regia*) stands.

Source: Hunter and Heywood[23]

4.4 Privately protected areas

Public protected areas are supplemented in some countries by extensive private reserves[21]. **Privately protected areas (PPAs) have a substantial, if not widely recognised or understood, part to play in biodiversity conservation**. PPAs have been variously defined but IUCN adopts that of Stolton *et al*.[22]: 'a privately protected area is a protected area, as defined by IUCN, under private governance (i.e. individuals and groups of individuals; non-governmental organisations (NGOs); corporations – both existing commercial companies and sometimes corporations set up by groups of private owners to manage groups of PPAs; for-profit owners; research entities (e.g. universities, field stations) or religious entities)'.

There are tens of thousands of such reserves around the world. They are particularly developed in parts of Latin America, Australia which has a growing movement and there is a long tradition in Canada, the USA and Mexico. There are many PPAs in western and northern Europe but few in central and east European countries. The tropics and subtropics, South Africa and Kenya have well-developed PPA systems and some other southern and east African countries have mainly commercially run PPAs. There are, however, few sites of this kind in Asia.

What role PPAs play in biodiversity conservation is not always clear and it is difficult to evaluate how effective they are[24], as they are seldom monitored to see if they are achieving their stated aims. The conservation of target species is seldom a priority goal, although they can be used to protect iconic species or even individual trees.

4.5 Community Conserved Areas (CCAs)

Involving the local community in *in situ* conservation and recovery of species, especially those which have an economic or social value or which otherwise impinge on the community's interests is discussed in detail in Chapter 10. The level of community participation in the planning and management of protected areas varies greatly. In some cases, communities play a leading role, an example being the Parque de la Papa (Potato Park) in Peru[25] which was established after an intensive collaboration over several years between six Quechua communities, the Asociación ANDES and other organisations. The park is a centre of diversity for a range of important Andean crops such as the potato.

Left: Local community members tending to *Butea monosperma* saplings planted in a restoration plot in northeast Pakistan.

4.6 Sacred groves or forests

A particular form of community involvement in the protection of areas is the tradition in many parts of the world of protecting small areas of forest as sacred groves or forests or even single trees. Such sacred sites are characterised by the community adhering to a belief system that includes a number of prescriptions, such as taboos that have the effect of regulating human behaviour and actions and result in a restrained or restricted use of the resource concerned.

Such sacred areas afford a high degree of protection and monitoring and would therefore be of interest in the conservation *in situ* of any target species that occur within them. The sites also provide important seed sources in areas where the rest of the forest has been more or less destroyed. Examples of such sites may be found in the volume *Protected Landscapes and Cultural and Spiritual Values*.[26]

4.7 Conclusions

When designing a conservation or recovery programme for a species that occurs partly or wholly within a protected area, the following actions are recommended:

- Work closely with land managers at all stages of species conservation/recovery planning
- Cooperate with protected area management in ensuring that the biodiversity inventory of the area is accurate and complete
- When designing a species management/recovery programme obtain as much information as possible about any areas that are likely to be selected because of the presence of populations of the target species in them, including details of the management plans
- Ascertain the state of protection and level of management of the protected area(s) in which the target species occur
- A prescription for further protection of the area may be included in the species recovery plan
- Negotiate with the land managers of the area(s), whether publicly or privately owned, to see if any necessary management interventions planned for species recovery will be acceptable and compatible with the area's existing management objectives
- If necessary, cooperate with land managers in the enhancement of the area's management plan, including measures specific to managing biodiversity and in particular the target species
- In the case of economically important species, such as Crop Wild Relatives and forestry tree species, ensure that the relevant guidelines and good practices are taken into account
- Ensure that the local community is well informed, consulted and whenever possible closely involved at all stages from planning to monitoring
- Develop guidelines for working with protected area authorities and managers or other relevant actors.

In addition, efforts should be made to help in capacity building to improve the ability of staff, local communities and landowners to participate in the actions to monitor and restore plant species populations within the protected area.

Every effort should be made to publicise the importance of the conservation and recovery actions and explain the significance of the target species concerned.

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Chapter 5.
Nature of threats

Aim of this chapter

An understanding of the prevailing and potential threats to plants is essential for successful conservation and species recovery. This chapter outlines the main types of threats that are impacting plant species at different levels.

5.0 Introduction

'We recommend that more energy be expended early in the recovery process to understand the factors that threaten species. No matter how much ecological theory, natural history, and monitoring sophistication we bring to bear on threatened and endangered species recovery, the science will be squandered without detailed insight into the threats that are putting the species at risk'[1]

For successful conservation and species recovery outcomes, we need a detailed understanding of the nature of the threats affecting threatened species and how to deal with them; otherwise our efforts may be undermined and valuable resources wasted. Misidentification of threats and subsequent misinformed threat management can lead to failure of species recovery projects.

While general classes of threats are obvious, detailed threats within these can be highly complex and diverse. These threats vary in their impact and extent between different regions and ecosystems, but most are humanly driven, or at least exacerbated by humans. Human induced threats greatly outweigh the natural threats to plant species and their habitat[2].

5.1 Types of threats

The major overarching threats to biodiversity are:

- Population growth and resource consumption
- Climate change and global warming
- Habitat conversion and urbanisation
- Invasive alien species
- Over-exploitation of natural resources and,
- Environmental degradation[3].

The five most common threatening processes listed for plants are:

- Habitat loss through conversion of land to agriculture
- Over-harvesting as biological resources
- Residential and commercial development
- Natural system modifications
- Invasive species.

These processes affect both threatened and not threatened plants similarly[4] (See Table 5.1).

Some threatening processes affecting plants are natural, such as fire, cyclones, volcanic eruptions and also habitat change due to succession. However, the majority of threatening events today are human induced.

Threatening processes can act **independently**: in such cases, if the threatening process were to be halted, the threat would be removed and the plants would no longer be threatened and are likely to recover in their natural environment, providing there are no other threats affecting the species. One such example is collection of orchids for the horticultural trade, where if this threat is controlled and stopped the species is likely to recover naturally.

Box 5.1 Threats for Cacti

An assessment of all species of cacti (Cactaceae) shows that nearly one third of species are threatened with extinction[5]. Also more than a half of all cactus species (57%) are used by people.

Cacti are subjected to a range of threats, the predominant threatening processes are:

- Land conversion to agriculture
- Collection as biological resources, and
- Residential and commercial development.

In areas where all three threat processes occur, such as eastern Brazil and central Mexico, the highest concentration of threatened cactus species is found.

The most important proximate drivers of extinction risk, that is the ultimate factors contributing to or enabling the threat process among threatened cacti, are unscrupulous collection of live plants and seeds for the horticultural trade and for private ornamental collections (affecting 47% of threatened cacti), smallholder livestock ranching (31%) and smallholder annual agriculture (24%).

However, threatening processes rarely act on their own; the majority of threats are more **complex**, or act in combination with other threatening processes. These are causing plant responses that are more difficult to predict, and possibly much harder to recover from. One example is climate change, which is a complex threat that can cause changes to the natural habitat, climatic factors and interacting organisms. Also **interacting** threats, such as fire and invasive species, may exaggerate the impact on plant diversity.

Threatened species management needs to consider interactions between threats and their mitigating actions for obtaining most successful species recovery[6].

While general classes of threats affecting plant diversity are clear (see Table 5.1), detailed threats within these can be diverse and often multi-faceted. Threat classification systems are complex as threats can be defined on multiple levels, such as the threatening processes, the sources of the threat and/or the impacts from each threat[7].

An example of the IUCN Threat classification scheme is given in Table 5.2. This scheme lists the threatening processes that impact a species, each of these threats also need to be coded based on the timing of the threat (past, ongoing or future), scope (proportion of species affected) and severity[7].

It is also important to identify the timing of threats, to distinguish between past and current threats. For example, loss or fragmentation of habitat has commonly led to reduction of species populations to a state in which they are threatened with extinction. If populations of the species now occur in a protected area that is adequately managed, then loss of habitat should no longer be a current threat for such populations. The current threats, to be addressed in a species recovery management plan, are the genetic and demographic consequences of being reduced to a small population and any other factors that affect it within the protected area. Any populations of the species that occur outside protected areas will of course be vulnerable to habitat loss and other threats.

Habitat loss and fragmentation	Habitat loss includes not only its destruction but degradation and fragmentation. Habitat loss is one of the most significant threats to plant diversity, particularly in the tropics. Most habitat loss and fragmentation is due to conversion for agricultural crop lands, forest plantations, pasture, mining, industrialisation and urbanisation.
Over-exploitation	Over-exploitation is the unsustainable, targeted extraction or collection of particular species or parts of them, for human use. It affects a relatively small set of species, but often with devastating effects. Examples are the unsustainable targeted logging of timber trees, excessive wild harvesting of medicinal and aromatic plants and extraction of non-timber forest products (NTFP), such as fruit, nuts, latexes, resins, gums, medicinal plants, spices and dyes.
Natural system modifications	Natural system modifications refer to changes in land management and disturbance regimes of natural or semi-natural systems, often to improve human welfare, such as changes in fire regimes, including season, extent, intensity or frequency, inhibiting regeneration from seed or by vegetative reproduction; generally, inappropriate fire regimes lead to the competitive disadvantage of the threatened species against local and introduced species, or represent a future threat if fire recurs before plants are mature and seed is produced. This can also include threats to species due to the loss of management, for example when former agricultural lands are abandoned.
Pests, diseases and invasive species	Increased travel and trade, has led to organisms (including invasive species, pests and disease vectors) being moved further and more frequently than ever before. Species and their habitats may be threatened by alien invasive organisms following their introduction, spread or increase in abundance. Invasive alien species (IAS) can be a major problem in some areas and habitats and are a common threat in protected areas. habitats. There is increasing recognition of these threats as more information becomes available although they are often underreported in many countries. Control or eradication of invasive species can be a challenging and expensive task[9]. See Box 5.2 for an initiative to serve as an early warning system for detecting new and emerging plant pests and pathogens – the International Plant Sentinel Network.
Climate change	The impacts of climate change together with other aspects of global change on plants and their habitats are highly complex. Their most important impact on plants and their habitats are likely to be on our fixed system of protected areas, many of which may not be able to withstand the changes, and on the extent to which species are able to adapt to changing climatic conditions or to migrate and track the changes.

Table 5.1 Details on major threats to plants

Box 5.2 The International Plant Sentinel Network

Horse chestnut scale (*Pulvinaria regalis*).

International Plant Sentinel Network

The International Plant Sentinel Network (IPSN), coordinated by BGCI and the UK Department for Environment, Food and Rural Affairs, provides an early warning system to identify new and emerging pest and pathogen risks on a global scale. It works via a network of both national and international partnerships between government bodies such as National Plant Protection Organisations (NPPOs), plant protection scientists and botanic gardens and arboreta. Botanic gardens help to provide scientific evidence regarding known quarantine organisms and potential new risks to native and horticulturally important plants. This information is used by NPPOs to support plant health activities such as Pest Risk Analysis (PRAs) and management. The IPSN provides an opportunity for botanic gardens to build on their research and conservation efforts by helping to safeguard plants from damaging organisms.

Table 5.2 IUCN Threat classification scheme version 3.2

1. Residential & commercial development	1.1 Housing & urban areas 1.2 Commercial & industrial areas 1.3 Tourism & recreation areas
2. Agriculture & aquaculture	2.1 Annual & perennial non-timber crops 2.1.1 Shifting agriculture 2.1.2 Small-holder farming 2.1.3 Agro-industry farming 2.1.4 Scale Unknown/Unrecorded 2.2 Wood & pulp plantations 2.2.1 Small-holder plantations 2.2.2 Agro-industry plantations 2.2.3 Scale Unknown/Unrecorded 2.3 Livestock farming & ranching 2.3.1 Nomadic grazing 2.3.2 Small-holder grazing, ranching or farming 2.3.3 Agro-industry grazing, ranching or farming 2.3.4 Scale Unknown/Unrecorded 2.4 Marine & freshwater aquaculture 2.4.1 Subsistence/artisinal aquaculture 2.4.2 Industrial aquaculture 2.4.3 Scale Unknown/Unrecorded
3. Energy production & mining	3.1 Oil & gas drilling 3.2 Mining & quarrying 3.3 Renewable energy
4. Transportation & service corridors	4.1 Roads & railroads 4.2 Utility & service lines 4.3 Shipping lanes 4.4 Flight paths
5. Biological resource use	5.1 Hunting & collecting terrestrial animals 5.1.1 Intentional use (species being assessed is the target) 5.1.2 Unintentional effects (species being assessed is not the target) 5.1.3 Persecution/control 5.1.4 Motivation Unknown/Unrecorded 5.2 Gathering terrestrial plants 5.2.1 Intentional use (species being assessed is the target) 5.2.2 Unintentional effects (species being assessed is not the target) 5.2.3 Persecution/control 5.2.4 Motivation Unknown/Unrecorded 5.3 Logging & wood harvesting 5.3.1 Intentional use: subsistence/small scale (species being assessed is the target) [harvest] 5.3.2 Intentional use: large scale (species being assessed is the target) [harvest] 5.3.3 Unintentional effects: subsistence/small scale (species being assessed is not the target) [harvest] 5.3.4 Unintentional effects: large scale (species being assessed is not the target) [harvest] 5.3.5 Motivation Unknown/Unrecorded 5.4 Fishing & harvesting aquatic resources 5.4.1 Intentional use: subsistence/small scale (species being assessed is the target) [harvest] 5.4.2 Intentional use: large scale (species being assessed is the target) [harvest] 5.4.3 Unintentional effects: subsistence/small scale (species being assessed is not the target) [harvest] 5.4.4 Unintentional effects: large scale (species being assessed is not the target) [harvest] 5.4.5 Persecution/control 5.4.6 Motivation Unknown/Unrecorded
6. Human intrusions & disturbance	6.1 Recreational activities 6.2 War, civil unrest & military exercises 6.3 Work & other activities

Logging of native tree species in Bhutan.

7. Natural system modifications	7.1 Fire & fire suppression 7.1.1 Increase in fire frequency/intensity 7.1.2 Suppression in fire frequency/intensity 7.1.3 Trend Unknown/Unrecorded 7.2 Dams & water management/use 7.2.1 Abstraction of surface water (domestic use) 7.2.2 Abstraction of surface water (commercial use) 7.2.3 Abstraction of surface water (agricultural use) 7.2.4 Abstraction of surface water (unknown use) 7.2.5 Abstraction of ground water (domestic use) 7.2.6 Abstraction of ground water (commercial use) 7.2.7 Abstraction of ground water (agricultural use) 7.2.8 Abstraction of ground water (unknown use) 7.2.9 Small dams 7.2.10 Large dams 7.2.11 Dams (size unknown) 7.3 Other ecosystem modifications
8. Invasive & other problematic species, genes & diseases	8.1 Invasive non-native/alien species/diseases 8.1.1 Unspecified species 8.1.2 Named species 8.2 Problematic native species/diseases 8.2.1 Unspecified species 8.2.2 Named species 8.3 Introduced genetic material 8.4 Problematic species/diseases of unknown origin 8.4.1 Unspecified species 8.4.2 Named species 8.5 Viral/prion-induced diseases 8.5.1 Unspecified “species” (disease) 8.5.2 Named “species” (disease) 8.6 Diseases of unknown cause
9. Pollution	9.1 Domestic & urban waste water 9.1.1 Sewage 9.1.2 Run-off 9.1.3 Type Unknown/Unrecorded 9.2 Industrial & military effluents 9.2.1 Oil spills 9.2.2 Seepage from mining 9.2.3 Type Unknown/Unrecorded 9.3 Agricultural & forestry effluents 9.3.1 Nutrient loads 9.3.2 Soil erosion, sedimentation 9.3.3 Herbicides and pesticides 9.3.4 Type Unknown/Unrecorded 9.4 Garbage & solid waste 9.5 Air-borne pollutants 9.5.1 Acid rain 9.5.2 Smog 9.5.3 Ozone 9.5.4 Type Unknown/Unrecorded 9.6 Excess energy 9.6.1 Light pollution 9.6.2 Thermal pollution 9.6.3 Noise pollution 9.6.4 Type Unknown/Unrecorded
10. Geological events	10.1 Volcanoes 10.2 Earthquakes/tsunamis 10.3 Avalanches/landslides
11. Climate change & severe weather	11.1 Habitat shifting & alteration 11.2 Droughts 11.3 Temperature extremes 11.4 Storms & flooding 11.5 Other impacts
12. Other options	12.1 Other threat

Plant Post-Entry Quarrantine Center, Shenzen, China.

Collecting seed from *Betula megrelica* in Georgia (Image: Paul Bartlett).

5.2 Impacts of threats on plant diversity

Threatening events impact plant diversity on different levels: on a landscape or habitat level, on the level of the individual plant and on a genetic level.

5.2.1 Landscape or habitat level

Many threatening events can impact the extent or quality of the habitat that a species inhabits. For example, deforestation causes a shrinking of the natural habitat for plants inhabiting that impacted area. Although seeds or pollen may move long distances, the sessile nature of plants themselves means they are unable to relocate. Threatening events leading to the loss of habitat therefore can have a direct and devastating impact on plants.

In addition to the loss of habitat, the threat to the landscape scale can also cause fragmentation which impacts the connectivity between plant subpopulations. Smaller fragments of habitat may only be able to support smaller species populations. In addition, the edge-effect of fragmented habitats may affect species that are unable to withstand these conditions. Dispersal and pollination may also be impacted as the wider ecosystem and associated species are affected. Fragmentation can also provide increased access to plants for pests and invasive species, as well as easier access for harvesting or illegal collection of plants.

5.2.2 Individual level

Threatening events may also operate on the scale of the individual plants. In such ways, the threat directly targets individual plants, such as in selective logging of certain timber species, or collection of rare orchid plants for trade. These threats would decrease the population size of the species. The threat may specifically target individuals that are able to reproduce, and in such a way impacts the future stability of the species.

5.2.3 Genetic level

Loss of habitat can lead to a loss of genetic diversity of the populations affected. This restriction in the number of individuals and also the restriction in habitat in which they are found may impact the ability of a species to maintain a healthy, evolving population. Especially if the individuals lost are not random but chosen due to certain characteristics (large timber trees, brightly coloured flowers, early fruiting, etc.). Threatening processes that may not impact habitat structure nor affect a change in population abundance may still have an impact on the genetic level. For example, disease may spread to reproductive parts of a plant and impact the reproductive success. In addition, climate change may also impact species' reproductive success (such as altering phenology so associated species are no longer synchronised, i.e. pollinators) and ultimately change the genetic structure of a species.

5.3 Measuring impacts of threats and the risk of extinction

Taking into account the types of threats and how these threats may impact plants, the question is then how do we measure the risk of extinction to plants? The IUCN Red List of Threatened Species aims to identify species at high risk of extinction in the near future[10]. It predicts the probability of extinction within a specific time period using five different criteria:

- A - Population reduction
- B - Restricted range and decline
- C - Small population size and decline
- D - Extremely small or restricted population
- E - Quantitative analysis.

The five criteria are based on a set of quantitative thresholds and several subcriteria.

The IUCN Red List system aims to capture species at high risk of going extinct. It therefore, does not list species that are naturally rare and currently unaffected by any threats; but can include widespread and common species that are undergoing significant decline. Only species with extremely small population sizes (<1,000 individuals) can be listed as at risk of extinction without evidence of possible decline.

The IUCN Red List categories and criteria were developed with all organisms in mind, not only plants, in order to be comparable between groups. The longevity of some trees, as well as the sessile nature of plants, in addition to the ability to disperse over large distances are challenges to their application.

The IUCN Red List does not directly assess extinction risk below the taxon level, and although the criteria take into account genetic diversity indirectly, it is implied rather than explicit. For example, there is no distinction between a species that has undergone a genetic bottleneck (more than three generations ago) to a similar taxon that has not undergone a genetic bottleneck. A genetically depauperate species may no longer have the genes to be able to respond to a change in environmental factors. The genetic makeup and ability to respond to threatening events is likely to be very different for these two species. Therefore, species that have experienced a genetic bottleneck are at higher risk of extinction than species that have not.

Testing plant material for *Dothistroma* needle blight, Yorkshire Arboretum, United Kingdom.

Surveying and collecting *Carpinus hebestroma* in Taroko Gorge National Park, Taiwan.

Species recovery planning and actions should not be based solely on red list assessments but need to take into account all the threats that are found to impact the target species and their populations as well as the genetic factors involved, for example in locally adapted populations.

5.4 Conclusions

Threats to plant biodiversity are very diverse as is their impact and extent between different regions, ecosystems and species populations. They are often driven, or at least exacerbated by human action. Human pressure will increase as the global population continues to grow, impact on the natural world increases and the land available for plants to survive with limited interruption decreases in extent and quality. If we are to successfully protect plants from the impact of these threats we need to be aware of and control threatening events. It is also important to look at conservation action from a species-specific perspective to ensure that responses are appropriate.

Because of the diversity of possible threats to individual species populations it is critical that a comprehensive threat assessment is undertaken in the preparation of a recovery plan. Failure to do so may lead to the failure of the recovery process and a waste of resources.

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Chapter 6.
Which species and which areas to select? Priority determining mechanisms for species, populations and areas

'In the face of scarce resources, it is necessary to establish priorities for biodiversity conservation, but it is also necessary to know clearly what, where and how to conserve.' [Translated from the Portuguese][1]

Aim of this chapter

The aim of this chapter is to give guidance on how to decide which species should be selected for conservation or full recovery and in which areas.

6.0 Introduction

In many cases, the list of species requiring conservation action will exceed the available financial and human resources. Consequently, a decision has to be made on:

- Which species and how many populations of each to conserve
- Which areas where the species occurs should conservation or recovery actions take place.

Various systems of triage to select priority species and areas have been proposed.

Box 6.1 New Zealand's plant species priority ranking system

The ranking system assessed a subset of the plants listed in the New Zealand Botanical Society's threatened and local plant list against a set of criteria and assigned the plants to one of seven categories[2]:

A = Highest priority for conservation action
B = Second priority for conservation action
C = Third priority for conservation action
I = Plants about which little information exists but which are considered threatened
M = Plants that are rare or localised and of cultural importance to Maori
O = Plants which are threatened in New Zealand but are thought to be secure in other parts of their range outside New Zealand
X = Plants which have not been sighted for a number of years, but which may still exist.

Camellia azalea (Image: Ton Hannink).

6.1 Methodologies and criteria for selecting species

There is no internationally agreed methodology for deciding on which species or populations should be selected for priority conservation or recovery action, but many tools exist to support decision making. The criteria adopted vary from country to country, and also reflect the particular context in which the choice is to be made.

6.1.1 Policy instruments

The selection of priority species may be influenced by the policy, mandate and priorities of the responsible agency or institution. The species selected by an environment agency, for example, are likely to differ from those chosen by an agricultural or forestry service[3]. As noted in Chapter 2, national or regional policy instruments often result in a list of species in need of conservation action.

6.1.2 Conservation status

It is likely that many, if not the majority, of the candidate species under consideration will be threatened to some degree. The most commonly used system for assessing conservation status is the IUCN Red List of Threatened Species. Many countries, while recognizing the IUCN system, apply their own national or subnational systems (see for example Box 6.1 for New Zealand's Species Priority Ranking System).

The IUCN Red List status of a species may disagree with that determined in national or subnational assessments. IUCN notes that it is not always possible to integrate information from global species assessments into national or regional-level conservation planning and priority setting[4]. This can be attributed to:

- Differences in assessment scope (national vs global level)
- Use of different information technology systems
- Use of different threat categories and criteria – resulting in different assessment outcomes
- Use of different scales (global level maps are often of broader resolution than maps used in national assessments)
- Differences in language of assessments.

To address this issue, IUCN has provided guidance to help countries apply the IUCN Red List Categories and Criteria at national and regional scales[5].

A common error is to adopt uncritically global or national Red List or conservation status of species as a primary criterion for selection for recovery actions. Instead such assessments should be used as a filter to be applied alongside a detailed analysis of other criteria (see below).

6.1.3 Other criteria

A variety of other factors come into play when deciding which species to select for conservation and recovery actions. In many countries the number of species assessed as threatened or listed as priority species will exceed the resources available.

In practice, the selection of species (and areas) for recovery action is often influenced by the information already or readily available on the candidate species, local knowledge and already established priorities. This is especially the case for species with economic importance such as Crop Wild Relatives, forestry species, medicinal and aromatic plants, etc.

There may be good reasons for selecting species that are of economic importance, such as forestry trees or Crop Wild Relatives for conservation, even though they are not currently threatened, so as to ensure that important genetic variation is maintained into the future when climate change and other factors may threaten them or their habitats.

Silene perlmanii (Image: O'ahu Plant Extinction Prevention Program).

Box 6.2 Selection of Crop Wild Relatives for conservation action in Armenia, Bolivia, Madagascar, Sri Lanka and Uzbekistan

As part of a UNEP/GEF Crop Wild Relatives (CWR) project, the five partner countries were required to select five priority taxa for *in situ* conservation. Although guidance was given, each country adopted a different approach.

For example, in Armenia, meetings, debates and discussions were held to consider particular crops and methods for their evaluation and selection. Botanists representing various fields were involved to ensure objectivity and transparency of the process and, on the basis of the chosen criteria the crops were evaluated. As a result of the discussions, all CWR were divided into four key groups: cereals, pulses, vegetables, and fruits, berries and nuts. For each group a separate set of criteria was developed, paying special attention to the group's ecological, biological, economic and agricultural indicators/values.

In Madagascar, the selection of the five priority taxa for conservation action was discussed with representatives of partner institutions involved in the implementation of the CWR project and members of the Ministry of Environment, Water, Forests and Tourism and the Ministry of National Education and Research. They covered various fields of expertise in plant biology, such as taxonomy and systematics, botany and ecology, genetics and plant breeding, forestry and agronomy, and management of natural resources. See Box 6.4, below for a scoring system applied to help identify priority taxa.

Source: Hunter and Heywood[6]

Ideally, all interested parties should be involved or have a say in the choice of species. A useful approach is to hold a workshop (or series of workshops) for this purpose (see Box 6.2).

Commonly used criteria to identify species in need of recovery action are given in Box 6.3.

Given the potentially large number of criteria that might be considered, a scoring system could be applied to each of the questions raised in Box 6.3, with some having more weight than others depending on the objective of the strategy. An example of a scoring system is given in Box 6.4.

6.1.4 Pragmatic considerations

In addition to the criteria outlined in Box 6.3, experience shows that often much more pragmatic considerations often come into play, such as:

- The likelihood of conservation success and sustainability
- The relative monetary costs of conservation actions
- Being taxonomically well known and unambiguously delimited
- Being readily available and easy to locate and sample
- The biological characteristics of the species (e.g. breeding system).

Box 6.3 General criteria for selecting target species for recovery action

- What is the actual or potential use of the target species? Is it a Crop Wild Relative, medicinal plant, forest timber tree, fruit tree, ornamental or forage plant, etc.? Can the species be used for habitat restoration or rehabilitation?
- What is the current conservation status of the target species?
- Is the species endemic, with a restricted range or is it widely distributed?
- Is the species experiencing a continuing decline in its occurrence?
- Is there evidence of genetic erosion?
- Does the species have some unique characteristics in terms of:
  - a. eco-geographic distinctiveness
  - b. taxonomic or phyletic distinctiveness or uniqueness or isolated position
- Does it play a special role in the ecosystem as:
  - a. focal or keystone species
  - b. indicator species
  - c. umbrella species
- Does the species have cultural importance or is it in high social demand? Is it regarded as a flagship species (i.e. will conservation of this species generate support for wider conservation)?
- Does the species occur in a protected area system or does it have some sort of legal or community protected status?

Source: Heywood and Dulloo[7]

6.2 Criteria for selecting areas and critical habitat

Once a species has been selected for recovery actions, the next decision to make is to determine which of the areas where the species is present are most appropriate to implement conservation and recovery actions. For species with a single population or small number of populations, all populations may be deemed critical habitat. For species with wider or fragmented distributions or multiple populations, financial and resource restrictions will mean that conservation actions cannot be implemented across the full species' range, so must be targeted in selected areas.

The selection of an area(s) is of course initially determined by the presence of the species concerned within it. The relevant biological, distributional, genetic and demographic information about the target species/populations will, of necessity, require a prior eco-geographical survey (for more information see Chapter 7).

6.2.1 Species within existing protected areas

Presence of a population(s) of a target species in an already existing protected area(s) is an obvious advantage and that area will normally be chosen for conservation action if this is an option. If the target species occurs in more than one protected area, a choice of area or areas then needs to be made.

The questions to be asked are:

- Is the area effectively protected?
- Is the area well managed?
- Is the local community involved in the management of the reserve?
- Is the area ecologically viable?
- Is the management of the area conducive to allowing the target species population to persist and develop?
- What is the size and representativeness of the target species' population(s) in each area?
- How much genetic diversity is captured in the area?
- Is the area within a centre of plant diversity?

Box 6.4 Selection criteria and scoring system for priority Crop Wild Relatives in Madagascar

As part of the project outlined in Box 6.2, an initial list of eight important Crop Wild Relative (CWR) genera was proposed by experts from various fields in biology, agriculture and forestry and representatives from government ministries: *Cinnamosma, Coffea, Dioscorea*, *Musa/Ensete, Oryza, Piper, Tacca* and *Vanilla*. To reduce this list to five taxa, the following selection criteria and values were used:

- Number of species occurring in Madagascar for each genus
- The presence status of the species in each taxon (0 – introduced; 1 – naturalized; 3 – endemic)
- Use of the taxon as food (0 – no; 3 – yes)
- Contributions of species within the genus to food security (0 – no; 3 – yes)
- Economic value of the crop relative (0 – low; 1 – mid; 3 – high)
- Potential of the species as specific gene donor for crop improvement (0 – low; 1 – mid; 3 – high)
- Level of threats to the taxon (unrated due to lack of data)
- Availability of information (0 – high; 1 – mid; 3 – low), a lack of information is highly rated in this example because the committee considered the CWR project as an opportunity to gather information on the taxa.

The selection of the actual species to be targeted within each of the five genera was made after eco-geographical studies had been completed.

Case study 4 *In situ* conservation by fenced enclosures in Sinai, Egypt

In St Katherine's Protectorate, Sinai (Egypt), a project for *in situ* conservation of five endemic species, *Primula boveana, Rosa arabica, Phlomis aurea, Bufonia multiceps* and *Anarrhinum pubescens,* involved establishing 48 permanent enclosures of various sizes, ranging between 7m^2 and 300m^2 to protect, manage and monitor them. The enclosed plots were chosen to represent, as far as possible, the prevailing environmental variation associated with the distribution of the target species. The enclosures were protected against animal grazing and human activities by fencing (See Fig.6.1).

An evaluation was made of the effectiveness of the enclosures as a conservation tool after ten years of protection (2004-2014). Results of this evaluation showed that while in general enclosures are a good method of conservation for species affected by threats such as grazing and over-collecting, when comparing vegetation parameters for target species inside and outside enclosures, only *Bufonia multiceps* and *Primula boveana* responded favourably after 10 years of protection, while the other three species showed declines in their populations.

The reasons for the decline are the other threatening processes that affect these species. These include the persistent drought, scarce and irregular precipitation and rare flooding, insect pests and human disturbance of the habitat. This reinforces the importance of a full threat assessment when planning conservation actions (for more information about threats see Chapter 5 and Chapter 7).

Source: Omar[8]

6.2.2 Species outside of protected areas

Many threatened species have very restricted distributions and do not occur within protected areas. A decision must then be made to determine whether it is possible and appropriate to establish a protected area for the species, or what other actions can be taken to ensure that species recovery outside of protected areas is effective.

6.2.2.1 Establishment of protected areas

When a target species does not occur within a protected area, a decision may be made to establish a protected area to conserve it. This does not necessarily mean establishment of an expensive and large protected area: smaller scale measures, such as fencing of population fragments as a means of protection from grazing animals and human activity, can also lead to effective recovery.

While it is tempting to establish reserves for rare populations without first obtaining detailed information from an eco-geographical survey (see Chapter 7) this seldom provides adequate medium to long-term conservation although it can be argued that it is better than taking no action (See Box 6.6 and Fig. 6.1).

Normally, establishing a new protected area or reserve for a target species involves a whole series of legal, financial, social, economic and political questions and will involve negotiations with the owners, land managers and other interested parties. There is extensive guidance on this topic which may be consulted[9], although most of it is aimed at establishing national systems of protected areas for the conservation of biodiversity, landscape and other values, not at establishing protected areas for single target species. However, guidelines for the design and location of genetic reserves for Crop Wild Relatives are given in the volume *Conserving Plant Genetic Diversity in Protected Areas* and these are largely relevant for any target species[10].

The following aspects should be reviewed when selecting the area:

- The location of the area and how accessible it is
- The size of the reserve(s) which will reflect the nature and distribution pattern of the target species and the minimum area need to house a Minimum Viable Population (see Chapter 11)
- The health and quality of the area
- The current state of management of the area
- Whether there is a management plan for the area and whether it is compatible with the proposed management actions for the target species' populations
- Resilience to climate change.

The following criteria regarding the target species/populations should also be considered:

- What is the level and pattern of genetic diversity of the target species' populations and what is the presence of desirable alleles within the proposed area, if known or relevant?
- How many populations/subpopulations are included in the proposed area?
- What is the number of individuals within the population(s) included in the proposed area?
- What is the current conservation status of the species and what are the threats this species is facing?

Fig.6.1 *In situ* enclosure of *Anarrhinum pubescens* in St Katherine's Protectorate, Sinai, Egypt (Image: V.H. Heywood).

Box 6.7 What is critical habitat?

Critical habitat is a term defined and used in the US Endangered Species Act. It is **a specific geographic area(s) that contains features essential for the conservation of a threatened or endangered species and that may require special management and protection**. Critical habitat may include an area that is not currently occupied by the species but that will be needed for its recovery. In the USA, an area is designated as "critical habitat" after publishing a proposed Federal regulation in the Federal Register and following consideration of public comments on the proposal. The final boundaries of the critical habitat area are also published in the Federal Register, but is not necessarily physically marked on the ground, e.g. by a fence.

What is the purpose of designating critical habitat?

Federal agencies are required to consult with the US Fish and Wildlife Service on actions they carry out, fund, or authorise to ensure that their actions will not destroy or adversely modify critical habitat. In this way, a critical habitat designation protects areas that are necessary for the conservation of the species.

Source: US Fish & Wildlife Service[11]

6.2.2.2 Other methods to increase protection of an area

Formal establishment of a protected area may not be necessary. Areas may be selected, where removal of the threat(s) is sufficient to deliver species recovery, without fencing an area or creating a boundary. For example, if the threat is over-harvesting, establishment of a nursery next to a popular area for harvesting may result in reduced pressure and species recovery, without the need for a formally established reserve. To determine whether a formally established protected area is required or not, a clear understanding of the species and threats facing it is required (see Chapter 7 eco-geographical surveying). Community involvement will affect the success of recovery actions, particularly when a formal protected area isn't established (see Chapter 10 on community engagement).

Restoring land in the wheatbelt region of Western Australia (Image: Barney Wilczak).

Fraxinus velutina (Image: Ian Harvey-Brown)

6.2.3 Critical habitat

It is necessary to determine which areas contain the **critical habitat** that is considered essential for the effective conservation of the species. The term **critical habitat** originated in the US Endangered Species Act where it is defined as a specific geographic area(s) that contains features essential for the conservation of a threatened or endangered species and that may require special management and protection[11] (see Box 6.7). Although some doubts have been raised about the effectiveness of the approach in practice[12], it is now widely adopted by other countries as in the New South Wales Office Threatened Species Conservation Act 1996 in Australia, and the Canadian Species at Risk Act 2002.

'The protection of critical habitat is an essential step in the threatened species recovery process. It is also one of the most contentious and protracted decisions faced by environmental agencies. Uncertainty about what constitutes critical habitat, and the challenges of balancing competing societal objectives and of protecting critical habitat once identified are stalling the recovery process'[13]

It is often considered essential that the critical habitat is defined in the recovery strategy or in an action plan of a species given that for most species, recovery is only possible if critical habitat is identified and protected, maintained or restored[14]. Protection of these areas is usually afforded by prohibiting activities that could result in adverse changes, significant damage or destruction of part or whole of the critical habitat.

6.3 The problems of conserving small populations

We assume that priority should be given to securing a species from extinction by stopping significant declines in numbers and then managing the secured populations to recovery by creating opportunities for population growth. This two-prong approach endorses the importance of ameliorating the agents that are causing populations to decline and then understanding the genetic issues that can arise once populations become small but stable or slowly recovering[15]

Box 6.8 Targeted genetic conservation of wide-ranging tree species at the pan-European level

In Europe, forest conservation genetics have improved the theoretical basis for the genetic management of tree species and various guidelines have been published. In terms of practical implementation and legal frameworks, European countries have organised the conservation of forest genetic resources in various ways. However, nearly all countries use the same conservation approach; networks of forest stands or areas harbouring tree populations which have adapted to specific environmental conditions or have distinct characteristics. Such stands, i.e. **genetic conservation units**, are typically located in forests that are managed for multiple uses, in protected areas or as seed stands[23].

The European Forest Genetics Programme (EUFORGEN) established a working group to help European countries develop the pan-European genetic conservation strategy for forest trees. The results are presented in the report Pan-European strategy for genetic conservation of forest trees and establishment of a core network of dynamic conservation units[24]. For each tree species, the strategy calls for a core network of dynamic conservation units (DCUs), also known as genetic/gene conservation units. These units are not interconnected by geneflow, but together capture the current genetic diversity across the European continent. In Europe, according to the European Information System on Forest Genetic Resources (EUFGIS), as at November 2017, the EUFGIS database contains information on 3773 units and 102 tree species in 34 countries. The dynamic conservation units house a total of 4308 tree populations. This extensive network, however, suffers from gaps in coverage: for example, more than 80% of the conservation units represent just five economically important species. Technical guidelines giving short, practical advice for forest managers and others on the genetic conservation of more than 40 tree species have been prepared[25].

The 2016 World Conservation Congress adopted a motion calling for forest genetic conservation units to be recognised with the IUCN protected areas status of category IV - Habitat/Species management area. It is likely that the genetic conservation units listed in EUFGIS will be among the first to benefit from this new status.

Sources: Koskela *et al*.[26]

It is likely that the majority of reserves created for the conservation of target species will be small scale or micro-reserves (see Box 1.2), reflecting the small size and limited distribution of the species and will consequently house only small populations of target species. Notable examples are:

- The establishment of Plant Micro-reserves (PMR) in Spain and in several countries in central and eastern Europe[16] and less formally in many other countries such as Australia and South Africa
- The Chinese programme for the conservation of ‘species with extremely small populations’ (PSESP)[17] (See Case study 1).

The effective conservation of both the reserves and the small populations of the target species concerned pose a series of special problems[18]. The possibility of maintaining small reserves in the long-term in the face of changing climatic and environmental conditions is likely to be challenging. Often the populations of the target species will be small, as a result of the fragmentation suffered by the habitat. On the other hand, some species have evolved as small populations only, although they contain large amounts of genetic variability. Such small, often isolated, population fragments of threatened species may be affected by inbreeding depression, loss of evolutionary potential, and higher risk of extinction[19]. It should also be noted that the flora of old, climatically buffered, infertile landscapes (OCBILs) that are widespread, for example, in Australia[20] ‘exhibit unusual resiliencies and vulnerabilities, showing enhanced ability to persist in small fragmented populations, and natural, common rarity, yet vulnerability to disturbance’[21].

The conservation of small population fragments in small reserves may be recommended as a short to medium term recovery strategy, not as a long-term solution. It has been suggested that an overemphasis on short-term recovery targets is a likely cause of failure of many recovery programmes:

‘For recovery planning purposes, it is eminently sensible that the immediate causes of population decline be clearly identified and prioritized for conservation/management. However, consideration of evolutionary potential may be essential for setting long-term recovery targets, even if they are not the proximate driver of current endangerment. Correct identification of short-term threats may allow population recovery for several hundred individuals with minimal risk of inbreeding depression, but loss of evolutionary potential leading to increased risk of extinction may be a legitimate long-term concern if populations remain in the hundreds for an extended period’[22]

Restored Schulenberg Prairie at The Morton Arboretum (Image: The Morton Arboretum).

6.4 Special needs for species with extensive distributions

While many of the species selected for conservation or recovery action will have a narrow or restricted distribution, widespread species, especially those of economic importance such as forestry or timber species may also be selected. In the former case, one would normally aim to include all, or as many as possible, known populations in the conservation management or recovery plan. In the case of wide-ranging species, the extent and distribution of the populations will raise special problems that need to be addressed such as:

- How many populations and how much variation to include
- If the variation is partitioned into ecotypes, then how many to include
- If the variation is clinal, then how many samples along the cline(s) to include
- How to deal with species that have their populations occurring in more than one country or jurisdiction within a country.

Good examples of how such problems have been addressed can be found in many European tree species whose distribution ranges extend across wide geographical areas and countries that have different forest management traditions and practices. Such widely distributed tree species may form stands or have a scattered distribution. In Europe, examples of the former are: *Abies alba, Fagus sylvatica, Picea abies, Pinus brutia, Pinus halepensis, Pinus nigra, Pinus sylvestris, Quercus petraea* while examples of the latter are: *Fraxinus excelsior, Populus nigra, Populus tremula, Sorbus torminalis* and are addressed in the EUFORGEN Technical Guidelines[27] (Box 6.8).

Much work has been carried out over the past several decades to conserve the genetic diversity of European forest trees, notably under the European Forest Genetics Programme (EUFORGEN)[28] using dynamic conservation of genetic conservation units (see Box 6.8). Technical guidelines have been published for 41 European tree species[29].

Some of the most detailed *in situ* genetic conservation studies have been made on forestry species such as the Monterey pine (*Pinus radiata*). Although this species is widely commercialised outside its native range, its natural distribution is limited to five fragmented populations, three of them in central coastal California and two on Guadalupe Island and Cedros Island in Mexico. A detailed account of the *in situ* genetic conservation biology of Monterey pine also contains a series of principles and recommendations for the conservation and management of species *in situ* conservation[30].

6.5 Conclusions

The choice of which species and which areas is a key element of any species conservation or recovery strategy. Many countries apply their own criteria for selecting priority species for conservation. Whether using national or IUCN criteria, conservation status is just one element that should be considered alongside a wide range of additional criteria, both scientific and pragmatic. The choice of area will also depend on a range of criteria, that are also both scientific and pragmatic. The concept of critical habitat is often applied.

The population size of a species and its distribution will vary the recovery actions required. Species with small populations can pose genetic and demographic problems and are often the subject of special approaches.

Species with wide distributions may also present particular problems for their conservation. Further guidance on implementing species recovery actions is provided in subsequent chapters.

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Chapter 7.
Eco-geographical surveying

Aim of this chapter

This chapter aims to enable practitioners to gather detailed information about the current and historic status of the target species, in order to help identify the recovery actions that will be most appropriate for the species.

7.0 Introduction

In order to effectively restore populations of species *in situ*, it is essential to have a clear understanding of the status of the species in its natural habitat. An understanding of both the current status as well as the historic status is important for recovery. To determine these factors, a combination of methods should be employed. A comprehensive survey will include a desk study and field work, followed by analysis and interpretation of the data obtained from both methods.

7.1 Aims and purpose

An eco-geographical survey is the process of gathering and synthesising information on ecological, geographical, taxonomic and genetic diversity[1]. An eco-geographical survey can:

- Guide a species recovery programme and help to ensure its success – the results are predictive and can be used to assist in the formulation of complementary *in situ* and *ex situ* conservation priorities
- Help leverage funding for a species recovery programme, by demonstrating a comprehensive understanding of the species' status and needs to funders
- Provide a baseline against which to measure progress and the success (or otherwise) of a recovery programme.

It is important to carry out an eco-geographical survey *before* or *alongside* designing a species recovery plan. The information obtained during the eco-geographical survey will help ensure that a successful species recovery programme is designed by providing an understanding of the current and historic status of the species, including **what has led to the decline of the species** and the need for its recovery, **which conditions the species requires** (or prefers) to ensure its continued survival, **which actions are required** for species recovery and **what scale of action is required**. Hodgkin and Guarino[2] provide a useful review of the different components of an eco-geograpical survey and how the components help inform conservation strategies, using case studies from Europe.

Sampling of leaf material for molecular analyses in natural populations of *Arnica montana* (Image: Sandrine Godefroid).

In general, the more information that can be gathered about a species prior to designing and initiating a recovery programme, the more successful the recovery programme will be.

A well thought-out species recovery programme based on sound research is also more likely to receive funding than a proposed recovery programme based on little evidence. Some components of the survey work can be expensive, so, depending on the scope and format of the survey, some initial funding may be required to carry out the survey work as well. Scoping grants or "seed funding" can be useful for survey work (and initial conservation measures), providing the opportunity to develop a strong proposal for the full recovery programme.

The survey work will **provide a baseline** against which to measure the impact of recovery actions. It will also **help to identify appropriate indicators of success** (see Chapter 12 on developing a monitoring programme for a recovery programme). Both a strong baseline and identified indicators of success will help to measure and demonstrate the success (or otherwise) of the recovery programme.

7.2 Components of the knowledge baseline

A strong knowledge baseline can be developed through a combination of a desk study and field work. Whilst desk studies are usually less costly than field work, practical survey work in the field will ensure a current and more in depth understanding of the status of the species of interest. Even if the population (or species) to be recovered has been completely extirpated from an area, it is still important to gather information from sites where it was previously found.

Depending on the species of interest, the items below will be of differing relevance and importance to the survey. Aim to gather information from as many of the sources and for as many aspects as noted below, but for some species (particularly those that are not well studied or those that are now extirpated from their natural habitat) information will not always be available.

Through desk study and field work, aim to obtain information on the following:

- **Taxonomy and nomenclature** – It is essential that the material surveyed and sampled for recovery is correctly identified. This is particularly important for taxonomically variable or difficult species.
- **Ecology of the species** – Habit, growth rate, reproduction mechanisms, pollination, seed dispersal, population structure, seed storage behaviour, predators, diseases etc.
- **Genetic information** – Estimate of effective population size, amount of genetic variation within populations, description of genetic structure, assessment of gene flow among populations, estimate of inbreeding (from molecular marker studies), assessment of inbreeding depression, amount of hybridisation and/or introgression, amount of outbreeding depression, breeding behaviour/mating system, chromosome variation, nature and extent of clonal propagation.
- **Habitat preferences** – Habitat type (e.g. forest, woodland, grassland), distribution, associated species, soil type, soil moisture content, aspect, climate/microclimate (including annual and daily temperature changes, rainfall, shelter).
- **Cultivation requirements** – For example, what watering regime leads to the best survival and growth rates? Are there any mycorrhizal or nurse species associations that can improve survival and growth rates?
- **Human interactions with the species** – Including information on human induced threats, and uses of the species.

This information will enable a thorough understanding of the species' requirements (or preferences) for survival to be obtained. It will also help to identify or gain a better understanding of the threats that resulted in the species' decline. Recovery actions will be most successful when the species requirements are met and the threats are removed or mitigated.

Detailed eco-geographical survey
Good understanding of species requirements
for survival + threat

→

Successful species recovery programme
Species requirements are met
+ threats are removed or mitigated

Table 7.1 Useful information sources for desk studies

Source	Description	Useful links
Species description	Species descriptions often include details of growth habit and habitat preferences.	Try searching for the species name in Jstor Plants plants.jstor.org/ or GBIF www.data.gbif.org or Plants of the World Online www.plantsoftheworldonline.org. More detailed information is often available in national Floras and any relevant monographs or revisions.
Red list/ conservation assessment	If a conservation assessment has been carried out it will contain information on distribution, population status and threats affecting your species of interest that will need to be removed or mitigated to ensure the success of the species recovery programme. Conservation assessments may also provide information on habitat type.	Try searching for the species name in BGCI's ThreatSearch database, which compiles conservation assessments from multiple sources, including the IUCN Red List of Threatened Species, national red lists and published Red Data Books: www.bgci.org/threat_search.php
Statement of conservation needs/ conservation statement	Many examples can be found in national or regional red lists (see above) which often give a summary of what conservation management actions have been taken to date and/or an outline of what actions are recommended.	Other examples are the 'fiches' in the *Inventaire des Plantes Protegées en France*[3], the species accounts in the Flora Amenazada y Endémica de Sierra Nevada[4] and the Plant Profiles in *The Conservation Requirements of New Zealand's Nationally Threatened Vascular Plants*[5].
Herbarium records	Herbarium vouchers often contain notes on locality, associated species, habit and habitat type. Most herbaria allow people to visit for research purposes. Many herbaria are also in the process of digitising their records and making them available online.	Search on independent herbaria websites, and look for digitized vouchers on Jstor Plants plants.jstor.org/ or GBIF www.data.gbif.org or Tropicos www.tropicos.org

Published journal articles	More in-depth information is often published in scientific journal articles.	Search in an appropriate web browser (such as Google Scholar) for the target species. Some papers will not be public access, but most provide contact details for the lead author.
Websites or books containing information on cultivation requirements	If a species is widely cultivated there will likely be published material available in books or online on horticultural requirements and preferences.	Search for the species in BGCI's PlantSearch database and send a request for horticultural information to botanic gardens holding the species of interest: www.bgci.org/plant_search.php
Websites or books containing seed information	Published information may be available about the seed storage and germination requirements of the species of interest. If not, search for information for species of the same genus or family as many seed traits are shared within family groups.	Search for the target species in the Kew Seed Information Database: data.kew.org/sid/ Look for examples of published literature such as the Pilbarra Seed Atlas, published by Kings Park and Botanic Gardens and the University of Western Australia[6].
Existing conservation efforts for the target species	A web and literature search will help to identify whether conservation actions have been undertaken previously for the target species.	See Chapter 2 of this manual for an overview of who is doing what and where. You can also try contacting conservation agencies that are local to where your species of interest is found.
Historic photographs of habitat	Access to historic photographs will enable a comparison of previous population distribution, size and structure and compare this to the current status.	Use a web search engine to search for images. Visit a national archive or local museum to see if historic images are available.
Point/location data	GPS point data can be used to make a map of the distribution of the target species to obtain an idea of current and past distribution. Some point data is available on GBIF, but it is good practice to also access point data from herbarium vouchers.	A distribution map for the target species can be quickly and easily plotted using Kew's GeoCat tool, which imports available point data from GBIF, Flickr, iNaturalist and other websites (be careful to check the accuracy of imported data), and additional point data can also be added to the map as well: geocat.kew.org/
Habitat or vegetation or land cover maps	Comparing point data to habitat or vegetation maps, will enable identification of appropriate vegetation type for the target species.	Look for national or regional vegetation maps, which are often available in printed format or online. It is also possible to download GIS base layer maps, e.g. from ArcGIS: www.arcgis.com and ESRI www.esri.com. Google Earth will help to determine whether the native habitat of the target species is still remaining before you go into the field https://earth.google.com/web/

7.2.1 Desk studies

Carrying out desk-based research for the species concerned is a cheap and effective way of gathering information. Ideally desk-based research will be accompanied by field work, but if there is insufficient budget to carry out survey work in the field, or if survey work can only be carried out in a single season, supplementary information can be gathered through desk-based research.

If the target species is not well studied, it is recommended to look for information available on species of the same genus, or family, as in some cases they may share some of the eco-geographical features. Table 7.1 gives some useful information sources for the desk study.

Germination testing at the Millenium Seed Bank, Royal Botanic Gardens, Kew (Image: Barney Wilczak).

7.2.2 Field work

Carrying out field work as well as a desk study is essential to ensure the most up to date information is obtained for the target species. During field work additional data can be collected to supplement the desk study, as well as photos, herbarium vouchers or plant samples if needed. If sufficient budget is available, repeat the field work in different seasons to capture additional information. Thorough planning will improve the success of field work.

Before you go to the field

Check if **permission** is required to carry out your field survey, for example from a national park or other mandated local authority. Additional permissions may be needed to take herbarium vouchers, seed or DNA samples.

Make sure suitably **qualified team members** have been identified for field work. Of primary importance is the necessity to have people with excellent field skills, including a thorough knowledge of the flora. The team may also include people with first aid skills or climbers if the target species is a tree or in an inaccessible place.

Make sure appropriate **equipment** is sourced for the survey. Make a list and double check it before going into the field. In addition to the equipment required to carry out the survey, this should also include a first aid kit, sufficient food and water supplies and communication equipment. An example equipment list is provided in Box 7.1.

Consider whether carrying out a **risk assessment** or having an emergency response plan is required, particularly if the target species is found in a remote area.

What information to collect

Decide what data to collect *before* going into the field and prepare a form to ensure the same information is collected at each site or population. See Figure 7.1 for an example format and suggested information to collect. Gathering the same set of information from multiple sites or populations will help to identify the most appropriate site(s) for the recovery programme, i.e. sites with suitable characteristics and conditions, where threats are low or have been removed and hence where success rate will be high.

Box 7.1. Example list of the equipment to consider taking into the field

- GPS with extra batteries
- Data collection forms (electronic or paper)
- Tape measure (if quadrats are to be used for population count)
- Camera
- Binoculars
- Secateurs
- Field guides or identification keys
- Herbarium press and straps
- Sufficient water and food supplies
- Mobile or satellite phone with sufficient credit

Seed collecting in the field (Image: Germplasm Bank of Wild Species).

Forms can be prepared in a notepad, in Excel or Word then printed, a laptop or tablet can be carried to the field or a form can be developed and downloaded to a mobile phone (e.g. using opendatakit.org/). The first two options are cheaper, however recording the data directly to a laptop, tablet or mobile phone can save time as there is no need to copy the data when returning from the field. If paper forms or a notepad is used, take a photo of the form whilst in the field in case it gets wet or lost. If electronic forms are used, make sure the data is backed up as soon as possible.

Herbarium vouchers, photos and samples

It is good practice to collect **herbarium vouchers of the target species and associated species** in the field to provide a reference collection and to verify identification.

Photos taken during field work can be compared to historic photos (if available) to show change over time. Photos can also provide a visual baseline against which the impact of the species recovery actions can be measured. Take as many photos as is feasible and be sure to **photograph features of the plant that will not be captured on the herbarium voucher**.

A decision may be made to collect **seed** to carry out tests to identify seed characteristics, storage requirements and germination techniques. **DNA samples** can also be collected for genetic analyses between and within populations.

Ensure vouchers, photos and samples are **accurately labelled** and **linked to field data forms**.

It can be helpful to write the site or population number on a piece of card or paper on arrival at each site and take a photo of it so that when photos are processed later they can be accurately linked to each site. If the camera or phone records GPS points or can plot directly to Google Maps or similar, make sure this setting is switched on as it will facilitate visual interpretation of the data afterwards.

Project name		
Site ID or number		
Data recorder		
Date of survey		
Target species name		
Family		
GPS Latitude and Longitude		
Altitude		
Vegetation type		
Vegetation type		
Notes on vegetation type		
Intactness of vegetation	(tick which applies)	
Pristine		
Disturbed		
Heavily disturbed		
Species composition / associated species		
Canopy layer (list species)		
Shrub layer (list species)		
Ground layer (list species)		
Notes on species composition (e.g. invasive species)		
Threats *See Chapter 5 for a list of the most prevalent threats to plant species and consider adding a tick box for each threat you are likely to encounter for your species.*		
Is this threat ongoing?		
Notes on threats		
Is this species used by local people? If yes, add details of the uses and level of exploitation		
Are there any protection measures in place for this species? If yes, add details of the protection measures and their effectiveness		
Site characteristics		
Locality type (e.g. mountain slope, plateau, agricultural field, forest)		
Site soils (e.g. sand, loam, clay)		
Lithology (e.g. granite, sandstone)		
Estimated slope angle		
Site exposure level (full shade / partial shade / full sun)		
Climatic / microclimatic conditions		
Site notes		
Population information *Aim: To gather information on both current and, if possible, historic populations and profile (age structure of current population).*		
Number of alive individuals present		
Number of alive mature individuals present		
Number of juvenile individuals present		
Was the population number counted or estimated?		
(if quadrats were used what was the quadrat size?)		
Is there evidence of natural regeneration?		
Number of dead individuals present		
Cause of death		
Notes on population		
Samples *Aim: To gather sample material to support the survey, e.g. to determine seed characteristics, verify ID or carry out genetic analyses. Make sure that all accompanying samples are carefully labelled and linked to this collecting form. If carrying out a seed collection for propagation purposes, complete a full data form for each collection. If the species is Critically Endangered, keep seed from each individual separately.*		
Type of material collected (seed, herbarium voucher, DNA sample)		
Seed specimen number		
Number of seeds collected from population		
Purpose of collection		
Herbarium voucher number		
Number of duplicate vouchers taken		
Purpose of collection (e.g. to verify ID)		
DNA specimen number		
Number of DNA samples collected from population		
Purpose of collection		
Photo checklist *Aim: Take as many photos as possible, e.g. to help verify ID and provide a visual baseline for the recovery programme. It is particularly important to photograph features that will not be captured on the herbarium voucher.*		

Habitat/site		Flower	
Canopy layer		Seed	
Shrub layer		Leaf arrangement	
Ground layer		Bark	
Full plant		Evidence of threats	
When complete, take a photo of this data collection form			

Figure 7.1. Sample data collection form

Case study 5 Using survey work to improve recovery actions for Mulanje Cedar

Mulanje Cedar (*Widdringtonia whytei*) is endemic to Mulanje Mountain in Malawi. Its timber is heavily sought-after as it is durable, termite proof and good for carving. Mulanje Cedar has been harvested to the brink of extinction on Mulanje Mountain, but efforts are underway to recover this species in its natural habitat.

A Cedar Management Plan was developed as part of an IUCN Save Our Species project. This called for a five-year harvesting ban and 500,000 Mulanje Cedar seedlings to be raised and planted on the mountain each year for the next five years. A follow-on project led by the Mulanje Mountain Conservation Trust, the Forestry Research Institute of Malawi (FRIM) and BGCI is implementing a recovery programme for Mulanje Cedar, following the recovery targets recommended in the Management Plan.

To improve the success of the recovery programme, significant efforts have been taken to gain a full understanding of the species' requirements. Whilst some information was available in reports, mostly thanks to previous planting efforts led by FRIM and the Forestry Department of Malawi, the current project aims to address knowledge gaps. Survey work has been a key component of this work.

In early 2017, a survey was conducted on Mulanje Mountain, to gather more detailed information on the ecology, genetics and habitat preferences of Mulanje Cedar. Over a two-week period, the survey team visited historic clusters of Mulanje Cedar and recently planted areas across the mountain, recording factors such as associated species, threats, soil type, slope angle, aspect, site exposure, presence of natural regeneration and health of natural regeneration or planted seedlings. The team also collected foliage and wood samples for genetic analysis to determine if there is a genetic difference between Mulanje Cedar populations in different basins on the mountain. Additional foliage and soil samples were collected from healthy and unhealthy planted seedlings and historic clusters to determine if there is a mycorrhizal association that benefits the growth and survival of Mulanje Cedar, as well as to determine the cause of early death experienced by some planted seedlings.

Information gathered from survey work was used during a consultation exercise with staff from FRIM, local Forestry Department offices and MMCT, to identify initial planting sites on the mountain. Sites were selected based on the success of previous plantings, where fire risk is low, soil conditions, micro-climatic conditions and access, with the aim to select sites that provided the best chance of survival. Information from the survey work and mycorrhizal studies is also being used to set up nursery trials and planting trials, to identify the optimum growing conditions for Mulanje Cedar to help improve the success of recovery actions. A follow-on survey will be carried out in the final year of the project to track progress against the baseline data.

Talk with local people

A useful part of the knowledge baseline will be information gathered from local people. In addition to contacting local conservation agencies when carrying out the desk study, information can also be gathered in the field and recorded on the data collection form or through a separate more detailed questionnaire or interview. More detailed information may be particularly helpful if there is a strong connection between people and the decline of the target species.

Asking people, particularly elders, for information about the current and past distribution and uses of the species can improve the study by adding a historical element to it. Engaging the community during survey work carried out prior to commencing the species recovery actions can also help to develop a relationship with the local community, who may be able to provide useful advice on species recovery actions, become involved in recovery actions and ensure the longer-term sustainability of the recovery programme. Chapter 10 provides further detail on community engagement throughout the recovery programme.

Above: Mulanje cedar survey team. Top: Mulanje Mountain in Malawi

7.3 Data analysis

When the desk study and field work has been completed, it is good practice to collate this information in a report. It is advisable to share this report with all parties who are involved or may be impacted by the recovery programme to provide them with an opportunity to provide further input, comment or advice on species recovery actions. This report will also be a helpful tool for fundraising to carry out species recovery actions.

Box 7.3 Guidance resources and useful links

Eco-geographical surveys

Hunter, D. and Heywood, V.H. (Eds.). (2011). **Crop Wild Relatives: a Manual of *In situ* Conservation**. Earthscan, London, United Kingdom. *Chapter 8 provides eco-geographic surveying guidance and case studies*.

International Plant Genetic Resources Institute. (1997). **Ecogeographic Surveys**. Available at: cropgenebank.sgrp.cgiar.org/index.php?option=com_content&view=article&id=378&Itemid=538 *An online training course on the use of ecogeographic data in conservation activities*.

Maxted, N. and Guarino, L. (1997). **Ecogeographic surveys.** In: Maxted, N., Ford-Lloyd, B.V. and Hawkes, J.G. (1997). *Plant Genetic Conservation*. Chapman & Hall, London, United Kingdom.

Field surveys for threatened plants

Elzinga, C.L., Salzer, D.W., Willoughby, J.W. and John, W. (1998). **Measuring and monitoring plant populations.** Bureau of Land Management. Denver, Colorado, United States.

Global Trees Campaign. (2013). **How to survey an area for threatened trees**. Available at: globaltrees.org/wpcontent/uploads/2014/01/GTC-Brief-1-hi-res.pdf

NSW Government. (2016). **NSW Guide to Surveying Threatened Plants**. State of NSW and Office of Environment and Heritage. Available at: www.environment.nsw.gov.au/resources/threatenedspecies/160129-threatened-plantssurvey-guide.pdf

Precise documentation of the species being collected (Image: Kristián Halász).

Sandberg bluegrass (*Poa secunda*) being collected in Wyoming (Image: University of Wyoming).

If historic data is available, compare current and historic data to determine the rate of decline of the target species. Understanding the rate of decline can help to identify the urgency of the recovery actions.

Map as much of the data as possible. This will help visualise and interpret the data, but will also help communicate the project plan to funders and other interested parties. Photos and points can be added easily to Google maps (www.google.com/maps), or iNaturalist (www.inaturalist.org/). More detailed mapping may require GIS skills and software or employment of a consultant to map the data.

7.4 Conclusion

A well designed and thorough eco-geographical survey will provide the basis for identifying and implementing appropriate recovery actions and disqualifying actions that are unsuitable for the target species. For example, the eco-geographical survey information will help to identify appropriate populations for seed collection or identify appropriate sites for population recovery. The more information that can be gathered, the fuller understanding you will obtain of the target species and its survival requirements, and the more successful your recovery programme will be.

Endnotes

[1] Maxted, N., van Slageren, M.W. and Rihan, J.R. (1995) Ecogeographic surveys. In: Guarino, L., Ramanatha Rao, V. and Reid, R. (Eds.). *Collecting Plant Genetic Diversity: Technical Guidelines*. CAB International, Wallingford, United Kingdom.
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[3] Danton, P. and Baffray, M. (1995). *Inventaire des Plantes Protegées en France*. Éditions Nathan, Paris, France.
[4] Blanca, G. *et al*. (2002). Flora Amenazada y Endémica de Sierra Nevada. Consejería de Medio Ambiente, Junta de Andalucía. Editorial Universidad de Granada, Granada, Spain.
[5] Dopson, S.R., de Lange, P.J., Ogle, C.C., Rance, B.D., Courtney, S.P. and Molloy, J. (1999). The conservation requirements of New Zealand's nationally threatened vascular plants. Threatened Species Occasional Publication No. 13. New Zealand Biodiversity Recovery Unit Department of Conservation, Wellington, New Zealand.

Chapter 8.
Designing species recovery strategies and action plans

'Research and practice have shown that recovery planning is a very challenging task given the complexity of its ecological, socioeconomic, political and managerial aspects. One of the weakest aspects is the lack of a universal methodological framework and adequate criteria by which to assess recovery success.' Ortega-Argueta & Morales-Vela[1]

Aim of this chapter

This chapter explains how to prepare species recovery strategies and action plans and outlines the main elements they should contain. It points out that the extent and detail included will vary from species to species, depending on the particular circumstances and stresses, and that there is no single model to follow.

8.0 Introduction

Effective recovery of threatened species is greatly improved through preparation of a strategy and an action plan to implement it.

Each species or population of target species differs in terms of its eco-geographic profile and the nature and diversity of the habitat in which it occurs. Likewise, the combination and nature of the threats to the species/population or habitat will vary from case to case. Consequently, although the basic elements are the same, there is no universal methodology and so no single general protocol can be recommended. However, we indicate what the essential features of a recovery strategy and plan are, based on best practice; and we point out that good guidance for recovery plan preparation can be gained by searching for other known cases with similar characteristics (see Chapter 2 who is doing what where). As might be expected, species action plans can vary considerably in scope size and complexity. This chapter provides guidance on key elements to include in a recovery plan.

A handbook on strategic planning for species conservation has been published by the Species Survival Commission of IUCN[2] . Although primarily intended to provide guidance to IUCN/SSC specialist groups on when and how to prepare and promote species conservation strategies (SCSs), and largely animal-oriented, it contains much information of relevance to plant species conservation and recovery.

Right: Restoration of Nardus grasslands (EU-habitat 6230) in southern Belgium (Image: Stéphane Bocca).

8.1 Species conservation management plans vs recovery plans

As already explained in Chapter 3, the distinction between **species conservation/management plans** and **species recovery plans** is largely one of degree, reflecting the scale and extent of the management interventions needed. As noted in Chapter 1, the terms recovery (and recovery plans) are frequently used in a broad sense to cover all kinds of management actions and conversely, species recovery (and plans) are of course types of management plans. However, it is useful to maintain a distinction between them so as to reflect a series of different situations that need to be addressed and the different responses to them[3]:

8.2 Species management plans

Species management plans will normally be prepared for those target species that require some form of management intervention to ensure the maintenance and survival of viable populations. They share many elements with recovery plans but differ from them in the lesser degree or intensity of management intervention, reflecting the lower degree of threat to the population(s).

The detailed composition of a management plan will vary from species to species, depending on the biological characteristics of the species, its population status, the location, the aim of the plan and so forth so there is no single approach appropriate to all situations or even generally applicable[4]. They may cover single species or groups of species occurring in the same area.

The features found most commonly in species management plans are given in Box 8.1.

Magnolia longipedunculata planted at Shimen National Park, China.

8.3 Species recovery plans

A **species recovery plan** is a document stating the research and management actions necessary to stop the decline of a target species, to support the recovery of a target species to levels where protection is no longer necessary and to enhance the chance of long-term survival of the target species in the wild.

A recovery plan may be concise and just a few pages long or extensive and up to 100 pages or more (see Box 8.3 for examples), depending on the range of activities involved. They may involve both habitat recovery actions and population recovery actions. For example, habitat restoration can assist in the recovery of endangered species, some of which may require restoration of degraded habitat for their eventual recovery[5].

8.3.1 Content of a species recovery plan

There are three essential components to a recovery plan:

- An evaluation of the current status of the species, including a thorough analysis of the threats
- The aims and objectives of the plan
- The actions proposed.

It is important to agree on the objectives of the plan and include a statement on what the plan will achieve and how these aims will be fulfilled. This will reflect the key decisions made on which populations and how many will be included and how many individuals are needed to ensure a Minimum Viable Population, as detailed in Chapters 6 and 9. This, in turn, will depend on the distribution pattern of the species, its demography and the distribution of genetic variation within its populations.

- In target species with a narrow or restricted distribution, the aim will normally be to include all the population(s) within the recovery plan
- In the case of species with a wide distribution, and in which the variation is partitioned into races or ecotypes, a choice must be made as to how many populations and how much of the variation is to be selected for conservation and inclusion in the recovery plan.

The main features that are included in recovery plans are outlined in Box 8.1. Much of the information required will have been gathered during the eco-geographical survey (see Chapter 7). The content of the species recovery plan can be modified based on local requirements and information available. As much information as possible should be included to help inform and justify the species recovery actions.

Box 8.1 Common features of a species recovery or management plan

– A description of the species, including its scientific name, essential synonyms, common names, its reproductive biology, phenology and its current conservation status
– Eco-geographical information – location of the populations, their habitat, ecology, soil preferences, demography, size and viability, distribution of genetic variation
– An assessment of the nature of the threats affecting the conservation status of the species
– A summary of existing conservation actions that are already being undertaken and by whom
– The detailed actions that will be required to contain, reduce or eliminate the threats and ensure the maintenance of viable populations of the species
– Actions that may be needed to safeguard and manage the site
– The management objective(s) and targets (both short- and long-term), and a set of criteria for indicating when the objective(s) are achieved
– A statement on how the plan will be implemented and what scientific techniques will be adopted
– Identification of any policy or legislative actions that need to be undertaken
– Identification of the lead agency or party and a list of the organisations that will play a part in the management actions (e.g. national/regional/local conservation institutions, botanic gardens, community bodies, etc.);
– Arrangements for negotiation with the site authorities and other interested parties or stakeholders regarding management interventions
– An implementation schedule, including priorities of tasks
– A detailed budget with annual cost estimates for the various actions involved
– A monitoring programme and schedule (including post-recovery monitoring)
– Arrangements for external reviews
– Plans for communication and publicity.

Source: modified from Heywood[11]

Ideally, plans should contain photographs or other illustrations of the plant and its habitat, maps and other graphic material. If necessary, some of the detailed information or explanations of threats, species biology, implementation, historical or cultural factors, may need to be published as a separate document or annex.

Recovery plans may be produced in a range of formats, from electronic files on official environment agency websites, as books[6] or as booklets. Plans are occasionally published in journals[7] and often supplemented by a series of journal articles on various technical aspects, or as free-standing publications such as the recovery plan of *Dactylanthus taylorii* published by the New Zealand Department of Conservation[8]; the recovery plan for *Dodoneaea subglandulifera* published by the Australian Government Department of Environment, Water, Heritage and the Arts[9]; and the action plan for the recovery and conservation of *Abies pinsapo*[10]. For further examples see Box 8.2.

Box 8.2 Examples of recovery plans

The **United States** Fish and Wildlife Service Threatened and Endangered Species System website lists the species for which recovery plans have been prepared: www.fws.gov/endangered/species/recovery-plans.html

For **United Kingdom** species action plans, see the UK Biodiversity Action Plan site which lists numerous examples: jncc.defra.gov.uk/page-5171

For the **Swiss** flora, summary species action/data sheets for over 140 priority species have been prepared (Fiches pratiques pour la conservation Plantes à fleurs et fougères). See: www.crsf.ch/index.php?page=fichespratiquesconservation

An example of a **Spanish** species recovery plan for *Cheirolophus duranii* (as published in the Official State Bulletin) is available at: http://www.uam.es/otros/consveg/documentos/Cheirolophus%20duranii%20Plan%20Recup.pdf

Australia: Conservation and recovery profile for *Haloragodendron lucasii*: www.environment.nsw.gov.au/threatenedSpeciesApp/profile.aspx?id=10394; Recovery plan for *Alectryon ramiflorus* www.environment.gov.au/system/files/resources/0b732a00-29a5-4659-9f67-a6ad7cc7f728/files/ramiflorus.pdf

For **New Zealand** species action plans see: www.doc.govt.nz/about-us/science-publications/series/threatened-species-recovery-plans/

While conservation planning of endangered species normally depends on national government agencies, relatively few governments provide a legal framework for species recovery and conservation.

In some countries, plans must be published officially once approved and are in effect statutory instruments with a series of conditions regulating the whole recovery process and involving extensive review and consultation. It is important to be aware of the requirements in the country of operation (see Chapter 2 for country specific information).

(Image: Paul Smith)

Arid coastal restoration in Western Australia (Image: Barney Wilczak).

Case study 6 Developing a Species Action Plan for a small island endemic

Although they only represent approximately 5% of the earth's land surface, around one quarter of all extant terrestrial plant species are endemic to islands[12]. However, this unique diversity is at risk, with 80% of known species extinctions having occurred on islands[13]. Lundy Cabbage (*Coincya wrightii*) is one of Britain's few endemic plant species and resides exclusively on the island of Lundy. The species is listed on the UK Biodiversity Action Plan (BAP)[14] and an associated Species Action Plan was developed to help secure its future. Actions recommended in the report included the control of mammalian herbivores introduced to the island and the eradication of the invasive alien shrub *Rhododendron ponticum*.

As a result of the Species Action Plan, extensive efforts have been made to clear *Rhododendron ponticum* from the island as a part of a Countryside Stewardship Scheme[15]; in 2018 only a few bushes remain on the cliff faces. A management plan for herbivores is now also in place on the island with the aim of maintaining their numbers at an acceptable level. Although the number of flowering plants on the island continues to fluctuate from year to year there has been a marked increase in the flowering population over the past ten years, most likely as a direct result of improved management.

The clearance of *Rhododendron ponticum* on Lundy Island between 2007 (left) and 2010 (right) can be clearly seen on GoogleEarth.

Box 8.3 Content of species recovery plans in Australia and Canada

Australia

In Australia, for species of threatened plants (other than conservation dependent species) listed under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999, the Australian Government Minister for the Environment may make or adopt and implement recovery plans. Their aims are described as follows[16].

'Recovery plans set out the research and management actions necessary to stop the decline of, and support the recovery of, listed threatened species [or threatened ecological communities]. The aim of a recovery plan is to maximise the long-term survival in the wild of a threatened species or ecological community'.

'Recovery plans should state what must be done to protect and restore important populations of threatened species and habitat, as well as how to manage and reduce threatening processes. Recovery plans achieve this aim by providing a planned and logical framework for key interest groups and responsible government agencies to coordinate their work to improve the plight of threatened species and/or ecological communities'.

Canada

In Canada under the Species at Risk Act (SARA) two stages of recovery planning are required: a recovery strategy and a recovery action plan. A recovery strategy is a planning document that identifies what needs to be done to arrest or reverse the decline of a species. It sets goals and objectives and identifies the main activities to be undertaken. Detailed planning is done at the subsequent action plan stage. In preparing a recovery strategy, the competent minister may adopt a multi-species or an ecosystems approach. The competent minister, in cooperation with others, must prepare a recovery strategy in response to a species being listed as endangered, threatened or extirpated under the Act. Recovery strategies must be completed within one year of the species being listed as endangered, and within two years of the species being listed as threatened or extirpated.

More specifically, the **recovery strategy** will:

- Describe the species and its needs
- Identify the threats to survival of the species
- Identify the species' critical habitat unless it is not possible to do so
- Provide examples of activities that are likely to result in its destruction
- Set the goals, objectives and approaches for the species recovery
- Identify information gaps that should be addressed
- State when one or more action plans relating to the strategy will be completed.

Interested parties may include federal, provincial, and territorial ministers, wildlife management boards, Aboriginal organisations, landowners, tenants, and any other person or organisation that the competent minister considers appropriate. In preparing a recovery strategy, the competent minister may adopt a multi-species or ecosystems approach. Under the Act, proposed recovery strategies allow for a 60-day comment period. Within 30 days of the closing of the public comment period, the proposed recovery strategy must then be finalised. Recovery strategies are evaluated every five years and updated as necessary.

An action plan outlines the projects or activities required to meet the goals and objectives outlined in the recovery strategy. This includes information on the species habitat, protection measures, and an evaluation of the socio-economic costs and benefits. It is the second part of the two-part recovery planning process and is used to implement the projects or activities to improve the species status. The competent minister, in cooperation with others, must prepare one or more action plans based on a recovery strategy. The recovery strategy indicates when an action plan will be completed. More specifically, the action plan will include:

- An identification of the species' critical habitat (unless it is not possible to do so) and examples of activities that are likely to affect it
- Proposed measures for protecting the critical habitat
- An identification of any portions of the critical habitat that have not been protected
- A statement of the steps for implementing the recovery strategy and when they are to take place
- An evaluation of the socio-economic costs of the action plan and any implementation benefits.

Source: Government of Canada: Recovery Strategies[17]

Hippocrepis comosa in beds being grown to produce seed for restoration, Royal Botanic Gardens, Kew (Image: Barney Wilczak).

8.3.2 Recovery Outline

The USA Endangered Species Act (ESA) Guidelines require the preparation of a **Recovery Outline** as part of the preparatory process in drafting a recovery plan. This is defined as a *'succinct, strategic, document used to direct the recovery effort and maintain recovery options for a species, group of species, or ecosystem, pending an approved recovery plan'.*

The rationale is as follows:

'In the interim between listing and recovery plan approval, the recovery outline provides a preliminary strategy for conservation that conforms to the mandates of the ESA. The recovery outline both guides initial recovery actions and ensures that future recovery options are not precluded due to a lack of interim planning. The recovery outline also lays the groundwork for recovery planning by documenting preplanning decisions'.

Most other national recovery systems do not require such a formal document as part of the recovery process although some of the actions are in effect covered in an informal way.

8.3.3 Participation in recovery planning

Recovery plans require teamwork, involving specialists from a number of disciplines as well as concerned stakeholders and the general public. The drafting of a recovery plan is normally undertaken by a team of experts although it may be carried out in some cases by an individual expert or a small number of experts. The US ESA guidelines[18] suggest that recovery teams are often appropriate for more wide-ranging species, those that raise more controversial issues, and larger-scope plans. In some circumstances, it may be appropriate to engage a contractor to prepare the plan, especially when the necessary expertise is not available in-house to the agency commissioning the work.

Good practice is to involve, or at least consult, all interested and knowledgeable parties – conservation biologists and conservation practitioners from academia and other institutions (such as environment agencies, forestry institutes and botanic gardens), environment officials and managers, protected area managers, local conservation NGOs – in the preparation of conservation and recovery strategies and action plans. It is important that local knowledge is considered. It is recommended to engage local communities to improve planning (see Chapter 10).

As discussed below (see Section 8.4 Single-species versus multi-species plans), the more comprehensive the plan, the more agencies are likely to be involved. Thus, in the case of a single-species plan, the number of interested parties is much more limited than if a multi-species approach is adopted. Well documented examples of the multi-species approach can be found in Habitat Conservation Planning as endorsed in the USA under the ESA and in California's Community Habitat Conservation Planning Program[19]. In such cases, a wide range of interested parties become involved in the planning process, which can make it complex and time-consuming.

Generally, however, it is recommended that the drafting group should have a diversity of contributors but still maintain small, manageable expert-based teams[20].

Brackenhurst Botanic Garden native tree nursery in Limuru, Kenya.

Conservation and recovery plans may also be undertaken independently of the official national framework by NGOs but the onus is then on them to ensure that good practice is followed and that any proposed actions are in conformity with the relevant legislation.

In New Zealand, the notion of **Recovery Groups** has been developed[21]. A recovery group is made up of species experts and is charged with providing advice on the management and recovery of the species. Membership of recovery groups normally includes scientists from academia and community representatives as well as conservation managers. The national website Nature Space (www.naturespace.org.nz) has been developed to support these recovery groups providing up to date information on active groups, upcoming events and community notices.

Participation in recovery planning and implementation is discussed further in Chapter 10.

As emphasised in this manual, the effective conservation of any species *in situ* depends critically on identifying the habitats in which they occur and then protecting both the habitat and the species' populations through various kinds of management and/or monitoring. Thus, although *in situ* species conservation is essentially a species-driven process, it also necessarily involves habitat protection. It follows that the conservation management or recovery plan of a target species may call for some actions at the habitat level, such as ensuring its effective management of the area (although that is normally the responsibility of the land manager), weeding to remove competitors, control or removal of invasive species, control of disturbance or fencing to exclude herbivores.

However, full-scale habitat or ecological restoration is not normally part of the business of targeted species conservation; although, when this is carried out for other reasons, and one or more target species are known to occur in the restored habitat, then advantage can be taken to develop an appropriate species management plan, provided the conditions are appropriate and the genetic variability of the species is adequately represented.

An example where regeneration of the vegetation is combined with a targeted species approach is a mixed recovery programme for habitats and rare and endangered species on the Spanish eight hectare island of Columbrete Grande (L'illa Grossa), the largest of the Islas Columbretes (Province of Castellón), where efforts have focused on recovery of the Critically Endangered local endemic *Medicago citrina*, as well as protection measures for other threatened endemic plant species[22].

Rocla silica sand extraction and Banksia habitat restoration in Western Australia (Image: Barney Wilczak).

8.4 Single-species versus multi-species plans

A key decision that should be made in species conservation and recovery planning is whether to focus on a single species or on multiple species in the same ecosystem. This is discussed in detail in Chapter 3.

In arriving at a decision, the ESA Management Guidelines propose that the following considerations should be taken into account[18]:

- Each listed species in the plan should be fully addressed in terms of status, threats, and biological needs and constraints (this does not mean that these items need be addressed for each species separately but that a reader should be able to discern each species' status, threats, etc., easily from the information provided)
- Objective, measurable recovery criteria must be developed for each species, although it may be possible for the same criteria to apply to more than one species where the threats are identical
- Recovery actions should be consolidated for multiple species whenever possible to maximise effectiveness, but should indicate which species will be affected
- Individual species can be independently listed, reclassified, or delisted, and the plan updated or revised accordingly
- In general, multiple-species plans will be more expansive documents, and means for keeping them updated and current will be more complex.

8.5 Conclusions

- The preparation of a conservation or recovery strategy and action plan for a threatened species is one of the most important steps in the whole recovery process.
- It has been described as serving as a road map for species recovery, setting out where we need to go and how best to get there.
- Failure to prepare such plans or to formulate them adequately has been one the main factors responsible for continual growth in the number of plant species facing partial or total extinction.
- These plans lead to a much better understanding of the problems involved and the importance of conserving plant diversity.
- The development of a plan brings together conservation practitioners, conservation biologists, academia, protected area managers, conservation agencies, NGOs, planners, administrators, local authorities and the public, all of whom have an interest and a part to play.

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Staff and volunteers from Botanic Garden Meise transplanting 500 individuals of clustered bellflower (*Campanula glomerata*) in southern Belgium (Image: Daniel Parmentier).

Chapter 9.
How many individuals? How many populations?

Aim of this chapter

This chapter aims to help practitioners to understand the key concepts involved in deciding how many individuals and populations of a target species should be selected for a recovery programme. The chapter also covers how to sample and collect seed and other material for population enhancement so that enough genetic variation is represented in the recovered populations to ensure that they are functional, self-sustaining and able to survive future changes.

9.0 Introduction

Genetic variation is at the very heart of species recovery. In general, the more genetic variation that is captured, the more likely is it that the long-term survival and recovery of the target species will be successful and have enough evolutionary potential to allow it to adapt to changing conditions. But as Pierson *et al.*[1] comment, despite the importance of genetic factors in helping to ensure the persistence of wild populations, they are frequently absent from conservation and management initiatives. This conclusion was based on a survey they undertook of 318 threatened species recovery plans (Box 9.1).

9.1 How many populations?

The primary concern in species recovery is to ensure, if possible, that the targeted populations are sufficiently large and contain enough variation to allow their long-term survival and continuing evolution. Deciding on how many populations should be involved in a species recovery programme will depend on a range of factors such as:

- The detailed distribution of the species
- How many distinct populations exist and their size
- How the genetic variation is partitioned between the populations
- The breeding system
- The nature of the threats to the species and the kind of actions needed to counter these, ranging from simple interventions such as fencing and habitat weeding to more complex procedures such as population augmentation or genetic rescue (Chapter 11)
- Whether sufficient seed or other propagules can be taken from the remaining populations as a source for population augmentation without jeopardising their survival.

Box 9.1 Genetic factors in species recovery plans

In a recent study by Pierson *et al.*[1], 318 threatened species recovery plans were selected for review: 100 from the USA, 108 from Australia, and 110 from five European countries (France, the Netherlands, the UK, Germany, and Luxembourg). They reviewed three broad categories of genetic data addressed by the recovery plans: population genetics, fitness-related and life history data. They found that while genetic factors were sometimes considered, genetic data were seldom included. Some plans involved collection of genetic data, but this was highly dependent on the region. Species recovery plans in the USA (82%) were more likely to include genetic data, while only 52% in Australia did so and a remarkably low proportion (17%) in Europe. Only 10% of species recovery plans across these three geographic areas consider key concepts such as effective population size and inbreeding. This was probably due in part to different legislative requirements in the regions and in the case of Europe also by a 'lack of input by conservation scientists, notably geneticists, in the interpretation of the European Union (EU) concept of Favourable Conservation Status (FCS) of endangered species…'. The authors recommend development of an international standard that requires explicitly how recovery plans should include genetic factors in recovery efforts.

In the case of species which have become endangered through loss of habitat, decrease in population size and loss of genetic variability, and which are consequently reduced to one or a few small populations, or in extreme cases to a single remaining population, few options are available other than using whatever populations are available. Then the focus is on whether there is a sufficient amount and diversity of plants in them to make the chances of successful population augmentation realistic. In such cases, seed of the target population or of other non-local populations of the same species stored in genebanks or collected from living conservation collections in botanic gardens or other propagules from field genebanks may be used. For species with a single population or small number of populations, all populations may be deemed critical habitat.

The advantages and disadvantages of using such *ex situ* material and their genetic implications for the effective recovery of the target species are discussed below.

In the case of wide-ranging species, for example in species selected because of their economic importance such as forestry tree species and Crop Wild Relatives, the aim may be to capture the most significant variation relating to the use made of the species within the available populations as well as enough genetic variation to allow the continued survival of the species[2,3].

The nature and state of the recipient habitat can also be a limiting factor. If the habitat itself has been reduced or damaged there may not be sufficient suitable habitat left into which augmentation material may be planted so the option of using large numbers of explants in population augmentation is not available.

9.1.1 Need to survey all existing populations

It is important to ensure that a thorough field exploration is carried out to establish how many populations of the target species exist in the wild. This is especially true when the species is reduced to a small number of relict populations in which case repeated surveys may locate further hitherto unknown remnant populations as was the case in the endangered Mauna Loa silversword, *Argyroxiphium kauense*[4].

When several populations of a target species are found to exist, it is important to survey the genetic variation in each of them as they may well contain different amounts of genetic differentiation and, especially in endangered species with small populations, access to all the variation may be needed for effective population augmentation.

9.1.2. Rule of thumb

For some rare species, there may only be a few locations remaining. In cases of fewer than five populations, all should be sampled. For species with broad distributions, recommendations range from five populations to fifty populations per ecoregion (potentially hundreds of populations).

9.1.3. Ecoregions

Chosen populations should cover a range of environmental conditions, space and geography, to ensure that potential restoration material can have well-matched and high genetic variation for the target environment. A thorough genetic conservation collection will cover all the ecoregions (a geographical area defined by moisture, temperature, environmental resources, and/or plant community) that the species' occurs in. However, for some specific recovery or restoration programmes, collecting from the whole range would be unnecessary (see Section 9.4.1). Currently there is not an agreed number of populations to sample from; the appropriate number will depend on the species, scale of recovery programme planned (collecting seed from far outside the temperature range of the recovery sites may be unnecessary). As mentioned above, the ecoregion approach does emphasize similar environmental characters more than proximity - a site 100 km away may have more similar characteristics than a site 10 km away.

9.1.4. Measuring collection breadth

There are methods to help determine the completeness of a seed collection in terms of number of populations and to identify populations providing the biggest benefit for a next phase of collection. Niche models can measure coverage in environmental space, while genetic models can measure coverage in genetic diversity. Both approaches require some knowledge of the species' current or historic distribution. A final approach is to perform an initial survey with genetic markers (costing $2,000 to $10,000 USD) to reveal genetic subdivision, how many populations are needed, and whether any populations appear particularly unique.

Collection of seed samples of wild vascular plant species (Image: Kristián Halász).

Genetic studies can also be performed before and after reinforcement to determine whether the reinforcement altered the genetics of the population.

9.2 How many individuals?

In species recovery, it is often necessary to use *ex situ* material such as seed for population augmentation (discussed in detail in Chapter 11). The origin and sampling of this material is critical so that appropriate genetic variation is represented.

Seed bank accessions are used for a variety of purposes and consequently different seed collection programmes will be devised to meet these different goals. For example, seed collections may be made for the long-term conservation of particular species or whole floras as an insurance against global change, providing material for research projects, reintroduction, ecological restoration, breeding programmes, or, as is the focus of this chapter, population augmentation as part of species recovery. A collector may try to maximise genetic diversity, conserve particular alleles in the case of species of economic importance, or simply aim to collect a particular quantity of seed for use in ecological restoration. The seed sampling strategy employed should suit the programme's goals.

A seed collection for recovery or reintroduction is typically stored short to mid-term before use (direct seeding, growing plants for transplantation, or producing plants to generate larger quantities of seed). It is best to plan ahead and make collections in advance of their need.

Box 9.2 Examples of seed collection and storage programmes for species recovery

Chicago Botanic Garden. (2012). Dixon National Tallgrass Prairie Seed Bank: www.sciencecollections.org/content/dixon-national-tallgrass-prairie-seed-bank

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Benefits of having collections already made and available for use include:

- Knowing the amount and quality of seed available
- Time and ability to confirm identification from a voucher specimen
- Having seed available in seasons or years when low or no wild seed is produced
- The ability to store extra after seasons of high wild seed production.

Seed collected for recovery should:

- Be of high quality and purity (percentage of target species' seed)
- Be of known provenance (location of origin) and
- Contain sufficient genetic variation.

Introduced plants (or their next generation offspring) with insufficient genetic variation to tolerate site environmental conditions may be unfit and/or unable to reproduce. Genetic variation should be high in order to help buffer the population against yearly fluctuations, adapt to long-term environmental changes, and avoid problems of inbreeding. As such, many discussions on genetic variation focus on 'how much' and 'how to sample' variation.

This chapter aims to help samplers collect enough seed and genetic variation to ensure that the newly planted individuals are functional and resilient. We assume that there is adequate space, personnel, expertise, and resources to maintain and use the seed, that there is some knowledge of seed storage behaviour and germination, that there is a method to verify seed purity, and that collectors have the necessary expertise (such as to identify the species and stages of seed maturation). If knowledge, expertise or personnel is lacking, the seed may fail to germinate or may die due to improper care, and is wasted. In such cases, resources may be better spent in solving infrastructural deficiencies, forming partnerships with institutions that can provide expertise, or making a small scale seed collection and conducting research that will gain basic knowledge needed on the species.

9.3 Collecting your own material

It is recommended to collect your own material for recovery programmes. For rare taxa, seed or plants are unlikely to be available from commercial sources. Material of known provenance and appropriate genetic diversity may, however, be available from a botanic garden or seed bank.

It is recommended to collect seed rather than vegetative material (e.g. cuttings). Vegetative cuttings produce plants that are genetically identical to the mother plant and therefore limit the genetic diversity captured. The benefits of high genetic diversity are detailed later in this chapter. Some target species may be threatened and in need of recovery programmes because of their inability to produce viable seed. In such cases, vegetative propagation material will be the only option. Sampling techniques should follow the guidance provided in this chapter about number of individuals and populations to sample from, but fewer cuttings would be taken from each mother plant, compared to the number of seed recommended (the number will depend on the type of plant and efforts should ensure that collection of vegetative propagation material does not harm mother plants). In some cases, both seed and vegetative material (even sourced from different populations) may be used in a recovery programme.

9.3.1. Adaptation

Adaptation is a key concern for species recovery. Each particular recovery site will have its own set of environmental conditions. The available seed source may be many hundreds of km away and/or from a different environment. Commercially sourced seed may also have been produced with an emphasis on traits that are seemingly attractive on first principles but are ultimately non-adaptive in real settings. For example, Leger and Baughman[5] showed that many commercially available sources for Western United States grassland species emphasise high seed set and large size (which would seem to be valuable traits) but successful plant establishment is associated with the opposite traits, such as small size and allocation to roots rather than seed production.

There is increasing evidence that success of many recovery and restoration efforts will depend on using genotypes that are suited or "matched" to the local current or future environmental conditions. For example, the use of non-adapted seed in the Western United States has often resulted in low establishment in spite of large amounts of money invested, but reforestation with "matched" or local seed may show increased fitness and productivity. Key traits to consider include the need for **vernalisation**, relative investment in aboveground and belowground plant tissue, flowering time and salt tolerance.

To be "matched" does not necessarily require seed to be geographically local (i.e. from within that site), but it is clear that some degree of environmental matching is important. A first step to choosing locally appropriate seed would be to use environmental delimitations like Omernik's ecoregions or established forestry seed zones. **Choosing seed source sites based on the environment is preferable to simpler metrics such as 100 km radius of the recovery site, and ignoring environment**. Omernik's ecoregions[7] are determined based on a combination of temperature, precipitation, elevation, vegetation, soils, climate, and other factors. Availability of pollinators and seed dispersers are not considered but are also important. (The question of whether and when to use seed sourced from within or immediately near the site to be restored depends on population size and inbreeding; this will be discussed in the next section). Ideally, seed source populations should have at least 1000 plants and a history of stable population size as these conditions help develop local adaptation (see also Box 9.3). This is seldom possible for rare species with few or small populations.

Local adaptation is not universal and is often imperfect, such that plants may flourish or even perform better at sites other than their origin. Although, local adaptation is a good starting point for choosing source sites, for many plant species introducing non-local seed does not mean it will be severely mal-adapted to local conditions (as evidenced by the long history of agriculture and forestry).

Box 9.3 The importance of genetic diversity in recovery programmes

In an analysis of 250 plant restoration actions, Godefroid *et al*.[8] found that the single largest contributor to successful plant restoration was the number of source populations - **mixing seed from multiple source populations resulted in survival rates (after three years) three times higher than if seed came from a single population source (more than 60% survival vs. 20% survival).**

In addition, they showed the **importance of collecting seed from large, stable populations**, with survival rates (again after three years) for plants established from stable source populations several times higher than that of declining sources (more than 80% compared to about 25%, though sample sizes were small). Declining populations will have already lost genetic diversity and may be suffering inbreeding, and thus a stable, healthy seed source is better.

The authors also found that having genetic data on the species contributed to recovery success, though the reason is not clear - genetic knowledge may have helped avoid outbreeding depression or prevented mixing ploidy differences, or this may be an artifact (species having genetic data studies will likely be species that are better studied in general, and this general knowledge may contribute to recovery success). Lastly the authors demonstrated that at least 100 individuals should be reintroduced, which is likely due to both demographic and genetic effects. Best practice in conservation suggests that at least 1,000 individuals are needed for a genetically healthy population in the long-term. These findings emphasise the importance of genetic diversity for recovery, restoration or reintroduction.

When trying to recover a very small population, it is important to consider sourcing seed from outside the local site, if available. This is because small populations often suffer inbreeding depression – which is manifest as poor seed set or germination, unhealthy plants, or other dysfunction – or very low genetic diversity which will hinder plant populations under future environmental change. In such cases, collecting and using only seed from the local site could soon lead to population extinction. If sufficiently large and accessible populations exist, populations smaller than 100 plants should usually not be sampled for seed. While there is some progress being made to determine minimum sample sizes for capturing genetic diversity in seeds (see remainder of this chapter), there are as yet only general suggestions for restoration and recovery programmes, partly because programmes differ widely in goals, scale of recovery or restoration, target species and local environmental challenges.

It is commonly suggested to sample populations **in environmentally marginal locations (poor, polluted, disturbed sites, or those on the geographic range edge)** because those populations may be uniquely adapted to challenging conditions and may be especially useful to recovery and restoration programmes. However, the degree of local adaptation to ecological extremes at such sites is usually unknown (such locations may be transitory or be of small size) and more work is needed to verify this recommendation.

9.3.2 Other genetic considerations

A further concern for introducing seed is the possibility of disrupting the local adaptation of the plants that still remain in the site (outbreeding depression). This is of particular concern when only small population(s) remain. However, most recovery programmes are focused on small, decreasing, and/or inbred populations and it is increasingly recognised that these concerns may outweigh concerns about genetic disruption, though further research is certainly needed. While not relating to environmental adaptation as such, a further important consideration is ploidy compatibility. Some plant species have multiple ploidy types (i.e. number of chromosomes) - populations of different ploidy should generally not be mixed. Each recovery or restoration programme must determine the extent of these risks based on available botanical and genetic knowledge.

9.3.3 The advantages of high genetic diversity

High genetic diversity is known to help populations survive future stresses, such as seasonal extremes or gradually increasing temperatures. Genetic variation influences other aspects of an ecological community such as number of co-occurring species (like arthropods) and productivity. Commercially available seed will often have low genetic variation due to few sources and one or multiple seed increase steps. Cultivars in particular may have almost no genetic variation. However, some cultivars are developed for very challenging conditions (drought, disease resistance) and will be important in some situations. In addition, cultivars are often easier to grow, harvest and plant and may be needed for some large scale or emergency situations. Nonetheless, the long-term success of a recovery or restoration programme can most likely be increased with genetic variation. As this chapter will explain, wild collected seed from across large landscapes and multiple source maternal plants will usually provide much more genetic variation and thus be a better choice from an ecological standpoint.

Suggestions to help ensure high genetic variation include:

- **Composite provenancing** – to use predominantly "matched" seed while including a substantial percentage of seed from more-or-less non-matched locations, enabling efficient natural selection and future adaptation. This may include one or more nearby or intermediately distant populations.
- **Predictive provenancing** – where the seed source is selected based on future projected environmental change, e.g. planting southern or low altitude seed sources in northern or higher altitude locations in the expectation that such locations will warm.

A (simple) example of predictive provenancing would be sourcing from a location with the climate that is expected at the restoration site in 2050. A different strategy aims at building knowledge based on experiments, by sourcing from only one location. This type of restoration, if controlled and replicated, can serve as an experiment to learn which seed is most adaptable in different places. A controlled experiment can give lessons that mixed seedlots cannot, because with a mixed seedlot it is hard to know which seed sources or which genetic combinations were successful. Single population sourcing may be a useful way to turn small scale and low risk restoration into lessons for the future.

9.4 How many individuals and how many seeds per individual?

9.4.1 A theoretical minimum for each population

The theoretical **minimum** samples required to capture 95% of existing genetic variation (number of alleles) from a **single population** of randomly mating, well distributed plants is to sample from 50 well-separated individual plants, from which typical practice has been to sample 100 seeds from each of 50 plants to achieve a total of 5,000 seeds. (Note that such sampling focuses on alleles rather than genotypes e.g. cultivars, which are sometimes of interest but not for recovery programmes).

Here we will explain why this theoretical number is **not** always sufficient to ensure that the restored population has the vast majority of genetic material from the source. More informed strategies can be employed that take into account spatial sampling, the target species' life history, distribution and the project goals. Such strategies will lead to a higher success for recovery programmes.

9.4.2 Maximise distance between sampled plants

One important takeaway message about sampling is: **how seeds are sampled can be as important as how many seeds are collected**. The theoretical recommendation assumes that samples are taken randomly or at least with broad spatial coverage. This is because restricted dispersal of pollen and seeds leads to nearby individuals being more closely related than distant ones. Thus, increasing the distances between sampled plants results in collections comprised of less-related individuals and thus more diversity in the seeds collected.

Spatial distance is important at all levels for capturing more genetic diversity for a recovery seed collection;

- Sampled **populations** should be distant
- Sampled **plants** within a population should be distant
- Sampled **seeds** should be collected from different parts of the plant, especially for large plants like trees because they are likely to have been pollinated by different paternal plants.

Minimum inter-plant distances can be determined using the concept of neighbourhoods - roughly the distance an average seed or pollen grain might travel. For collecting tree seed, at least 100 m is often used.

9.4.3 Possible sampling strategies

Good spatial coverage can be achieved by:

- Sampling truly randomly (using random numbers)
- Sampling in a stratified manner (randomly within chosen microhabitats or other strata), or
- Sampling systematically (at regular intervals on a grid).

Systematic sampling is recommended in large, uniform landscapes, while stratified sampling is recommended in highly variable sites. Sampling the 50 nearest plants to a parking area is not recommended - this approach will likely select related individuals and miss much of the population's total variation. **Sample from as much of the population as possible**. In choosing plants, a collector should include a variety of ages, growth forms, and vigour (though avoiding diseased seeds). However, highly isolated plants of outcrossing species are best avoided as their seed could be inbred. If sampling cannot be made with good spatial coverage (e.g. due to land access limits), the number of plants sampled from should be increased by at least a factor of two, and more if possible.

9.4.4 How many seeds?

There are several key principles for determining the number of seeds to collect. As mentioned above, sample seeds from as many maternal plants as possible - the genetic reward is always better by sampling from a new plant. Sampling 50 seeds from 10 plants is not equivalent to 10 seeds from 50 plants. The former seedlot is less valuable because it has less variation.

Also, **equalise as much as possible the number of seed taken per plant**, i.e. take the same number of seeds per plant, which will reduce redundancy in genetic variation, help maintain population allele frequencies, and help prevent inbreeding in the restored population.

Lastly, care must be taken **not to over-harvest**. The level of safe harvest will vary dramatically among species, from 10% of available seed to over 95%, with 20% recommended if no knowledge of the species is available. Annual plants, especially those without a seed bank, should be harvested below 20%. Demographic modeling, in which different harvest rates are evaluated, can help ensure rates that avoid extinction risk. There are, however, exceptions. If the species or population is in imminent danger of complete loss (e.g. demolition by humans, on an eroding cliff, etc.), collecting as much seed as possible may be advised. Such action has saved some species from extinction, such as the tiny water lily (*Nymphaea thermarum*).

Case study 7 Preparing for recovery: The Florida Torreya

Torreya taxifolia, known as the Florida Torreya, is one of the rarest conifers in the world. Once commonly found as a canopy tree, *T. taxifolia* is a Critically Endangered evergreen tree endemic to a narrow range of bluffs and ravines adjacent to the Apalachicola River in northwest Florida and extreme southwest Georgia. In the mid-20th Century, this species suffered a catastrophic decline, to approximately 0.3% of its original population size, as all reproductive age trees died from a disease that remained unknown until very recently. In the decades that followed, this species did not recover.

In 1990, Atlanta Botanical Garden (ABG) received 155 clones of *T. taxifolia* propagated from the remaining natural population. Since then propagation efforts have increased ABG's collection to include almost 1,000 individuals, including nearly 500 distinct vegetative clones from the wild. ABG has increased representation of wild individuals through extensive field surveys, which have located additional trees, along with continuous collection and propagation efforts.

Allozyme analysis was used to evaluate multiple populations within the five ravines in which *T. taxifolia* occured in 1994. Genetic diversity detected using allozyme markers in the *ex situ* collection of *T. taxifolia* maintained at ABG was found to be higher than that in wild populations. Differences are likely due to the bottleneck effect and decline in genetic variation in the wild.

One of the limiting factors to *ex situ* conservation of this species is that *T. taxifolia* produces recalcitrant wet seeds that cannot be dried for storage in freezers. Therefore, until recently the only way to maintain *ex situ* germplasm was through living collections.

ABG in collaboration with Georgia Institute of Technology, developed a somatic embryogenesis tissue culture system to initiate cultures, produce somatic seedlings, and cryogenically store cultures of *T. taxifolia*. Large numbers of somatic embryos and resulting seedlings can be developed in culture from a single seed which can be used for disease research, restoration or establishment of seed nurseries for conservation.

ABG in collaboration with Florida Park Service and the University of Florida have mapped wild trees and identified the disease-causing agent as a new species of *Fusarium* (*Fusarium torrayae*).

Field surveys have found that stem damage from deer antler rubbing is a significant source of stress in addition to disease, and is causing severe impacts to more than 50% of trees.

Efforts at understanding ecological requirements of this species for reintroduction, include caging the trees to protect them from deer damage. To date 21.6% of surveyed wild trees have been caged for protection. Although the majority of habitat for *T. taxifolia* is protected, recovery of the species is still dependent on *ex situ* conservation efforts due to damage from deer and stem canker which are currently not completely controlled.

ABG and the University of Georgia have also established a *T. taxifolia* seed orchard, where nearly 5,000 cones were harvested in 2016. Seed and seedlings are being distributed to other botanic gardens to establish additional *ex situ* collections and another seed orchard. The next step for the conservation program is to reintroduce the species into areas where it has been lost and to continue protecting trees from deer pressure.

Contributed by: Atlanta Botanical Garden Conservation Team

This female *Torreya taxifiolia* was grown from lateral cuttings and, along with 20 others, was planted in 2000. Nearly 5,000 fruit were harvested in 2016 (Image: Carrie Radcliffe).

Left: Collecting and recording *Taxus contorta* in Manang District, central Nepal (Image: RBGE). Middle: Collecting seed cones of *Glyptostrobus pensilis* in China. Right: Collecting and recording *Taxus contorta* in Manang District, central Nepal (Image: RBGE).

9.4.5 Adjusting seed quantities

Some seeds are empty, inviable, or diseased and some plants will not establish, will die before reaching maturity, or will produce few seeds as adults. Recovery and restoration is only successful when the adult plants reproduce. Thus the initial collection must have enough seed to compensate for losses along the entire recovery process. Data from real recovery programmes shows that each species is different, and losses at each stage can be small or very large. Way and Gold[9] recommend accounting for at least 90% loss over the stages. Some botanic gardens, seed banks, and restoration programmes have data on germination and restoration success which can be used to determine appropriate quantities for a given species (see Section 9.6.4).

9.4.6 Scale

Lastly, 500 randomly sampled seeds may produce one population of 50 adult plants roughly genetically similar to the original wild population. If the restored population is to be larger, and/or if there are to be more populations introduced, the seedlot must be proportionally larger. To create 10 small populations of one species (*Dryandra ionthocarpa*) according to Cochrane *et al.*[9] would require 125,000 seeds. For very large scale recovery or restoration programmes, seed may need to be purchased from commercial operations, but, as noted above, they may have sampled with certain goals in mind (e.g. uniformity and ease of harvest), perhaps not always including high genetic variation.

9.5 Considering species biology

9.5.1 Taking into account biological information

Sampling should be adjusted for a species' dispersal mode, life history and other aspects, such that often larger sample sizes than the theoretical recommendation are needed. As Way[11] explains, "the most appropriate sampling strategy for any given situation can be decided by reference to the ecology and distribution of the species; geography of the collecting region; likely breeding system and pollinators; natural seed dispersal mechanism; and seed quality." More samples are needed for plants with low dispersal of pollen and seed, microsite variation within populations, perennial species, fragmentation, etc. As yet, the exact amount of seed to sample from plants with different characteristics is not known, but some examples exist, and for many species, sampling should be increased by a factor of **two to five or more** to gather sufficient genetic variation.

In comparing a collection of cycads and palms, Griffith *et al*.[12] found that more than 300 plants of the rare cycad *Zamia decumbens* were needed to capture the same genetic variation as in 10 plants of the rare palm *Leucothrinax morrisii*, because very few cycads flower each year (see Section 9.6.3).

Hoban and Strand[13] found that 1,600 seeds of a modeled highly-selfing, low-dispersal species may be needed to capture the same target genetic variation as 300 seeds of a mostly-outcrossing, high-dispersal species, though this modeling result needs to be tested in realistic restoration situations.

Timothy Putzke, Conservation Horticulturist, inspects *Torreya taxifolia* fruit prior to harvest (Image: Carrie Radcliffe).

For species where this biological information is unknown, a low-cost genetic study, a desk study, examination of herbarium sheets, floras or botanic garden specimens, or inference from related species can reveal needed biological information.

9.6 Other considerations: logistics, time, costs and data

9.6.1 Backup, monitoring and other uses of seed

Ideally, additional seed should be collected for backing up the collection, distributing material for study, monitoring seed viability, or other factors - all of which are essential for a long-term seed bank but may or may not be needed for recovery and restoration collections. In terms of recovery programmes, the minimum seedlot for each restoration might be 5,000, 10,000 or 20,000, e.g. sampling 100 seeds from each of 50 individuals. Again, it is better to sample 10 seeds from each of 500 individuals, than to sample 1,000 seeds from each of five plants. Collecting large amounts of seed can also help limit the number of cycles of "seed increase" - unintentional selection for the growing conditions, harvest, storage or seed cleaning is hard to avoid completely and each step results in loss of genetic diversity.

9.6.2 Costs

Genetic diversity typically accumulates with "diminishing returns" at all spatial levels. After collecting a few dozen seeds from a given plant, or a few dozen plants from a population, the "rate of return" decreases rapidly such that, while you always add new variation, the amount of variation per sample is smaller and smaller. This is another reason why, from a gene gathering perspective, it is much better for a collector to move to a new plant rather than take more seed from a plant already sampled. Likewise, it is better to move to a new part of the population, a new population, or a new region. This choice is of course balanced by logistical limitations (time and money). Griffith *et al*.[12] demonstrate that **a collector can use simple calculations that are effective in identifying an optimal number of seeds to collect**. Programmes that expect to propagate threatened species for recovery purposes may consider holding seed from each maternal plant separate throughout the collecting-processing-germination stages, but the additional costs and complexity of this need to be factored into a project, and it is not usually cost-effective to do this for large scale recovery or restoration efforts.

9.6.3 Timing of collection

The fruiting season of a given species may be spread over multiple months, and not all individuals will have mature seed simultaneously. Collecting at a single point in time will therefore omit some individuals. A temporal collecting strategy is important for recovery success. Flowering time has a genetic basis. If only early-, mid-, or late-flowering plants are sampled, the restored population will flower over a limited time and is less able to survive late frosts or short drought periods. Temporal sampling also affects overall genetic representation - sampling at one time point means that all the genetic variation in the unripe seeds will not be captured. Thus, it is best to sample multiple times in the season, and over multiple years (as some individuals have poor seed years). Menges *et al*.[14] remark that collecting in multiple years has numerous benefits including the opportunity to combine sampling with monitoring, reduced extinction risk, and capturing more genetic variation. Lastly, it is best to sample before a population begins to decline, including creating proactive collections of even common, secure species.

9.6.4 Data

As the ENSCONET manual states, "seed without accompanying data is nearly useless"[15]. To be useful for recovery and restoration programmes, recorded data (called "passport data") for seed collections must include **where**, **when and how seed was collected** (georeferenced location, number of plants, random sampling methodology or not, etc.). Comprehensive field data (plant size, health, soil type, aspect, co-occurring species, site history, any management regime, etc.) will greatly assist in finding an environmental site "match", determining where the seed can be reintroduced, what seed can be mixed or inter-bred, and how to propagate further generations of plants *ex situ*. Example datasheets can be found in Way[11], ENSCONET[15] and Kallow[16]. Notably some of these characteristics vary at small spatial scales, in particular soil type, aspect, and competition.

Voucher specimens are essential for species identification and should be stored in herbaria for future reference. In addition, leaf or other vegetative material can be used to extract DNA samples, which are useful in measuring variation in an extant population.

In addition to soil data, some species may require inoculation with their soil micro-organisms for reintroduction success, or other soil remediation may be needed. In such cases, collection of soil samples should accompany seed collections.

Data should also be kept on losses at each stage of seed germination and growth of plants *ex situ* and in the recovery site. This information is invaluable for future recovery and restoration efforts as it helps to refine future seed collecting plans and determine the causes of restoration success and failure.

9.7 Conclusions

For recovery programmes, it is recommended to source your own material. Botanic gardens or seed banks may also hold appropriate material for recovery programmes. Seed collections are recommended rather than collection of vegetative propagation material. Key recommendations for seed sampling include:

- The theoretical minimum number of 10 seeds from each of 50 individual plants should be increased for many cases: insufficient coverage of the space of the population, plant traits listed in Guerrant *et al*.[17] (such as low dispersal and long life-span), imminent destruction of the population, non-equal number of seeds per maternal plant, a goal of establishing more than one recovery site, or other reasons. **Recovery and restoration collections may be many thousands of seeds**.
- The number of populations for a good conservation collection may be dozens, but a restoration practitioner should choose populations based partly on environmental matching, while considering some near-match sources and some marginal (though not very small) sites. Often, **environmental matching may be more important than local proximity**.
- It is best to collect multiple times per fruiting season. If a substantial proportion of individuals do not have sufficient seed in a collecting year, **collections should take place in multiple years**.
- Detailed data is critical for full use of the seed collection and success of the recovery and restoration project, including learning from the outcome: "**seed without accompanying data is nearly useless**".

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Chapter 10.
Community Conservation and other participatory approaches

Aim of this chapter

This chapter highlights the benefits of involving local communities in species recovery programmes. Guidance is provided on when and how to engage with them and the varying roles that they can play in species recovery. This chapter also explains the benefits of involving other stakeholders in the process of recovery, indicating in which contexts their participation may be appropriate and may work effectively to improve recovery outcomes.

10.0 Introduction

Species recovery programmes require specialist knowledge and skills. However, successful implementation of species recovery programmes also requires detailed knowledge of the target species, its uses and habitat and the local context. This knowledge is often held by local communities. Continued monitoring and care is also required for species recovery, which specialists are often unable to provide, if for example they are located far from the project area. Local communities can often help in the planning stages of a species recovery project and help ensure that appropriate interventions are selected. They may also become actively involved in practical components of the project to improve their success.

This chapter identifies the importance and benefits of empowering local people to conserve their own environment and the species within it. In many contexts, there are active community societies and local groups who are passionate and willing to support recovery projects and are well-placed to do so. Horwich and Lyon[1] state that NGOs must aim for 'working [them]-selves out of a job'. In many cases, the involvement of local communities will be the biggest asset to a species recovery programme and a key ingredient for success.

This chapter also describes how to undertake a broader stakeholder analysis to identify additional people or groups that may benefit the project, for example through provision of funding or supporting public outreach measures.

Members of the Dai ethnic minority replant an area of forest on a hill that is considered as a holy site at Mangyangguan, Xishuangbanna, China (Image: Barney Wilczak).

Box 10.1 Information sources on participatory approaches

The Center for People and Forests (RECOFTC): www.recoftc.org/

Chambers, R. (2002). **Participatory Workshops: A Sourcebook of 21 Sets of Ideas and Activities**. Earthscan, London, United Kingdom.

Communityplanning.net: www.communityplanning.net/index.php

The Community Toolbox: The Ideas, Methods and Tools for Participatory Assessment, Monitoring and Evaluation in Community Forestry: www.fao.org/docrep/x5307e/x5307e00.htm

Friis-Hansen, E. and Sthapit, B. (2000). **Participatory Approaches to the Conservation and Use of Plant Genetic Resources**. International Plant Genetic Resources Institute (IPGRI), Rome, Italy. *Chapter 3 provides a brief review of participatory tools and techniques*.

Grenier, L. (1998). **Working with Indigenous Knowledge: A Guide for Researchers**. International Development Research Centre (IDRC). www.idrc.ca/en/book/working-indigenous-knowledge-guide-researchers

Wilcox, D. (1994). Guide to Effective Participation: www.partnerships.org.uk/guide/index.htm. *Wilcox offers information on partnerships and participation, theory to practice including toolkits, ideas and other downloadable resources.*

International Institute for Environment and Development (IIED). **Participatory Learning and Action**. www.planotes.org. *An online series on participatory learning and action approaches and methods*.

IUCN Indigenous and Community Conserved Areas http://www.iccaforum.org/. *This website contains many relevant resources including a worldwide database of ICCAs across the world and publications.*

Lockwood, M., Worboys, G.K. and Kothari, A. (2006). **Managing Protected Areas: A Global Guide**. Earthscan, London, United Kingdom. *This reference includes detailed chapters dealing with community conserved areas and collaboratively managed protected areas.*

Martin, G. (2004). **Ethnobotany; A Methods Manual**. Earthscan, London, United Kingdom. *Chapters 1, 4 and 8 contain useful information on participatory approaches*.

Parque de la Papa (The Potato Park). www.parquedelapapa.org /eng/03parke_01.html. *This website provides information about a community conservation project in Brazil*.

Voluntary Services Overseas (VSO). (2004). **Participatory Approaches: A Facilitator's Guide**. www.participatorymethods.org /sites/participatorymethods.org/files/VSO_Facilitator_Guide_to_Participatory_Approaches_Principles.pdf

Pretty, J., Guijt, I., Thompson, J. and Scoones, I. (2003). **Participatory Learning and Action: A Trainers Guide**. http://pubs.iied.org/pdfs/6021IIED.pdf

Terralingua. http://terralingua.org/our-work/bcd-conservation/. *The Terralingua website maintains a useful community of practice portal for exchange and sharing of information on biocultural diversity*. The portal is an online companion to the book **Biocultural Diversity Conservation: A Global Sourcebook** by Maffi, L. and Woodley, E. (2010).

Tuxhill, J. and Nabhan, G.P. (2001). **People, Plants and Protected Areas: A Guide to *In Situ* Management**. Earthscan, United Kingdom.

Appropriate and successful ways to engage with communities will vary considerably in different countries and contexts. The guidance given in this chapter therefore needs to be considered within the local context of the recovery programme.

Butchart *et al*.[2] suggest that the protected area network would need to be doubled to achieve cost-effective conservation of target countries, ecosystems, important sites and species, but as such extensive and rapid expansion is likely unachievable, it is important to supplement the protected area network with other alternative approaches, including community and privately managed sites.

In general, exclusionary measures, or 'fortress conservation', which prioritises the establishment and maintenance of protected areas with limited or no access, over the needs of local people is now recognized as inappropriate and unsustainable in most situations. Involvement of communities in species recovery projects helps to ensure that the impact of the project is sustainable and lasts beyond the timeframe of practical interventions. There is growing awareness of the need to meet economic and livelihood needs alongside halting further environmental degradation, by working in partnership with local people. A great deal of guidance about participatory approaches has been published (see Box 10.1 for useful references).

Community involvement is also increasingly a requirement from funders. For example, the UK government's Darwin Initiative scheme[3] requires the incorporation of livelihood improvement measures in all of their proposals, and the Critical Ecosystem Partnership Fund[4] supports projects that enable the participation of Civil Society Organisations in conservation.

10.1 Benefits of involving communities in species recovery programmes

The involvement of local communities in conservation projects can result in a positive outcome for the target species, as well as additional benefits to the project and the surrounding environment[6]. Some of the commonly experienced benefits are outlined in Table 10.1.

Involvement of communities in species recovery projects can also generate increased environmental awareness, which can in turn lead to reduced environmental degradation in the future, and often reduce the need for species recovery programmes.

10.2 Who to engage - Identifying stakeholders

Stakeholders are people or organisations who have an interest in, or are affected by, a programme or action and can be directly or indirectly included in the decision making process[7]. It is recommended that a stakeholder analysis be undertaken to identify and investigate the perspectives of key people, groups and institutions affected by a proposed species recovery action. Table 10.2 provides examples of people or bodies to engage in species recovery programmes. The stakeholder analysis should be as comprehensive as possible.

If the stakeholder analysis identifies additional groups that could be involved in the project to support its implementation, it is important to avoid a situation where their involvement may lead to conflict with local communities. For example, if a local business offers to provide free labour to clear invasive species before planting, but employment to clear invasive species was a benefit offered to local communities, the benefit to local communities should not be lost, even if a financial saving is involved, as this will risk losing community support for the project.

The following questions are suggested by the United States Endangered Species Act Recovery Planning Guidelines[8] to help identify the correct stakeholders to be involved in species recovery planning:

- Who are the people or groups most dependent on the resources involved?
- Who are the people or groups most interested in recovering the species?
- Who commented on the proposed listing or were otherwise involved in the listing process?
- Who best represents those likely to affect or be affected by the recovery process?
- Who can help you meet the potential recovery goal, objectives, and criteria?
- Who is likely to be responsible for actions required for recovery?
- Who possesses claims, including legal jurisdiction and customary use, over the resources involved?
- Who are the people or groups most knowledgeable about, and capable of dealing with, the resource issues?
- Who specifically is having an impact on the conservation of the species?
- Who has been primarily managing the species and its habitat?
- Have there been similar conservation initiatives in the area? If successful, who was in charge and how did stakeholders participate?
- What stakeholder participation might be missed without a special effort?

Table 10.1 Benefits of involving local communities in species recovery programmes

A better understanding of local and historic context	Local communities often have a wealth of information which can be utilised to improve species recovery outcomes. Involving local communities in the planning phases of a species recovery programme can help to better identify the causes of species decline and identify management interventions that will work in the local situation.
Financial costs can be reduced	Often conservation projects are under-resourced but can require a large labour force to be implemented, e.g. removal of invasive or competitive species.
Communities can provide continued monitoring	Whether through a formal or informal approach that involves payment or not, local communities will often be the best-placed people to carry out monitoring following species recovery interventions. In addition to scientific measurements, that can either be taken by the core project team or by local communities trained in monitoring techniques (see Chapter 12), local communities can help by informing project managers of an increased prevalence of threats, e.g. from fire, theft or extreme weather conditions. This will help to keep the project on track, even if project managers are located far from the site.
Communities can act as long-term custodians/protectors	Involvement of communities in species recovery planning and actions can lead to a heightened sense of responsibility, ownership or custodianship of the species or habitat involved. This often leads to people independently taking measures to continue to protect or improve the status of the species of interest, beyond the timeframe of the original project, acting as the "front-line" protection for the species.
Threats can be reduced	In some cases, humans pose the biggest threat to species survival. Through awareness raising, involvement of communities in project activities, or provision of alternatives or incentives to relieve pressure on wild populations (covered later in this chapter), a greater understanding of the negative impact of human activities and the importance of conservation can be achieved, which can reduce the prevalence of threats.

Table 10.2 Examples of people and bodies to engage in species recovery programmes

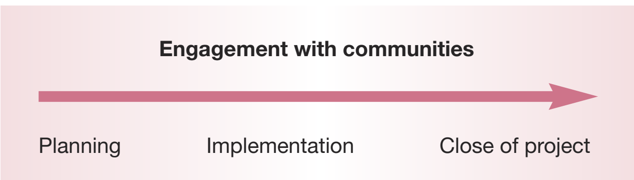
Examples of people or bodies that must be engaged/ informed before the project starts	Examples of additional people or bodies whose engagement will likely increase the success of the project
• Land owners/managers • National or regional government, e.g. if the species is protected by national or regional legislation • District / county / local government	• **People using the species, e.g. extracting whole plants or parts of plants** – *alternative sources may need to be offered* (see below) • **People using the land where the recovery interventions are planned, but who do not own the land** – *may be affected by the project activities, e.g. walking groups not allowed to access certain areas* • **Traditional Authorities** - *may hold a strong influence over the actions or opinions of their communities* • **Indigenous groups** – *may attach a strong cultural link to the species or site of interest* • **Local conservation NGOs** – *opportunity to pool resources, e.g. through shared monitoring programmes* • **Civil Society Organisations, Community-based Organisations, Community Forest Associations (or equivalent)** – *may hold local knowledge and want to be actively involved in recovery actions* • **Local schools, colleges or universities and local artists** – *may be able to help with the public outreach components of the project* • **Local businesses** - *may generate financial support for the project through Corporate Social Responsibility (CSR) contributions or activities, such as staff volunteering on a project* • **Media** – *may help to generate support for and wider understanding of the need for the recovery programme*

- Who is likely to mobilise for or against what may be needed?
- Who can make what is intended more effective through their participation or less effective by their non-participation or outright opposition?
- Who can contribute financial and technical resources?
- Who will use the plan to justify funding requests?

It is important to think about the order in which stakeholders are engaged. Are there formal consultations or permissions that need to be sought first? Think about whether there is an existing hierarchy within community groups, for example, is it appropriate to talk with Traditional Authorities or community leaders, before engagement with other community members?

10.3 When and how to engage with local communities

Efforts should be made to involve communities from the project outset, throughout the project and beyond the timeframe of the project if possible.



Community engagement is more than passive consultation. Conservation scientists will know what is technically required and possible, at least in theory, and whilst their knowledge is required for the success of a recovery programme, they may not understand the local circumstances, hence involvement of local people is key.

Box 10.2 Guidance resources for stakeholder analysis and community engagement

Stakeholder analysis:

Vogler, D., Macey, S. and Sigouin, A. (2007). **Stakeholder Analysis in Environmental and Conservation Planning**. *Lessons in Conservation*, 7, 5-16.

Fauna and Flora International (2013). **Stakeholder Analysis: Conservation, Livelihoods and Governance Programme Tools for participatory approaches**. api.fauna-flora.org/wp-content/uploads/2017/11/FFI_2013_Stakeholder-Analysis.pdf

Community engagement:

The Conservation Volunteers. (2015). **Engaging Volunteers: Guide to engaging volunteers in Citizen Science Projects**. The Conservation Volunteers. www.tcv.org.uk/sites/default/files/172/files/EngagingVolunteersCitizenScience.pdf

Tweddle, J.C., Robinson, L.D., Pocock, M.J.O. and Roy, H.E (2012). **Guide to citizen science: developing, implementing and evaluating citizen science to study biodiversity and the environment in the UK**. Natural History Museum and NERC Centre for Ecology & Hydrology for UK-EOF. www.nhm.ac.uk/content/dam/nhmwww/take-part/Citizenscience/citizen-science-guide.pdf

10.3.1 Gathering information

It is important to consider the best ways to share and obtain information, depending on the cultural and local context. Some key questions to ask when sharing and obtaining information are:

- Does information need to be translated into a local language(s)?
- Is written information appropriate or would verbal communication work better?
- Is a formal or informal approach better?
- Are people more likely to share information as an individual or in a group situation?
- Do the intended participants need support to attend a workshop? (e.g. travel or accommodation costs)
- Is there a cultural or gender-related approach that should be respected in the current context?

It is also important to be aware of relevant legislation that may restrict or protect the use of local knowledge. For example the Nagoya Protocol on Access and Benefit Sharing (ABS) covers traditional knowledge. Even if traditional knowledge is being used for conservation purposes, it is important to consider whether this information is sensitive and whether or how it can be shared. For example, specific uses of plants should not be published without prior consent of the owners of the traditional knowledge. Even if a plant is of no commercial interest at present, it may become of interest in the future. Records should be kept of the source of information and whether any of it is sensitive or should not be published. Further guidance on ABS related to plant resources is provided by Davis[9] and an ABS learning tool has been produced by BGCI and the Royal Botanic Gardens, Kew[10].

Gathering information to improve the project design will also provide an opportunity to inform people of the project's aims.

10.3.2 Community involvement in project design/co-creation

It may be possible to give local communities a more active role in project design, rather than just obtaining their views or guidance through consultation. Increased involvement of community members in project design can help create a sense of shared ownership. One example of how this can be achieved is through "co-creation", which enables professionals to co-operate with and learn from community members, to build a connection between groups that would not normally meet (e.g. scientists and community members). Co-creation aims to raise awareness and sensitivity towards important issues and to build relationships between groups and individuals that will last well beyond the scope of a project[11].

10.2.3 Community involvement in project implementation

Various opportunities exist for active community participation in species recovery projects. Key questions to ask, particularly for threatened species, include:

- Are community members equipped to carry out the task according to the specialist needs of the target species? If not, can community members be trained to implement the task effectively?
- Is supervision by an expert or trained specialist required?
- Should manuals or guides be produced to help communities carry out their tasks?

It is important not to compromise the outcomes of a recovery project by giving too much responsibility to people who are not sufficiently trained or skilled to carry out the tasks concerned. Species recovery projects therefore provide an opportunity for delivering training to address gaps.

In countries such as the USA, Canada, the UK and South Africa, there is a strong volunteering culture, and raising awareness of the need for species recovery may be enough to generate support from local communities, but it should not be assumed that people or groups are willing to help for free. In many cases, some kind of monetary or non-monetary incentive will be needed to secure community participation (covered later in this chapter).

10.3.4 Monitoring

Benefits of involving communities in the monitoring phase of recovery programmes include:

- Increased work force
- Cost-effectiveness.

In some cases, citizen science works extremely well to monitor the status of threatened species and their recovery or otherwise in the field. However, monitoring whether a species recovery programme is working effectively can be complex (see Chapter 12). Even if communities are involved in obtaining and recording the data, training is likely to be required to ensure that the data being captured is of high enough quality to accurately monitor the impact and effectiveness of the recovery programme. As well as formal monitoring, local communities can help by informing project managers of an increased prevalence of threats, e.g. from fire, theft or extreme weather conditions. This will help to keep the project on track, even if project managers are located far from the site.

10.4 Incentive-based mechanisms

It will often become apparent early on in a project if incentive-based mechanisms are required. This must be handled carefully. A key question to ask if incentives are offered, is: To whom are they offered or not offered?

Women from communities surrounding Mulanje Mountain participated in a day-long meeting to refine restoration objectives at the initiation of a project to restore Mulanje Cedar (*Widdringtonia whytei*) (Image: Kirsty Shaw).

The people who are offered incentives may be defined by a geographical area or sphere of influence, or incentives may only be offered to people who are immediately affected by the project. For individual species recovery programmes, the geographical area or group of people in question is unlikely to be large, but there needs to be a clear and transparent approach to determine who is eligible and why. If this is not the case, it may generate a negative response from people not receiving incentives.

Incentives may be offered to local community members to play an active role in implementation (e.g. site clearance, planting, monitoring). However, compensation may play an equally important role when encouraging people to forego utilising the species or land where the species recovery programme is taking place. In some cases, incentives do not have to be in financial form. Galbraith *et al*.[12] found that common motivators for voluntary participation are:

- Helping the environment
- Improving personal ecological literacy/training
- Social belonging
- Personal growth.

Table 10.3 identifies different kinds of incentives that can be offered to communities for their active or passive involvement in species recovery programmes.

Harvest of Cuckoo flower, *Cardamine pratensis*, from production beds used to provide seed for storage, research and restoration. Wakehurst Place, Royal Botanic Gardens Kew (Image: Barney Wilczak).

Table 10.3 Incentives that can be offered to communities for active or passive involvement in species recovery programmes

Active / passive role	Description of role	Type of incentive	Description of remuneration
Active	Weeding, removal of invasives, growing plants, planting, monitoring	Financial	*Employment* – community members are employed to work on the project and are paid for the work they do
		Financial	*Carbon / biodiversity credits* – Payment made for the planting or protecting tree species that sequester carbon or species of particular biodiversity value. The payment may be part of a government scheme or through a carbon-offsetting scheme whereby individuals pay to offset their own carbon emissions
		Financial	*Selling plants* – Communities gain income through growing plants that are sold to the recovery project or to a commercial market to take pressure off wild resources
		Non-monetary incentive	*Training or access to facilities* – Community members take an active role in the project, but instead of receiving payment, receive other benefits, e.g. training that may improve their employment prospects
		Voluntary	Community members receive recognition or a sense of achievement/ contribution
Passive	Agreement not to harvest material of the target species so as to take pressure off remaining wild individuals	Non-monetary incentive	*Alternative species* – A person using the target plant species is offered an alternative supply of the plant, e.g. plants to grow in garden / community
		Non-monetary incentive	*Alternative areas* – People using the area where the species recovery programme will take place are offered an alternative piece of land for the same activity
		Non-monetary incentive	*Alternative income* – People dependant on the target species for income are provided with an alternative livelihood / income-generating activity, for example by supporting them to produce biodiversity friendly products, conservation enterprises or become involved in community-based ecotourism
		Voluntary	*Recognition* – In some cases, achieving recognition for allowing their site to be used for conservation, or formal designation of a site as a protected area, may be enough reward for the land-owner(s)

Case study 8 Monitoring a Critically Endangered tree in Tanzania

In 2015, a survey was carried out of a population of one of Tanzania's most threatened tree species with fewer than 20 known individuals: *Karomia gigas* (Lamiaceae). The survey team included staff from BGCI, Missouri Botanical Garden, the Tanzania Tree Seed Agency, the Tanzania Forest Service and Tanga Coastal Forest Botanic Garden. Before the survey, the team gathered as much information as possible about this little-known tree species, from the only existing herbarium voucher and by talking with botanists.

On arrival in the target location, the team met with the Head of the village closest to the reported population. He was informed of the survey's aims and provided permission to survey the forest. The Village Head also introduced the team to a farmer from the village who knew where the trees were situated.

The survey team, led by the farmer, identified six mature *Karomia gigas* trees. There was seed beneath the trees, but the seed was old and no longer viable. Trees had been felled in the nearby forest and forest fires had occurred nearby.

The farmer was appointed to survey the trees every two weeks, to report on phenology – when new leaves, flowers and seed appeared – and any signs of increased threat. Mobile money transfer was used to pay the farmer after reports were received every two weeks.

Reports from the farmer enabled a seed collecting team to visit the site again when seed was available and collect fresh seed to initiate a propagation programme. Seedlings will be used to initiate a recovery programme for this species.

Without the involvement of the local community, the project would not have been able to monitor seed set and the opportunity to obtain seed from this Critically Endangered tree would have been lost.

Camellia nitidissima flowers.

Case study 9 Training local communities to conserve threatened trees in China

Local people working at the nursery.

Demonstrating propagation techniques such as grafting.

Habitat loss and the extraction of seedlings from the wild are responsible for the decline of several species of camellia in Guangxi, southern China, including Endangered *Camellia nitidissima* and *C. euphlebia*. These plants have high ornamental, medicinal and nutritional value, and are sold under the trade name Golden Camellia. The Global Trees Campaign, in collaboration with the Guilin Botanical Garden of the Guilin Institute of Botany is working to establish these species in *ex situ* collections, restore their habitats and to train local people to cultivate these threatened trees. Over 365 local households have signed agreements with a corporate enterprise which raises and provides seedlings to local people free of charge for cultivation on privately-owned land. The farmers collect the Golden Camellia flowers and leaves from these plants, which are then purchased and processed by the company.

This project has reduced the extraction of seedlings from wild camellia populations, whilst at the same time it is improving the livelihoods of local communities, by providing a secure source of income.

Source: Beech *et al.*[13]

Case study 10 Thinking outside the box – Borneo, Indonesia

The NGO Alam Sehat Lestari (ASRI) is using a novel conservation approach to tackle both human and environmental health at Gunung Palung National Park in south western Borneo. After finding that the high cost of medical care was pushing local people into debt and into the forest to obtain much needed cash from illegal logging, ASRI has established a programme which provides health care services to people, in exchange for their active involvement in conserving the national park.

This can be done in a number of different ways, such as providing native seedlings for restoration and recovery programmes, or ceasing illegal logging activities. This scheme has proved to be highly successful with illegal logging reduced by 68% after only five years.

Source: Heath in Harmony[16]

Box 10.3 Examples of Community Protected Areas supporting species recovery actions

Madagascar is one of the first countries in the Southern hemisphere to establish a legal framework for community based resource management. The Gestion locale sécurisée (GELOSE) law (1996) and Gestion contractualisée des forêts (GCF) decree (2001) promote the transfer of management of natural resources to local communities[17]. By 2014, more than 1,000 management transfer contracts encompassing 15% of Malagasy forest cover had been created[18], making Madagascar one of the most engaged developing countries in community resource management.

In **Peru**, approximately 6,000 Quechua indigenous community members are working within the Indigenous Community Conservation Area (ICCA) of Parque de la Papa (Potato Park) to safeguard more than 3,000 varieties of native potatoes. The park is community led and preserves not only agricultural biodiversity but also local livelihoods and traditional knowledge[19].

In 2005, the **South African** government set up a Biodiversity Stewardship Programme to provide a cost-effective approach to expanding its protected area network. Contractual protected areas are established on private or communal land acknowledging landowners as custodians of the biodiversity present. Biodiversity stewardship is based on voluntary commitments from landowners to support conservation and sustainable resource use. Some types of Biodiversity Stewardship Agreements are formally declared as protected areas in terms of the Protected Areas Act, providing long-term security for the sites involved. At least 450,000 ha have been secured through the creation of 74 protected areas, making considerable contributions towards South Africa's protected areas targets[20].

10.5 Community protected areas

Depending on the ownership or management of the land where the species recovery programme is to take place, there are a number of formal mechanisms for community protection of land and the species present[14,15]. In contrast to government owned or managed protected areas, the responsibility for caring for land or species within private or community protected areas sits with individuals or groups. If species only occur within a private or community managed site, their involvement in species recovery programmes is paramount to its success. Chapter 4 of this manual discusses different types of protected area in more detail. Some examples of community protected areas benefitting species recovery projects are provided in Box 10.3.

10.6 Conclusions

Community involvement in a species recovery programme can improve the success of the programme. It is best to involve the local community from the project outset and maintain community engagement and effective public outreach throughout the project.
It is important to be sensitive when working with local stakeholders. The aim should be to seek local knowledge (not issue instructions), and assess where local participation might be effective. It should be recognised that while there are many benefits to be obtained from active community involvement in species recovery programmes, this should not be at the cost of the effectiveness of the recovery programme. For example, for practical involvement in many recovery tasks, proper training will need to be provided by experts before responsibility is handed over to communities.

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Chapter 11.
Management interventions

Aim of this chapter

This chapter outlines the diversity of management interventions that may be required in a species conservation or recovery plan and provides details of some of them. It also considers the need for monitoring the effects of such interventions and defines what is meant by the terms recovery and recovered state. It then outlines the possible need for further management actions after recovery.

11.0 Introduction

Threatened species management that does not consider interactions between actions may result in misplaced investments or misguided expectations of the effort required to mitigate threats to species[1].

As we have seen, conservation and recovery plans usually involve some degree of management intervention. These interventions (also known as recovery actions) may be directed at the area or at the populations of the target species or both, and the nature and extent of these interventions depends largely on the details of the threats to which the populations or the area are subject, the population dynamics, the state and dynamics of the ecosystems and other factors. Many of the interventions are aimed at managing the threats to the populations that have been identified, such as weeding, removal of invasive species, control of predators, while others, notably augmentation, should not be employed until it has been shown that such threat management has not resulted in sufficient natural regeneration of the target population.

Often a species is the subject of a series of management interventions to achieve recovery (Case study 11).

Common interventions include:

- Habitat protection
- Habitat weeding to remove competitors
- Control or eradication of invasive species
- Control of unregulated livestock grazing or browsing
- Effective control of illegal collection of plant material
- Assisted pollination to increase seed set
- Removing risks to seedling recruitment
- Control of pests and disease
- Maintaining critical ecosystem processes or disturbance regimes, such as fire, that no longer occur naturally
- Restricting or promoting disturbance regimes such as salvage logging and prescribed burning
- Predator control
- Augmenting dispersers,
- Augmentation/Reinforcement/Enhancement of populations by seeding, seedlings, plants or vegetative propagules
- Soil improvement

Case study 11 Recovery actions for the Button Wrinklewort (*Rutidosis leptorrhynchoides*)

Button Wrinklewort is an endangered self-incompatible grassland herb endemic to the temperate grasslands of southeastern Australia which occurs today in three fragmented populations, one in eastern New South Wales, one in the Australian Capital Territory and the third in western Victoria. It is threatened by urban development, physical disturbance of sites, weeds, competition from native grasses, heavy grazing, unsuitable fire regimes, demographics of small populations, reproductive limitations resulting from the self-incompatibility system, genetic incompatibility between chromosomal races, and climate change.

In the 2012 version of the National Recovery Plan[2] for this species, the overall objective of this plan is to 'ensure that all populations consisting of more than 10 individuals are stable or increasing in size by reducing or managing threats, encouraging sympathetic site management to promote recruitment wherever possible, use of supplementary planting where appropriate and increased knowledge of the genetic diversity and response to disturbance of this species'.

To this end, the following management actions are proposed:

1. Remove threatening weeds
2. Monitor populations
3. Undertake ecological burning as needed
4. Prompt recording of new sites
5. Complete a survey of the genetic composition of all populations
6. Augmentation of small populations with germplasm from larger populations to achieve genetic enhancement
7. Formal reservation or negotiation of management agreements for populations on non-reserve tenure
8. Undertake various site-specific actions.

Sources: NSW Office of Environment and Heritage[2] and Weeks *et al.*[3]

- Control or prevention of soil erosion
- Improvement of associated mycorrhizal populations
- Windbreaks
- Human cultural education
- Strengthening legal protection.

As noted in Chapter 5, species populations will often be found to be exposed to multiple threats and in such cases, may require several different management interventions. As a consequence, there may be interaction between management actions and the cost, benefit, and feasibility of one action can change when another action is undertaken. As a result, practical decisions will need to be taken about which actions to implement and where[1].

Management interventions may be species-specific or part of threat-management strategies designed to conserve multiple species (plants and animals) in an area; or both may be required[4] (Case study 11).

Given the wide range of possible management actions that may be needed for species recovery, only some of the more common ones are discussed below in detail.

11.1 Habitat protection

As previously noted, habitat conservation is an essential requirement for species recovery planning. For example, the US Endangered Species Act requires that each recovery plan has to include 'site-specific management actions as may be necessary to achieve the plan's goal for the conservation and survival of the species'.

Case study 12 Management strategies for protecting 179 of the most threatened native plant and animal species of the Brigalow Belt bioregion, Queensland, Australia

Multiple, cumulative anthropogenic land use activities are threatening the persistence of native species in the Brigalow Belt bioregion, a highly modified biodiversity hotspot covering 20% of Queensland, Australia, part of which is protected. The suite of management strategies proposed include:

- Protecting remnant vegetation
- Protecting important regrowth
- Establishing key biodiversity areas
- Restoring key habitat
- Managing pest animals
- Managing invasive plants
- Managing fire regimes
- Managing grazing
- Managing hydrology
- Managing pollution.

Without effective implementation of these strategies, 21 species are likely to be functionally lost from the region over the next 50 years (persistence probabilities < 50%).

Source: Ponce Reyes *et al*.[4]

Because loss or degradation of habitat is the most common cause of species endangerment, site-specific actions should include identification, restoration, and management of habitat. Managing threats to the area as a whole is usually included in the management plan for the area. They are therefore primarily the responsibility of the area manager who will need to be consulted and who must be involved in any other management interventions being planned by the species recovery team.

11.2 Fencing

Fencing is a long-standing tradition in land resource management. The main aim of fencing is to prevent damaging agents or conditions from access to sensitive areas or ecosystems, and for land managers it provides 'defined units' that provide a limited and clear focus to exclude threatening agents such as livestock, humans, invasive species and diseases[5]. Fencing is widely used as a management tool in protected areas, to secure the whole or part of the territory.

Fencing is also a common management intervention in species recovery to close off the area in which a threatened population occurs to protect it from grazing by herbivores or other harmful activities. In translocation experiments with *Acacia aprica* and *A. cochlocarpa*, fencing seedlings immediately after planting clearly enhanced success, as seedlings of both taxa were more likely to survive when protected from herbivores[6]. Likewise, in a study of the role of fencing in the success of threatened plant species translocation of the narrow Sardinian endemic *Dianthus morisianus*, it was found that fences positively enhanced the plant's long-term survival, reproductive success and seedling recruitment by reducing herbivory and human disturbance[7].

Fencing may be employed for individual plants, for small groups of adjacent plants or for the site as a whole. This will depend on the size and habit of the plants concerned and how they are distributed within the area concerned. Likewise, the nature and height of the fencing will vary in relation to the size of the plants and the suspected herbivores. When fencing is employed, it is important that the site is regularly monitored to ensure that the fencing remains intact and to see how effective the action is.

The introduction of substantial fencing as part of a species recovery programme within a protected area may well have an effect on the ecosystem itself and on other species and will certainly require prior consultation with the area manager and other local stakeholders. It should not be assumed that agreement to proceed will be given, especially if there is a risk of its causing a detrimental effect to other species.

It should be recognised that conservationists and local people will have different perspectives on fencing: conservationists and resource managers tend to regard it as a means of maintaining the status of a resource or enabling recovery of degraded areas by excluding disturbance or threats (including humans) and to focus more on natural resource or species recovery, whereas the local people usually adopt a broader approach and take multiple objectives into consideration, for example exclusion fencing may be employed by local communities to protect sacred trees and forests[8].

11.3 Population augmentation or reinforcement

One of the commonest forms of intervention is **augmentation** or **reinforcement** (also known as restocking) of the target species' populations. It may be recommended when the populations of target species have decreased in number and genetic variability over time and are losing or have lost their viability. Augmentation is defined by IUCN[9] [as Reinforcement] as: 'the intentional movement and release of an organism into an existing population of conspecifics', and involves reintroduction of plants, propagules or seeds into pre-existing habitat or populations in an area that is currently known to contain the taxon, i.e. within the indigenous[10] range of the species. This approach is likely to be appropriate for species or populations with small or declining populations or ranges and/or high probabilities of extinction[11].

The aim of augmentation is to improve population viability by increasing the number of individuals in a population so as to enhance the possibility of cross-pollination, increasing genetic diversity or by increasing the representation of specific demographic groups or stages[12]. The genetic variability of the population may be enhanced by introducing individuals with new alleles into the population: for example, the introduction of specific genotypes when the presence of different flower morphs or S-alleles are necessary for successful reproduction has been proposed, or plants of particular gender to correct the sex ratio in a population[13].

At a genetic level, population augmentation is a key aspect of what is termed **genetic rescue** – the restoration of genetic diversity and enhancing viability and fitness in small populations that are suffering from genetic depletion through the introduction of new individuals or genotypes and enhanced geneflow through mediated pollination[14].

An example of genetic rescue in a Critically Endangered tree species, *Medusagyne oppositifolia*, is given in Case study 13.

Case study 13 Back from the brink: Genetic rescue of *Medusagyne oppositifolia*

Medusagyne oppositifolia is a Critically Endangered long-lived tropical tree endemic to the Seychelles. It has only 90 extant individuals in four populations, three of which suffer from recruitment failure and are also threatened by catastrophic events such as storms, drought and fire. Seed banking is not an option as the seeds are recalcitrant and lose viability rapidly in storage. In a study of the feasibility of genetic rescue it was found that artificial pollination between populations increased the proportion of viable seed and might represent a better option than within population crosses for the genetic and ecological rescue of the three smaller populations. For future recovery efforts, germination of seeds in nurseries to establish a supply of seedlings for genetic rescue to reverse the recruitment failure in the small populations is proposed, alongside artificial cross pollination with pollen from the large fourth population.

Source: Finger *et al*.[15]

Serruria furcellata restored to Bracken Nature Reserve in South Africa (Image: Anthony Hitchcock).

As with all translocations, augmentation carries with it risks (see below) and may be more costly to implement than alternative conservation actions, and so these factors have to be evaluated as part of the recovery process.

Guidelines and good practice on population augmentation are often found in reintroduction guidelines where they are included with other forms of translocation. As such, they have to be interpreted carefully as many of the recommendations do not apply to reinforcement of existing populations. Useful guidance can best be obtained from published recovery plans in which population augmentation is one of the recommended conservation actions.

It may not always be possible to undertake species recovery *in situ* through the augmentation of natural populations, due to lack of suitable habitat and other practical reasons. Such is the case of *Abies nebrodensis*, see Case study 14.

Case study 14 Recovery actions for *Abies nebrodensis*

Abies nebrodensis, the Sicilian fir, is a Critically Endangered species endemic to the Madonie Mountains in Sicily, Italy. It consists of a single relict population of some 30 adult trees spread over an area of 150 ha. Efforts to conserve it started in the 1940s and continue to the present day. They include programmes of dynamic *in situ* conservation, involving grafting, seed orchards and nursery cultivation and *in situ* conservation efforts.

Genetic analysis has revealed that there are three distinct zones within the population: the diversity core of the species, one site in a recolonizing phase and one site in an extinction phase. It appears that the diversity of microenvironments within its limited distribution area has been conducive to allowing the maintenance of a high level of genetic diversity, comparable in fact to that of other wide ranging Mediterranean *Abies* species with more numerous populations, such as *Abies alba*. This genetic variation contrasts with the generally unfavourable features of the present habitat which constrain efforts at *in situ* conservation and limit the survival possibilities of *A. nebrodensis in situ*. For more details see Ducci[16].

Case study 15 The Re-discovery and Restoration of *Serruria furcellata*

Serruria furcellata is classified in the SANBI Red list as Critically Endangered, the population having declined by nearly 100% in the past 100 years due to alien plant invasion, invasive alien ants, bush clearing, mowing, urban and industrial expansion, inappropriate fire management, increased mole rat activity and trampling, and only one plant is known to remain in the wild.

Last remaining wild plant of *Serruria furcellata* (Image: Anthony Hitchcock).

Serruria furcellata is a multi-stemmed, resprouting, shrub 0.5 m by 1 m across. The dissected leaves are distinctive of this species. The plant produces solitary, sweet-scented, pink flower-heads in spring from August to October. Once common in Sand Plain Fynbos from Brakenfell and Kraaifontein, its habitat has been transformed and by 1987 fewer than 250 plants remained at North Pine. Thereafter it was lost until two plants were rediscovered at North Pine by Ismail Ebrahim of the Protea Atlas Project. He and horticulturists from Kirstenbosch National Botanical Garden took cuttings and established them. Ismail also found a plant growing as part of the University of the Western Cape's rare species collection.

Seedlings germinated of *Serruria furcellata* (Image: Anthony Hitchcock).

It proved difficult to establish in pots and the garden. Success was achieved by planting them in the Kirstenbosch Threatened Species Stock beds. Here they have thrived with 100% survival rate and the two clones have produced viable seed that has been germinated in the nursery.

Plants were reintroduced to Bracken Nature Reserve in 2010, the nearest conservation area to its original home at North Pine. Unfortunately, the success rate is only 10.81% probably because Bracken Nature Reserve is a drier habitat. Tshepo Mamabolo, Area Manager for Bracken and Haasendal Nature Reserves reports that the 20 surviving plants are healthy and growing vigorously, but unfortunately no viable seeds have been produced. This is because only one clone was introduced.

Plants have been reintroduced to the original site at North Pine, but efforts by the City to establish a nature reserve at the site have been unsuccessful.

Kirstenbosch horticulturalists are meanwhile busy building up cultivated stock for future reintroduction as well as collecting seed to be stored in back up collections at the Royal Botanic Gardens, Kew Millennium Seed Bank.

Contributed by: Hitchcock, A., Kirstenbosch National Botanical Garden

Restoration planting of *Serruria furcellata* at Bracken Reserve (Image: Anthony Hitchcock).

Serruria furcellata restored to Bracken Nature Reserve (Image: Anthony Hitchcock).

11.3.1 Choice and location of source material

The material used for augmentation may be seed, seedlings or vegetative propagules such as cuttings or grafted scions (Case study 16 and see examples in Oldfield & Newton[17]) or cell/tissue cultures (micropropagation) derived from plants in the source population(s). The choice of the type of material to be used for augmentation differs from species to species, even within the same genus and several approaches may need to be tried. For example, in the South African *Protea roupelliae* subsp. *hamiltonii* whose population numbers declined to the point of near extinction before the greatest threat to its survival was identified, the following methods of *ex situ* propagation were applied: (a) semi-hard wood stem cuttings (b) germination of zygotic embryos (c) micropropagation through (i) direct organogenesis and (ii) indirect morphogenesis. In the event, the use of stored achenes under all storage regimes was found to be successful when planting achenes directly *in situ* or transplanting *ex situ* propagated seedlings *in situ* (transplants), but varied in their success between the two methods[18].

The source of seed or other reproductive material, both as regards its location and genetic composition, may have important consequences for the immediate success and long-term viability of augmentation efforts (for a detailed consideration, see Broadhurst and Boshier[19] and Boshier *et al*.[20], with particular reference to the restoration of forest trees but highly relevant here).

The source population(s) may be the target population itself or another viable population(s), preferably in close proximity to it. The use of local seed or other reproductive material for augmentation is widely recommended 'under the premise that this will be better adapted to local conditions and deliver superior outcomes through improved survival and growth'[21]. However, there is little guidance on how this should be evaluated. In the case of native tree species, concern has been expressed that 'local' can be interpreted in too narrow a sense, rather than being based on sound evidence of the scale over which adaptation occurs, and too restricted a seed collection could lead to the establishment of trees with restricted genetic diversity and limited adaptive potential[20] .

Material of the source population(s) of the target species stored in a seed banks may also be used, provided its provenance is well documented, as can seed from other populations of the species in the seed bank but if they are from a more distant area than the target population and adapted to a different set of conditions, this could carry the risk of outbreeding depression.

The following factors should be taken into account when using material for augmentation (based partly on Volis[13]; Falk *et al*.[12]; Maschinksi and Haskins[22]; and IUCN/SSC[9]. See also the Center for Plant Conservation (CPC) Revised Reintroduction Guidelines[23].

- The need for an assessment of genetic variability within populations and genetic distinctiveness between populations of the target species may be necessary to inform decisions about potential augmentation
- Also needed is an estimate of the Minimum Viable Population for the population to be augmented so as to inform the decision on how many individuals need to be introduced
- The origin and genetic makeup of the introduced plants in augmentation: the potential genetic consequences for the target population when choosing individuals for use in augmentation need to be considered
- Augmentation can be carried out using plants from a single source or by mixing plants from more than one source. Each will have its advantages and risks which need to carefully evaluated. On the one hand, the introduction of individuals derived from a limited number of families can lead to inbreeding depression and a decrease in effective population size while the introduction of plants adapted to different locations can lead to outbreeding depression.
- If the material for reinforcement comes from the same source population it should be genetically diverse (see detailed guidance in Chapter 9)
- However, as the threatened populations usually have already undergone dramatic reduction in size and genetic variation, propagation and introduction of local genotypes often will not improve the population's genetic make-up. A combination of plants from the source population and plants from populations that are an environmental match might be the best option (see Chapter 9 for guidance)
- If there is little genetic variation in source material used for translocations, there are two potential risks: the first is that reproduction between related individuals can lead to reduced vigour, reproductive output and survival (inbreeding depression); the second is a lack of adequate genetic variation to enable survival and adaptation in the face of environmental change
- Care musts be taken to ensure that the source population is able to sustain removal of individuals/propagules, and removal should not jeopardise any critical ecological function, except in the case of an emergency or rescue removal

Case study 16 Use of grafted scions of the Critically Endangered *Magnolia longipedunculata* in population augmentation trial in south China

In an augmentation project on *Magnolia longipedunculata*, scions were obtained from the largest wild plants available, i.e. large enough for them to be collected without threatening their survival. The scions were then grafted on to rootstocks of one year old *Magnolia kwangtungensis* (synonym *Manglietia moto*) and then planted in an augmentation plot. After artificial pollination of the flowers on two mature resprouted individuals derived from a stump of *Magnolia longipedunculata*, seeds were collected and immediately sown in the nursery. About 1,400 seeds germinated and the seedlings were also planted in the augmentation plot so that a comparison could be made with the grafted plantlings. Although both the grafted plantlings and the seedlings survived and grew well at the augmentation trial site, the grafted ones showed better survival and growth rates. This is one of only a few studies in which grafted scions were used in as augmentation material.

Source: Ren *et al*.[24]

- For reinforcement to be the optimal solution, it is necessary that the remaining populations of a threatened species are located in non-degraded and protected areas. If these locations are unprotected and have a low chance of being protected in the future, the populations are very likely to disappear as a result of human activity
- It is essential to engage with land managers at all stages when planning to use population augmentation.

11.3.2 The role of nursery-grown plants in augmentation

Although direct seeding or planting into the population being augmented may be practised, direct seeding is a risky procedure as seedling establishment is widely recognised as a bottleneck because of the low survival rates in the first years. More often seed of the material to be introduced is used to generate seedlings and grow on the plants in a nursery, in a botanic garden or other *ex situ* facility. Even when using seedlings or other outplants, fencing and watering are often found to be necessary interventions in the early stages of establishment.

It is important that strict protocols are adopted to ensure that the material grown is properly labelled and kept disease-free. If plants are grown on to maturity, care should be taken to avoid hybridisation.

It should be noted that nursery conditions are very different from those of the natural habitat. This can sometimes lead to unforeseen consequences. For example, in a study of the dipterocarp tree *Vateria indica* it has been shown that selfed individuals are more likely to survive under benign nursery conditions than under the harsher natural conditions of the forest floor[25]. They note that under natural forest conditions, effective selection against selfed and inbred wildlings has been observed in other dipterocarp species and that early acting selection appears to be common in tree species and augmentation may be less effective when seedlings are grown in nurseries. Elevated inbreeding under nursery conditions has been reported in restoration of other rare tree species. They recommend that 'where viable, restoration efforts using direct seeding of *V. indica* over planting nursery reared seedlings, should help to ensure natural selection against maladapted individuals and avoid establishment of inbred populations'.

Despite such issues, in view of the fact that many species cannot establish from seed under open conditions, the use of nursery-reared seedlings is often necessary in recovery programmes. In such cases, the proportion of inbred seedlings for restoration may be reduced by selecting only the most vigorous progeny[25].

11.3.3 Site considerations

Population reinforcement does not just consist of introducing new material into the pre-existing population. The micro-habitat conditions, such as topography, soil conditions, hydrology and overall condition of the ecosystem, and its state of management have to be taken into account to ensure the maximum possible chances of establishment and survival of the translocated material. It would be pointless, for example, reinforcing a population in a habitat that is infested with weeds or invasive species or that is otherwise threatened.

Also, if the habitat of the host population becomes degraded and cannot sustain a viable population, supplementation of this population may not compensate for local mortality and augmentation could prove to be a waste of conservation effort and also of valuable and difficult-to-replace plant material.

11.3.4 Sanitation

Care should be taken to ensure that the target population (and any other taxa in the site) is not contaminated by any pathogens that might be introduced by the materials used for augmentation (outplants), as the pathogens that affect them are likely to be deleterious also to the recipient population. The following actions that address these sanitation concerns have been suggested[26]:

- Strict sanitation and pest control measures at facilities preparing propagules or individuals for augmentation
- Strict protocols for prevention of contamination during the augmentation process
- Careful selection of augmentation sites
- Careful management of the augmentation sites
- Intensive monitoring of augmentation sites for contamination.

11.4 Habitat weeding and control of invasive species

A common problem is the presence of weedy species which can affect the ecological balance of the plant communities and also present a threat to the growth and survival of some of the individual native species. Some weedy species can become serious pests and develop invasive tendencies. The distinction between aggressively weedy and invasive alien species can be difficult to make. For example, on Lord Howe Island, Australia, at least 18 exotic species have been listed as noxious or environmental weeds. Several of these weedy species show a wide environmental tolerance and exhibit ecosystem changing characteristics such as the ability to invade intact communities and dominate the lower stratum to the extent of inhibiting native recruitment. As part of the island's threat abatement and restoration strategy, a Draft Weed Management Strategy and a Strategic Plan for Weed Management were introduced[27].

Invasive alien species affect ecosystems all over the world and are now recognized as an important threatening factor whose control may be difficult and expensive. A detailed assessment of the effect of invasive alien species in protected areas, with numerous examples from across the world, can be found in the monograph *Plant Invasions in Protected Areas* (2013)[28].

Removal of weeds from an area selected for a species recovery programme is a common management intervention although not always successful (Case study 17). Various weed control methods may be used – mechanical, chemical and biological – although in recovery areas, the options are often more restricted and great care needs to be taken when using herbicides so as to avoid affecting species other than the weedy ones and mechanical means or hand weeding may be the preferred means.

Case study 17 Recovering the devastated flora of the island of Rodrigues

Rodrigues in the Indian Ocean was once completely covered with evergreen forest but as a result of three centuries of human habitation all the original plant communities have gone and the island is today mainly barren hillsides, dotted with trees or covered with a usually monotypic shrub or thicket of introduced species; only a few areas of degraded native forest exist. According to the *Plant Red Data Book for Rodrigues*[29], at least 18 endemic plant species have become extinct and of the surviving 36-38 endemic flowering plants, 19-21 are Endangered, 7 Vulnerable and 8 Rare. Nine of the Endangered species are reduced to fewer than ten individuals and three are known from only a single wild individual. If the combined floras of Rodrigues and the neighbouring island of Mauritius are considered, at least 120 taxa are known from either fewer than 20 individuals or just one or two populations, and 28 species are known from fewer than ten individuals in the wild[30].

Recovery of such species is a major challenge: despite the work of Strahm[29] and others during the last 20–30 years through a programme of careful management, fenced-in areas, artificial propagation of plants, population augmentation of seed dispersing animals, replantation, weeding, promotion of conservation awareness and the designation of several areas as nature reserves, many of the most threatened species have still not recovered and are still at risk of extinction[31]. On the positive side, there is strong community participation in some of the restoration work and the fact that many of the threatened species still survive, albeit as only as small populations, is a remarkable achievement.

Source: modified from Heywood and Dulloo.[32]

11.5 Monitoring the effectiveness of management interventions: adaptive management

It is important that the progress and effectiveness of management interventions are regularly monitored as well as any impacts they may have on other species or on the habitat (see Chapter 12). It is difficult, however, to predict how species will react to management interventions, especially if the habitat is undergoing rapid change. To address this problem, **adaptive management** has been suggested. This is an iterative process whereby decisions are made in the recovery plan on how to meet the management objectives, and information is then obtained through monitoring the implementation of the actions and this in turn generates feedback to the conservation manager who can learn from the results how to improve future management actions. Structured management involves two phases of structured decision making: '*the deliberative phase*, in which managers assess the challenge, clarify objectives and alternatives, and design and implement a management strategy. In the *iterative phase*, managers monitor the results, evaluate the outcomes, and adjust their strategies accordingly. Throughout the process, managers integrate the elements of the iterative phase into the deliberative phase in an ongoing cycle of learning and adaptation.'[33]

A balance has to be struck, however, between using available resources for monitoring and for undertaking further recovery programmes.

11.6 How to decide if recovery has been achieved?

An important question that has to be addressed is, how to decide that a species has reached a state of recovery? This has been the subject of considerable debate[33]. The simple answer is: when the threats that affect the species have been eliminated, contained or managed and the species has recovered sufficiently so that it is no longer in danger of becoming extinct within the foreseeable future in the absence of or with little human intervention. Recovery is the attainment of the conditions by which the species is viable in the moderate-term future.

In practice, more objective, specific measurable recovery criteria need to be applied. The federal agencies that administer the US Endangered Species Act have recently adopted a 3Rs approach – the resiliency, redundancy, and representation of populations (see Box 11.1) – a science-based approach to developing species recovery criteria as proposed by Shaffer & Stein[34] for lowering extinction risk and maintaining self-sustaining populations

Box 11.1 The '3Rs' of Species Recovery

The 3Rs, resiliency, redundancy, and representation, are interconnected as the following definitions by Wolf *et al*.[35] (W) and Evans *et al*.[33] (E) indicate:

Representation: Representation requires the protection of populations across the full range of ecological settings of a species' range. (W)

There is sufficient genetic variation among populations of a species to conserve the breadth of the species' genetic makeup and its capacity to evolve and adapt to new environmental conditions. (E)

Resiliency: Resiliency encompasses population-specific attributes that increase long-term persistence in the face of disturbance. Resiliency can also address related issues regarding threats abatement and recovery of ecologically effective populations. (W)

Local populations of a species are large enough, have sufficient genetic variation, and are sufficiently mixed with respect to the age and sex of individuals to persist in the face of periodic threats such as drought, wildfire, and disease. (E)

Redundancy: Redundancy requires establishing multiple populations in each ecological setting to spread extinction risk and to increase species' viability. (W)

There are enough separate populations of a species to provide a margin of safety in case catastrophic events eliminate some populations. (E)

Case study 18 Conserving *Quercus brandegeei*, Morton Arboretum

Quercus brandegeei is a rare and highly restricted Mexican oak tree that is listed as Endangered on the IUCN Red List due to its small range. The species is found in only one location at the tip of Baja California Sur and faces major ecological barriers to regeneration in this area, undermining the long-term viability of the species. Lack of recruitment would cause population size to decline significantly within the next generation, however the factor(s) preventing regeneration and the extent of that decline is unknown. Since oaks are exceptional species and cannot be seed banked, living collections and *in situ* species recovery are extremely important conservation measures for preserving genetic diversity of rare species.

There are alternative theories as to what is preventing regeneration. Many experts agree that the lack of regeneration threatening *Q. brandegeei* is caused by increasing drought and the drying of the ephemeral streambed habitat. However, others point to heavy grazing by livestock across the range of *Q. brandegeei* as the largest threat to the species, seedlings being especially vulnerable to grazing.

Quercus brandegeei (Image: Neil Gerlowski/ Vallarta Botanical Gardens).

Quercus brandegeei (Image: Antonio Gonzalez Rodriguez/ Universidad Nacional Autónomo de México)

The Morton Arboretum, in collaboration with the Autonomous University of Mexico and others, is working to conserve *Q. brandegeei* through scientific research and scientifically informed conservation measures. The objective of this project is to uncover what exactly is preventing regeneration in order to inform future *in situ* recovery and restoration efforts. Currently, very few *ex situ* collections contain *Q. brandegeei*. By building *ex situ* collections, this project also ensures that *Q. brandegeei* is safeguarded against extinction and provides seedlings for future reintroductions.

The research and conservation of *Quercus brandegeei* entails performing a demographic study, collecting seeds from wild populations, performing acorn germination studies in greenhouses, disseminating seeds to botanical gardens, propagating material for reintroduction into the wild, and creating species-specific reintroduction plans that consider the tree's ecological restraints.

Contributed by: Denvir, A., The Morton Arboretum

Cattle grazing by *Quercus brandegeei* tree (Image: Audrey Denvir/ The Morton Arboretum).

Case Study 19 Promoting perennial grass regeneration by unpacking complex dormancy mechanisms and applying seed enhancement technologies: a hot desert example from northwest Australia

Grass regeneration in degraded landscapes is critical to reverse, or halt, the on-going impact of human disturbance. Yet for many species of grasses required for reclamation, rehabilitation, or restoration, initiating their establishment via seed is challenging. We lack clear protocols to address their complex seed germination requirements and to initiate establishment in often harsh and unpredictable environments. For the past nine years, researchers at the Botanic Gardens and Parks Authority and The University of Western Australia have focussed their efforts on a key grass genus, *Triodia* (R.Br.), which dominates large areas of inland Australia and possesses deeply dormant, difficult to germinate seeds.

The aim of this research has been to: categorise the seed dormancy class that regulates germination (Step 1); identify the underlying mechanisms that lead to the relief of dormancy and develop reliable seed pre-treatments (Step 2); and, combine this knowledge with novel seed enhancement technologies to maximise germination capacity under various seeding scenarios in field-based experiments (Step 3).

Step 1: Classification of seed dormancy

Triodia seeds are dispersed in an indehiscent floral husk (i.e. the floret comprised of the lemma and palea). Following the Baskin and Baskin[36,37] dormancy classification system, we have determined that *Triodia* seeds possess physiological dormancy. Physiological dormancy was confirmed based on: (1) the presence of a lateral, fully developed embryo within the seed; (2) the fact that florets, as well as seeds extracted from the florets, readily imbibe water; and (3) the low germination of freshly collected florets incubated over a broad range of temperatures suitable for germination.

Physiological dormancy is caused by an internal 'physiological' block to germination that restricts the embryo from growing and penetrating the external tissues (i.e. through the seed coat and floret structures).

Step 2: Breaking seed dormancy

Once the class of seed dormancy is known, dormancy-alleviation treatments can be developed to enhance germination. These treatments commonly mimic the conditions of the natural environment[38]. For instance, physiological ripening of dormant *Triodia* florets and/or seeds is induced by treatments that mimic the dry, hot summers (i.e. dry after-ripening), and periodically wet, followed by dry, soil conditions after sporadic thunderstorms (i.e. wet-dry cycling)[39,40]. Such techniques have assisted in unpacking the dormancy-alleviation and germination requirements of *Triodia* florets and seeds[39,41,42] with key findings including:

- Physical removal of the covering floret structures surrounding the seed improves seed germination drastically in multiple species, presumably through the release of the mechanical pressure imposed on the seed embryo by the floret. Optimum germination temperatures of >25°C align to the season of more reliable rainfall (e.g. the summer wet season in the north-western deserts of Australia).

- When compared to florets (+/- additional treatments), seeds extracted from florets germinate at lower soil water potentials (i.e. drier soil conditions). This is a major advantage under rehabilitation conditions with limited rainfall and soil moisture availability.

- Treatment of seeds extracted from florets with smoke-derived germination stimulants such as smoke water or karrikinolide, can further improve germination.

- Dry-after ripening of florets or seeds for up to 12-24 months in controlled storage conditions of 30°C and 50% relative humidity increases germination over time.

- Wet-dry cycling of florets by between two days of full hydration with 12 days in dry after-ripening conditions (as above) shortens the dormancy break period to as little as eight weeks (i.e. four 2-week long wet-dry cycles).

While most of these treatments increase germination of *Triodia* spp. in general, the specific treatments that maximise germination can be species-specific and treatments still need to be developed on a case-by-case basis. Subtle differences in the natural environment where species reside should be mimicked where possible.

Step 3: Maximising germination and emergence under field conditions

In historical rehabilitation attempts *Triodia* seeds lacked any germination capacity due to complex, unidentified dormancy mechanisms resulting in complete plant establishment failure (i.e. 0% germination and emergence) even after high rainfall periods. We have learnt to pre-treat florets or seeds to increase the overall germination capacity through specific cleaning methods and dormancy-alleviation treatments. We are now investigating the application of novel seed enhancement technologies to further optimise plant recruitment potential[43,44]. Combinations of 'flash flaming' to remove unwanted floret appendages, polymer seed coating to aid the mechanised seeding process, and priming of seeds in smoke-derived solutions are some examples that have increased the germination and emergence capacity of seeds under field conditions. In combination, these treatments improve the likelihood that each seed batch will recruit into mature, adult plants. Plant establishment success in this key grass genus has now increased from 0% to around 40% under multiple restoration scenarios (Figs. 2-5).

Contributed by: Erickson, T.E., Lewandrowski, W., Kildisheva, O.A., Guzzomi, A.L and Merritt, D.J., Kings Park & Botanic Garden

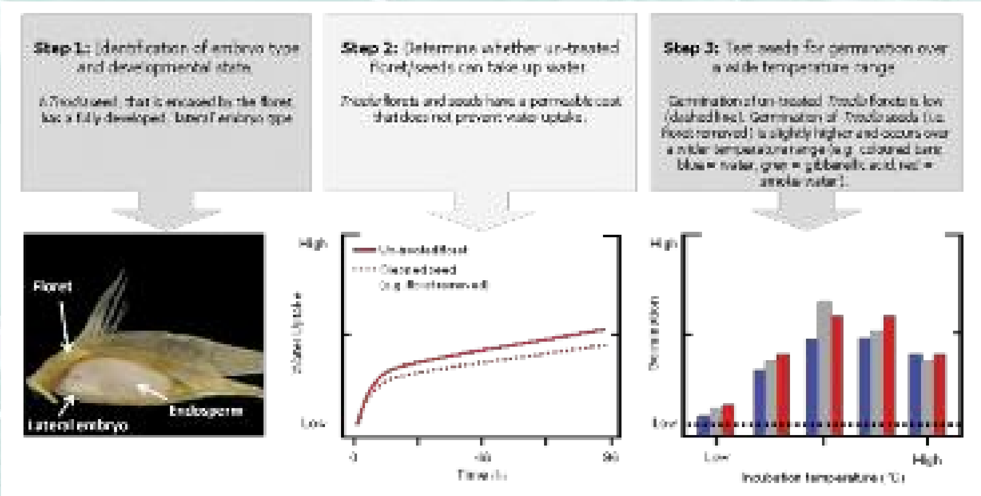
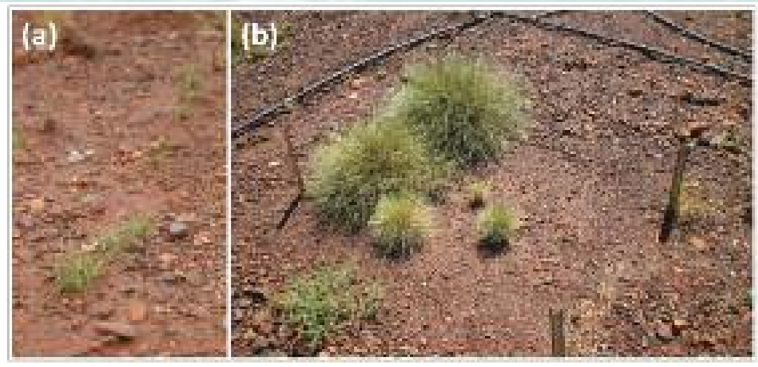


Fig. 1 – The seed dormancy classification process for grass species.

Fig. 2 – Seedling establishment of *Triodia* seeds is enhanced after the floret is removed and adequate rainfall is received (a). Once the initial recruitment bottleneck of germination and emergence are surpassed, *Triodia* plants survive and grow un-impeded for many years (b).



11.7 The need for post-recovery care: conservation-reliant species

It is often assumed that once the recovery goals for a species are met it will no longer require continuing management, but it has been found that even when management actions succeed in achieving biological recovery goals, maintenance of viable populations of many species will require continuing, species-specific intervention[45]. Such species have been termed 'conservation-reliant'. The term is rarely if at all used outside the US although many such species undoubtedly occur in other countries where the problem has not received much recognition. For conservation-reliant species requiring such ongoing management, **recovery management agreements**, designed to ensure that they will receive adequate protection and management may be proposed but these would involve not just agency supervision and support but a whole series of technical and legal requirements to be effective.

A review of all recovery plans for species listed as endangered or threatened under the Endangered Species Act found that 84% of the species are **conservation-reliant** and will require continuing, long-term management investments. If shown to be generally true, the economic and political implications of this analysis are serious and it is clear that decisions will have to be made by society as to how much investment it is prepared to sanction so as to maintain such species. Thus, a more nuanced definition may be preferred: A species is 'conservation-reliant' when it requires the management of threats to maintain its population or distribution at socially determined levels[46].

Rhododendron fletcherianum (Image: Ken Cox)

Zelkova abelicea fenced to test the effects of browsing in Crete.

11.8 Conclusions

The nature and extent of management interventions at the habitat and population level is extremely diverse and their planning and implementation requires considerable care and attention. Such interventions are aimed at removing or containing the threats that are endangering the species and may be supplemented by other actions such as population augmentation or genetic rescue if they are unsuccessful.

Population augmentation is a complex, often expensive and time-consuming process and requires careful planning by appropriately skilled experts such as population geneticists, ecologists, demographers, horticulturalists and propagators. The sourcing of the material to be used in augmentation is critical and can affect the chances of a successful outcome.

The decision that a species is successfully recovered is a difficult one and complicated by the fact that many species may require continuing management to maintain the target species recovered state once achieved.

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Brackenhurst Botanic Garden native tree nursery in Limuru, Kenya (Image: Barney Wilczak).

Chapter 12.
Monitoring and post-care

Aim of this chapter

This chapter identifies the different aspects of monitoring that need to be considered in a species recovery plan, highlighting that a successful monitoring programme, will integrate ecological, demographic and genetic monitoring, where possible. The different scales for monitoring and the different variables to be measured are outlined.

12.0 Introduction

Monitoring plays an important part in the conservation and recovery process, yet many monitoring programmes do not have a sound ecological basis, are poorly designed and do not lead to appropriate management interventions or responses, and are disconnected from decision making[1]. Monitoring is often given low priority because it can be difficult and expensive to implement and monitoring programmes are often inadequately funded and inadequately implemented.

Monitoring primarily consists of making reliable field observations and measurements. Whenever possible, experimental and genetic studies should be incorporated. Monitoring aims to:

- Detect, measure and evaluate how populations, species and ecosystems evolve in time and space, before (planning), during and after the implementation of a species recovery plan
- Draw conclusions about the success of the recovery in terms of long-term population viability and species sustainability
- Guide management decisions.

Regardless of the monitoring focus (individuals, populations, species or habitats), a monitoring strategy should be developed defining the:

- Objectives
- Methodology to be used for each parameter to follow
- Sampling strategy
- Review of the resources and equipment needed and any legal aspects such as licenses that may be necessary
- System and methodology for recording and storing data
- Process of data analysis and interpretation, and
- Timetable for the implementation of these steps.

An essential component of monitoring is the need to establish a baseline which will serve as a point of comparison for the data collected[2]. This involves compiling and reviewing available information on the population, species, habitat and any other element, process or action being monitored[2] (see Chapter 7 on eco-geographical surveying).

A successful monitoring programme will integrate ecological, demographic and genetic monitoring, where possible, as discussed in points 12.3-12.4 below.

12.1 What to monitor

The objectives pursued in the recovery plan will determine what has to be monitored so as to assess whether recovery actions are successful, for example:

- The viability of the recovered populations of the target species (both before and after management interventions) through the study of the spatio-temporal demographic dynamics and the changes in genetic diversity and structure
- The status of the target species' habitats in response to habitat restoration: changes in vegetation cover, hydrological or soil conditions
- The spread and control of invasive species.

Monitoring can be undertaken at different scales, from the individual plant to the landscape. In species recovery, most monitoring is undertaken on species and their populations and on habitats and areas.

12.2 Species and population monitoring

Species and population monitoring is the regular observation and recording of changes in status and trend of species, their populations or individuals in a population in a particular territory or location.

Definitions

Individual. An individual is the smallest unit that can be monitored. It is the basic unit of population dynamics. It is necessary to determine what constitutes as an individual[3], since many plant species propagate vegetatively, the individual must be defined as either a genetic or a functional entity. This has implications, for example, in the follow-up of recruitment it is necessary to distinguish between recruits resulting from sexual reproduction and clonal propagation, and in the estimation of effective population size[4].

Population. A population represents a group of individuals in a certain place and at a certain time. Monitoring of restored populations is often aimed at predicting the state of a particular population. This can be done by taking measurements from the whole population or a subsample of the population. If we choose to measure a subsample, then the studied subsample is considered to be representative of the whole population and we can assume that the variables measured on the subsample are a reliable estimate for the whole population (with a certain interval of confidence). A subsample can be selected by following a particular sampling design (e.g. random, systematic). It will represent either a subsample of the individuals present in a population or a subsample of the surface area occupied by the population (the latter will enable for measurement of environmental factors or vegetation composition, not just the target species).

12.2.1 Genetic monitoring

Aims and definitions

Genetic monitoring aims to determine whether the recovery plan contributes to the genetic restoration and/or to the genetic rescue of the populations under recovery (see also Chapters 9 and 11).

- **Genetic restoration** is the recovery of the genetic diversity to its former level, therefore increasing the evolutionary and adaptive potential of the population to future changing environmental conditions.
- **Genetic rescue** provides an opportunity to increase the fitness (i.e. the vigour) of plants suffering from genetic load (the presence of unfavourable genetic material) by the introduction of new genetic variation[5].

Sufficient contemporary gene flow between individuals, within and between populations, is often a key factor for the long-term persistence of populations. It is therefore a key factor to consider in population genetic viability assessments and genetic monitoring[6].

Genetic monitoring must also consider possible outbreeding depression which results in offspring with a lower fitness. This occurs when genotypes that are genetically very divergent mate, leading to the production of maladapted hybrids or to the breakdown of the local co-adapted gene complexes[7].

The following are examples of questions that may be addressed through genetic monitoring:

- Do populations under recovery show high, similar, or lower levels of within-population genetic variation, inbreeding and contemporary gene flow compared to the seed source and natural (inbred and/or healthy) populations? Have they diverged from each other?
- When multiple seed source populations are mixed from the translocation: is there admixture between the different sources in the newly produced individuals?
- Is there inbreeding and outbreeding depression, genetic rescue and local adaption when recovery programmes are carried out?

The genetic monitoring will provide recommendations for post-care (or aftercare) management interventions. This is particularly important for conservation-reliant species (see Chapter 11), which require continuing, specific management interventions for maintaining viable populations, also in terms of maintenance of high levels of genetic diversity and gene flow[8]. Therefore, some long-term genetic monitoring, even restricted to a few essential indicators (e.g. genetic diversity, gene dispersal and fitness estimates) may be needed for checking whether genetic restoration or rescue remain after recovery programmes are achieved.

Methodology

To evaluate whether there is effective genetic restoration and rescue in the populations under recovery, genetic data should be obtained from highly polymorphic molecular markers (preferably SNPs or microsatellites; also AFLPs or ISSRs) and fitness-related quantitative phenotypic character measurements for:

- Populations used as a seed source in cases of reinforcement or reintroduction
- Recovered populations (adults/transplants, newly recruited individuals and for the progeny obtained from seeds produced by the adults/transplants and the new recruits)
- naturally existing (inbred and healthy) populations.

The number of individuals to sample depends on the question being addressed and on the analyses to be performed. For instance:

- For paternity and parentage analyses, ideally all plants in flower should be sampled
- For calculating rates of self-fertilisation at least 20-30 offspring per maternal plant should be sampled
- For genetic diversity comparisons, a statistically sound subsample of individuals can be used.

Mapping of the individuals on the field is necessary for most analyses estimating gene dispersal.

Sampling of leaf material for molecular analyses in natural populations of *Helichrysum arenarium* (Image: Sandrine Godefroid).

Sampling of leaf material for molecular analyses in natural populations of *Arnica montana* (Image: Sandrine Godefroid).

Genetic variables and analyses

Several analyses of the molecular data can be performed to estimate genetic variation and structure using freely available software[9]:

- For within-population genetic variation: allelic richness and genetic diversity[10]
- For inbreeding: Wright's inbreeding coefficient (FIS) and selfing rates
- For contemporary gene flow: spatial genetic structure and parentage analyses[11], but also methods using powdered dyes as analogues for pollen[12]
- For between-population divergence: genetic differentiation statistics, Bayesian methods, and multivariate analyses (Principal Coordinate Analysis and Discriminant Analysis of Principal Components)[13].

How the new recruits result from seed germination or clonal propagation can be evaluated using individual genotypic data[14].

Evaluating whether there is admixture in the recruits can be realised using Bayesian methods, hybrid index, and parentage analyses[15].

To detect if there is inbreeding and outbreeding depression, genetic rescue and local adaptation newly produced individuals should be compared with plants from natural populations (seed source, inbred and/or healthy populations) for individual fitness-related quantitative traits, in relation to their molecular genotypes (e.g. heterozygosity), relatedness between individuals[16] or population of origin. Measurements should preferably be realised in standardised environments to avoid variation related to environmental effects[17].

The analyses should be conducted on several generations, in order to verify if the rescue effects are maintained, but also because outbreeding depression can be expressed after two or three generations of admixture (breakdown of the co-adapted genes) and because natural selection can occur, removing the poorly adapted genotypes[19].

To disentangle the above effects from effects of population or environmental factors, analysis of genetic data in relation to population demographic data (e.g. census population/patch size, plant density, sex/morph ratio for dioecious/heterostylous species, recruitment rate), and environmental data (see 12.4) should be completed[19].

Common garden (greenhouse) experiment at Botanic Garden Meise for the monitoring of the fitness progeny (F1 generation) of *Dianthus deltoides* with randomization of the plants (Image: Fabienne Van Rossum).

Common garden (greenhouse) experiment at Botanic Garden Meise for the monitoring of the fitness progeny (F1 generation) of *Arnica montana* with randomization of the plants (Image: Franck Hidvégi).

12.2.2 Demographic monitoring

Aims and definitions

Demographic monitoring consists of assessing changes in population size, dynamics and fitness. It may require frequent measurements or mapping to achieve the level of resolution necessary for an unbiased interpretation of the results. The frequency of monitoring may have to be adjusted, for example in cases of very short or very long life-times, episodic seed production, or abundant vegetative propagation[20].

Demographic monitoring often involves laborious procedures but is nevertheless essential for a good assessment of the restored populations. The benefits of demographic monitoring are:

- Better knowledge of the species biology, functioning and life cycle
- Information on population conservation status
- Identifying causes of population demographic decline or expansion
- Possibility of proposing evidence-based management measures[21], including aftercare in the period after the management interventions have been completed. This is particularly important for conservation-reliant species, i.e. those requiring continuous intervention for maintaining demographically viable populations (Chapter 11).

Methodology

Simultaneous monitoring of natural and restored populations is essential, because the comparison of population demographic dynamics and plant fitness allows one to determine the key parameters driving the viability of natural versus restored populations[22].

Although some monitoring does not distinguish different age classes or, on the contrary, focuses on only one age group, it should ideally identify the annual change in the demographic structure of a population, i.e. the distribution of individuals in different age classes[20]. For instance, to determine what percentage of the population in the restoration site is presented by seedlings, juveniles, non-reproductive, reproductive and senescent adults, individuals must be mapped and marked permanently. Such monitoring will be more sensitive to population changes than simply counting the number of individuals. Whatever the approach adopted, the following factors need to be measured in a demographic monitoring[23]:

Population variables

(a) Census population size

Monitoring the total number of individuals of a population allows for a relatively reliable assessment of whether the population is stable, expanding or declining. This method requires no special set-up and consists of a thorough survey to count all individuals, including those at young stages (seedlings, juveniles). For aquatic plants, which are frequently characterised by considerable year-to-year fluctuations in individuals, counting the number of individuals is also the most efficient way of monitoring[24].

Comprehensive counting has however several limitations:

- The process is usually long and tedious in the field
- There is a risk of observer errors
- It can be difficult to determine what is an individual while in the field
- Demarcation of the population is required year after year.

(b) Demographic structure

Recording the number of individuals by distinguishing plant stages (seedling, juvenile, and vegetative, flowering or senescent adult) can be highly informative[25]. Indeed, this method not only tracks the evolution of the total population, but also allows variations in survival for a given state and variations in reproductive performance and recruitment to be determined[26]. This method can also provide information on whether a population is expanding or senescing[27]. Instead of surveying the whole population, a rigorous sampling strategy can be used, provided it is representative of the entire population[24]. The shape and size of the quadrats or transects depend on the configuration of the populations, on the size of the plants, and on the analyses foreseen with the data (see 12.5).

(c) Recruitment and spatial extent

The reproductive success of the restored populations will be measured by the monitoring of adult (vegetative and flowering), juvenile and seedling recruitment. When the number of recruits is low, an exhaustive count may be considered. If recruitment is abundant, it may be wise to use small quadrats, especially for the early stages of life (seedlings and juveniles), which are sometimes difficult to spot among adults, and to extrapolate the results over the whole population surface.

Finally, to determine whether a population is expanding or regressing, it will be necessary to map the spatial extent of the population. This method consists of mapping the boundaries of the area occupied by a population[28]. It involves surveying the area surrounding the targeted population and identifying the position of any new individual, whether fertile or sterile, using a GPS. The population area can be calculated and the spatial extent of the population can be visualised on a map via GIS. In the case of species with a strong vegetative development easily recognisable from a distance, taking aerial photos at low altitude by means of a drone can also be useful for mapping the extent of a population. Alternatively, the mean and the maximum distance of the established juveniles to the next transplanted individual can also be measured[29].

Monitoring the recruitment of Everlasting (*Helichrysum arenarium*) using small quadrats. In order to save time on the field, the quadrats can be photographed, and pictures are subsequently imported into a software to count the number of ramets (rosettes) upon return to the office (Image: Sandrine Godefroid).

Individual plant fitness variables

The monitoring of plant fitness should be realised on a number of individuals representative of the population, covering several generations (including the newly recruited individuals), and high enough to allow statistical analyses and long-term studies (taking into account that some individuals being measured may die). The protocol must allow the same individuals to be easily identified year after year by marking individuals with permanent labels fixed in the soil or attaching labels directly to the plant and comprising a unique identification code to each individual. This can also be achieved by defining quadrats and/or by precise plant mapping via GPS or triangulation method. When the vegetation cover is dense, it is often necessary to reduce the size of the quadrat to limit problems related to the identification of individuals. Experience shows that monitoring is often abandoned on large quadrats in dense areas because of confusion between overlapping individuals.

The following variables can be measured:

(a) Survival

The most commonly reported assessment of the success of a species recovery plan is plant survival, i.e. the proportion of individuals surviving over a given period of time[30]. As survival may vary over time, it is recommended to record it over the long-term, e.g. more than 10 years[31]. For example, in the case of reintroductions, there is often a large mortality in the first year after planting due to transplantation shock[30]. A too short monitoring of survival could in this case lead to erroneous conclusions. Conversely, if there is little mortality in the first years, one could too hastily conclude the success of the recovery plan[32].

(b) Vegetative plant health and vigour

It may be useful to distinguish individuals that look healthy from those that are not, i.e. presenting signs of necrosis, wilting, dryness and infestation. Chlorosis, for example, may be a sign of damaged roots, presence of pathogens, deficiencies in nutrients, and/or inbreeding/outbreeding depression[33] (see 12.3.1). The presence of morphological aberrations (e.g. leaves or branches) can also be a sign of an alteration of the mitochondrial DNA[34]. This type of phenomenon may be of crucial importance, for example in the case of plants reintroduced using questionable genetic material.

In order to determine plant vigour, several variables can be used to measure plant size such as rosette diameter, leaf area, plant height, number of leaves, volume, and trunk diameter (for trees). The choice of variable(s) to select depends on the species' growth habit, for instance plant height will not be relevant for a creeping species, or counting the number of leaves is difficult for species producing numerous small leaves. To calculate growth rates, the measurements need to be repeated over time. Biomass estimates can be used to measure vegetative plant health and vigour (e.g. extrapolated from diameter at breast height (DBH) measurements for trees), but destructive biomass measurements that involve removing parts or all of the plant to weigh them, should be excluded.

For the monitoring of seed production, bagging inflorescences may be useful to prevent seed loss (Image: Sandrine Godefroid).

(c) Reproductive performance: flowering and fruiting

To monitor plant flowering, the following variables should be taken into account:

- Age of individuals at the time of first flowering
- Number of flowers per stem
- Number of stems per plant.

In the case of species with complex inflorescences in families such as Asteraceae or Apiaceae, counting the flowers can be, for practical reasons, replaced by a count and a measure of the diameter of the flower heads or umbels.

As each flower does not necessarily develop into a fruit (for several biological and environmental reasons), it is of utmost importance to estimate the fertility of individuals. The ability of plants to produce seeds leading then to offspring is one of the most important criteria for determining the sustainability of a restored population[35]. Estimating reproductive success requires examining quantitative as well as qualitative aspects:

- Number of fruits (and flowers) to calculate the proportion of flowers developing into fruits (fruit set)
- Number of ripe closed fruits (before seed dispersal)
- Number of unfertilised ovules
- Number of viable and aborted seeds, to calculate the proportion of viable and aborted seeds (viable and aborted seed sets)
- In controlled conditions, germination ability of a subsample of the seeds produced
- Seed weight, which can sometimes be used as a proxy for germination capacity[36].

Left: Monitoring of floral display (number of flowering stalks and flower heads per stalk) of Everlasting (*Helichrysum arenarium*) in Belgium (Image: Daniel Parmentier).

12.3 Ecological and habitat monitoring

Aims and definitions

Ecological and habitat monitoring is aimed at verifying whether the restoration of the environmental conditions specific to an ecosystem has enabled species targeted for recovery to find suitable conditions for their ecological niche in the restored site.

Methodology

In practice, such monitoring consists of repeatedly recording information on habitat status in order to detect any deviation from a predetermined criterion, target state or previous state. The standard method is based on the recording of biotic and abiotic field data and mapping of the vegetation[37]. However, the abiotic conditions necessary for a species can vary greatly during plant development, the adult niche being often wider than the recruitment niche[38], therefore the population might persist as adults under particular conditions but without any establishment of new recruits[39]. This highlights the importance of performing an integrated analysis, combining the ecological, demographic and genetic monitoring results.

The following variables can be measured during ecological and habitat monitoring.

Biotic variables

(a) Vegetation composition

The composition of the plant communities and the abundance of specialist species in the habitat are essential indicators for evaluating the success of a recovery project. Indeed, specialist species are more sensitive to environmental changes – and so to the restoration measures applied – than generalist species[40]. Important variables to measure are species richness, diversity, frequency, density and/or cover-abundance. Species recording can be undertaken along transects or in quadrats. Phytosociological surveying (e.g. using Braun-Blanquet cover classes) is a useful tool for evaluating the interactions encountered by the target species with the other species present on the site[41], allowing for various multivariate analyses[42].

(b) Pollinator guilds

For animal-pollinated obligate outcrossing species, reproductive success depends on pollination service, and therefore it is essential to evaluate whether the plant-pollinator interactions have also been restored[43]. Estimating the abundance and quality of pollinator guilds may be realised by an inventory of the flower visitors (to estimate species richness and diversity), and by conducting flower observations on target species for quantifying the abundance (number of individuals) and visitation rates, per visiting species or per taxonomic groups, depending on their importance as pollinators[44].

(c) Disturbance

Every disturbance (anthropogenic or natural) to the site, e.g. management regime, floods, wildfires, grazing pressure, should be recorded with its time and period of occurrence, so that their potential effects on demographic and genetic data can be taken into account in the analyses.

Abiotic variables

(a) Soil

Deciding which soil factors to monitor depends on the habitat concerned, e.g. in a grassland it will be relevant to measure the trophic level (N, P, K) and pH, while for a peat bog one can also focus on the level and fluctuations of the water table. Soil samples have to be collected in the field at root depth[45]. Variables such as soil acidity, moisture, and fertility can be inferred by means of vegetation surveys followed by the calculation of indicator values, such as Ellenberg's[46] and Landolt's[47]. In some cases, visualisation and computer-assisted interpretation of satellite images can also be applied to habitat monitoring (e.g. soil moisture assessment using radar images[48]).

(b) Microclimate

Some plant species can be very sensitive to the climatic variations, which can lead to population fluctuations from year to year, therefore complicating the interpretation of the outcome of the recovery plan. In such cases, it may be very useful to monitor, in time and space, the variations of the microclimate at the restoration sites. To do so, it is very practical and cheap to use data loggers placed in the target sites[49]. These devices record both air temperature and relative humidity at set intervals over a period of time, allowing, for instance, analysis of previous-year influence on current-year population performance.

12.4 Timing and frequency of the monitoring

The accuracy of the demographic, genetic and ecological monitoring for evaluating the success of recovery plans depends to a large extent on the timing and frequency of data collection, which may depend on the target species life cycle, phenology, growth form (annual, short-lived or long-lived perennial) and the season at which it is best suited to measurements[50]. The frequency and the timing of the monitoring must also be adapted to the frequency of environmental disturbances (e.g. management regime, floods, wildfires). Moreover, the more threatened a population is, the more frequent the monitoring is needed. It is important to keep in mind that if the timing of the monitoring is not appropriate to the circumstances, it may result in a lack of useful information. For instance, in some aquatic plants, the extent of fluctuations in growth is considerable, which means that monitoring timing is of critical importance for examining long-term population changes[24].

Repeated monitoring also allows:

- The estimation of effective population size (Ne), based on molecular data using linkage disequilibrium estimator (comparison of Ne over several years), temporal changes in allele frequency and/or sibship/parentage frequency method[51]
- The performance of a Population Viability Analysis (PVA), which builds a model to estimate the size needed for the persistence of populations and their risk of extinction[52]. The PVA is usually based on demographic data, by recording the state of individuals in each life cycle stage over time[53], but also on genetic data, taking the evolutionary potential into account[54].

Case study 20 Monitoring Critically Endangered species reintroduced in restored grasslands in southern Belgium

Monitored transplanted populations of *Dianthus deltoides* (Image: Daniel Parmentier).

In the framework of the EU-LIFE project "Herbages" (LIFE11 NAT/BE/001060), the Botanic Garden of Meise in Belgium has implemented population transplantations in the wild for four Critically Endangered species (*Arnica montana, Campanula glomerata*, *Dianthus deltoides* and *Helichrysum arenarium*). The aim is to increase the effective size of remaining populations (reinforcement) and to restore extinct populations (reintroduction) in order to improve connectivity in the landscape and consequently species survival prospects. For each species, a population of 500 to 700 young individuals was transplanted in three to six different sites using multiple seed source origins. Once *in situ* these plants were labelled and precisely mapped to facilitate their long-term monitoring (the first letter of the plant code showing its seed source origin). In the first years of monitoring, fences were placed to protect plants from ungulate herbivory and allow flowering and seed production. The demographic and genetic monitoring of the translocated plants, foreseen over 10 years, includes the following aspects (illustrated by the pictures shown across the text):

- Monitoring of the fitness of the transplanted individuals: survival, vegetative plant size (rosette diameter), floral production estimated by counting the number of flowering stalks per plant and the number of flowers per stalk (in the case of Asteraceae, flower heads are counted instead of flowers), and reproductive success by the sampling of closed ripe fruits or fruiting heads for estimating seed production and quality (aborted and viable seeds)
- Estimation of population extension by clonal propagation and seedling recruitment: counting the new recruits in the whole population or in permanent quadrats and measurement of the population area
- Testing for genetic restoration and rescue on offspring fitness: seeds produced by a subset of the translocated plants have been collected and germinated in controlled conditions in order to study the performances of the F1 generation, e.g. germination rate, seedling chlorosis, vegetative growth (number of leaves or ramifications, rosette diameter, leaf area and shape), and to perform molecular analyses to estimate genetic diversity and structure.

Contributed by: Godefroid, S. and Van Rossum, F., Botanic Garden Meise

Monitored transplanted populations of *Arnica montana* (Image: Sandrine Godefroid).

Monitored transplanted populations of *Helichrysum arenarium* (Image: Daniel Parmentier).

Monitored transplanted populations of *Campanula glomerata* (Image: Sandrine Godefroid).

It has also been shown that the duration of the monitoring under a species restoration programme is often too short, which means that recovery success and long-term population viability are not properly evaluated[55]. There may indeed be tremendous differences in short-term success and long-term viability of the restored populations[56]. Some conservationists believe that monitoring to measure success is necessary over several decades[57], but these timeframes will depend on the generation time of the species involved.

Measuring the success of a recovery project is also covered in Chapter 11.

12.5 Reporting

Reporting is an integral part of monitoring. It allows for communication with partners and stakeholders on what has been done, summarises the progress of the recovery of the target species or habitat, demonstrates the impact of a recovery plan, and highlights lessons learned.

Whatever the target audience, its requirements or imposed deadlines, it is necessary to develop a reporting strategy in order to align data collection with reporting needs and to optimize the time spent on reporting.

Before analysing the data, it is important to consider how to meet the reporting needs of the intended users. Several questions have to be asked, for example:

- What should be included in the report (e.g. methodology, monitoring location, equipment used, variables monitored, results of monitoring data analyses, pictures, conclusions, and management recommendations)?
- What is the level of detail required (executive summary or full technical report)?
- What is the frequency of reporting?
- To what extent should complex scientific data be popularized?
- In which format(s) should information be communicated (e.g. as a written report, in a workshop, conference, etc.)?

Reporting times are often a constraint in monitoring. A report is sometimes requested at an early stage of the monitoring process to guide funding or management decisions for the next phases of a restoration programme. In such cases a report may be required before effects can be observed, and it will be necessary to deliver preliminary results while providing evidence that these are important, but not necessarily concluding prerequisites for assessing the long-term success of the recovery plan.

Restoration site at Kadoorie Farm and Botanic Garden in Hong Kong, China.

12.6 Conclusion

Careful monitoring will ultimately assess the extent to which the implementation of a species management or recovery plan is successful or not. Even if the definition of success varies among authors[58], it always includes the ability of a population to survive and reproduce, and to adapt to changing environmental conditions. More specifically, a recovery plan will be truly successful when the target population grows in number and area, when individuals are flowering and fruiting, when subsequent generations of plants appear spontaneously, when the population shows signs of persistence in future decades, both in terms of demographic dynamics and maintenance of genetic diversity and gene flow, and when it disperses its seeds in the surrounding landscape and produces satellite populations.

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Chapter 13.
Lessons learned and future prospects

Aim of this chapter

This chapter summarises the main issues that have been highlighted in this manual and looks at the changing circumstances in which species conservation and recovery will be practised in the coming decades.

13.1 Lessons learned

- **Species conservation and recovery should be undertaken in a well-planned and structured manner to avoid wasted efforts.**
- **A diversity of approaches is possible in attempting to save species from extinction**. While many of these may fall short of successful recovery and serve mainly as short-term fixes that buy time until more effective actions can be taken, such actions should not be discouraged.
- **There is a current lack of strategic planning for species conservation and recovery both at a global level and at a national/subnational level.** Each country should develop a strategy and action plan for species recovery to enable it to meet national and international targets and proceed beyond conservation assessments to conservation action.
- **Many countries rely on protected areas as the primary strategy for conserving threatened species *in situ* without any further targeted action to remove threats to species.**
- **It is important to distinguish between the presence of a species in a protected area and its long-term persistence there as a viable population(s).**
- **The majority of threatened species occur outside protected areas**, although most known recovery plans are for species that are found within protected areas.
- **For threatened species within and outside of protected areas, species-specific actions are required to ensure the long-term persistence of viable populations.**
- **Conservation of target species outside protected areas can be carried out in many ways.** It relies on agreements being made with landowners and is usually dependent on the cooperation and participation of the local community. Too little is known of the long-term effectiveness of such approaches.
- **Species recovery work should be urgently increased in tropical countries**, where there is a high diversity of threatened species, little tradition for *in situ* conservation of target plant species, and strategies to achieve this are generally lacking as well as a lack of adequate capacity and infrastructure.
- **Species conservation and recovery typically involves a wide range of disciplines and participants and is essentially a cooperative process.**
- **The importance of community conservation actions aimed at saving threatened species from extinction deserves higher recognition**,
- **Proper identification of the threats to a species is a key requirement in developing a species recovery plan.**
- **Recovery objectives and how they are to be measured need to be agreed as a critical part of a recovery plan**.
- **Monitoring is another key component at all stages of recovery planning and action and must be continued as part of aftercare**.

13.2 Future prospects

Until recently, biodiversity conservation has been predicated on the assumption that we live in a dynamic but slowly changing world[1]. Now such an assumption has to be reconsidered with the realization of the scale and likely consequences of global change (demographic, land use and disturbance regimes, climatic change) on the maintenance and sustainable use of biodiversity and agrobiodiversity. With the current global population of 7.3 billion now expected to reach 8.5 billion by 2030, 9.7 billion in 2050 and 11.2 billion in 2100[2], the pressure on the world's biodiversity and the goods and services it provides will become unsustainable.

The rapid rate of climate change already being experienced and confidently predicted to continue, if not increase over the coming decades, according to the latest reports and assessments, has led to a drastic rethink of our planning horizons: the timescale of concern has been foreshortened and we now have to focus on the next 10 to 50 years during which critical actions will have to be taken to avoid irreversible changes.

Salad burnet, *Sanguisorba minor* being grown for restoration at Wakehurst Place, Royal Botanic Gardens, Kew (Image: Barney Wilczak).

Seed cleaning at the Royal Botanic Gardens, Kew Millennium Seed Bank (Image: Barney Wilczak).

Both the projected scale and the rate of climate change require us to rethink and recalibrate our conservation responses. All aspects of biodiversity conservation are affected by global change: it is driving large scale shifts in the distributions of species and in the composition of biological communities. The impacts on systems of protected areas will be profound in many regions of the world. The fixed nature of protected area systems makes it difficult for them to respond to change and considerable rethinking in the design of such areas will be needed if they are to survive and remain effective. Although it will be possible for some protected areas to be extended so as to cover more eco-climatically suitable territory for migrating species' populations, this option will often not be available. There will also need to be more flexibility in size and scale so that a connected network of patches of habitats at various scales is created so as to allow species the possibility to migrate and adjust their ranges in response to climatic and other change, although evidence suggests that this is more likely to be effective for animals than for plants. Many protected areas will suffer moderate to substantial species loss while other species will migrate into them (including alien invasive species), leading to changes in the assemblages of species that they house, and some protected areas may disappear altogether with catastrophic species loss.

Although the general picture is fairly clear, the details at a national and local level are still uncertain and likely to remain so until more accurate and sophisticated modelling reduces the uncertainty as to the scale and extent of climatic and other change. Given that species recovery projects take place *in situ*, the likely state of habitats once impacted by climate change is a further factor that needs to be taken into account when planning recovery programmes.

The probable impacts of global, change have yet to be taken into account in threat assessments for the majority of plant species. The general pattern, however, is clear: many species will migrate, tracking the changing climate, while others will be able to adapt to the changing conditions, and those that can do neither will become extinct. Long-lived species such as trees will be particularly susceptible to the impacts of climate change and many tree populations will become fragmented and individual specimens main only persist as 'living dead'. A great amount of modelling of the capacity of species populations to migrate in the face of climate change has been undertaken although very much more needs to be done[3]. Also, the ability of species to adapt to climate change is becoming an important research field and it has been suggested that we should focus more attention on the ability of species to cope with change and to help them survive through *in situ* management[4].

The likely consequences of global and in particular climate change for species recovery are that may more species will become candidates for such action. To address this, countries will need not only to enhance their species recovery efforts but seek innovative solutions as part of integrated conservation strategies.

13.3 Sustainability

Although it is now generally agreed that biodiversity conservation plays an integral role in sustainable development, the role of species conservation and recovery in environmental sustainability is not an obvious one. It is easy to point to the non-sustainable use of species through over-collecting, a common threat affecting species of economic importance, and so the recovery of species to a state where they can be sustainably used will contribute to sustainability in the sense of Brundtland: 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'[5]. Likewise, the fewer threatened species a protected area contains, the more likely it is to be healthy and able to provide the goods and services on which we are dependent.

Endnotes

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Mechanised seed harvest in a species-rich hay meadow for restoration of degraded meadows in southern Belgium (Image: Séverin Pierret).

Annexes
1. Glossary

Tissue culture of orchid species at the Xishuangbanna Tropical Botanic Gardens (Image: Barney Wilczak).

Accession: A plant sample held in an *ex situ* setting, such as a genebank or botanic garden, for conservation and use.

Adaptation: The evolutionary process by which species change over time in response to their environment.

Adaptive management: A systematic process for continually improving management policies and practices by learning from the outcomes of previously employed policies and practices. The use of new information gathered from monitoring and other sources to adjust management strategies and practices to assist in providing for the conservation of species.

Augmentation (population augmentation): The process of adding individuals to a declining/threatened wild population with the aim of enhancing its numbers and genetic diversity so as to improve its viability and help its recovery. Also known as **population reinforcement**, **supplementation** or **enhancement**. The term **genetic augmentation** is applied when the augmentation is specifically designed to alter the genetic diversity of the threatened population. See also **Genetic rescue**.

Circa situm: There is lack of consistency in the way this term is interpreted. It is sometimes referred to as 'conservation through use'. Other definitions include: the management of forest species outside of strict *in situ* reserves or natural habitats; a type of conservation that emphasizes the role of regenerating saplings in linking vegetation remnants in heavily modified or fragmented landscapes such as those of traditional agroforestry and farming systems; a form of conservation outside natural habitats but within a species' native geographical range whereby planted and/or remnant trees and wildings are maintained in agricultural landscapes where natural forest or woodland containing the same trees was once found. It is also referred to as '***circum situm***' and often, incorrectly and ungrammatically, as '***circum situ***' or '***circa situ***'.

Community conservation: Conservation actions carried out by local communities.

Conservation easement: A legal agreement that allows landowners to voluntarily restrict or limit the kinds of development that may occur on their land.

Conservation introduction: Establishing new populations of a species outside of its natural range.

Meadow restoration at the Royal Botanic Gardens, Kew Millennium Seed Bank (Image: Barney Wilczak).

Conservation reliant: A species is conservation reliant when it requires the management of threats to maintain its population or distribution at determined levels.

Conservation translocation: The deliberate movement and release of a living organism from one location to another with the purpose of improving its conservation status.

***Ex situ* conservation**: The maintenance of germplasm in facilities such as seed banks, pollen banks, field genebanks, botanic gardens (living collections), and tissue/cell culture laboratories for the short, medium or long-term storage.

Field genebanks: *In situ* conservation of seedling banks to maintain a large number of young plants in a relatively small area, especially for species with recalcitrant seeds.

Focal species: The species that is the subject of conservation or recovery action. Also known as **Target species**.

Gene flow: The exchange of genetic material between populations.

Genepool: The total amount of genetic diversity present in a particular population or set of populations of a species.

Genetic diversity: The genetic variation present in a population or species.

Genetic drift: The unpredictable changes in allele frequency which occurs in populations of small size owing to the disappearance of particular genes as individuals die or do not reproduce.

Genetic erosion: Loss of genetic diversity between and within populations of the same species over time, or reduction of the genetic base of a species.

Genetic resources: Germplasm of plants, animals or other organisms containing useful traits of actual or potential value.

Genetic rescue: The process whereby genetic diversity in inbred populations or endangered species is increased so as to improve or restore population fitness and survival.

Genotype: The genetic composition of an organism with reference to a single trait or a set of traits.

Germplasm: The genetic material which forms the physical basis of heredity and which is transmitted from one generation to the next by means of the germ cells.

Inter situs: The establishment of species by reintroduction to locations outside the current range but within the recent past range of the species. It is usually referred to as ***inter situ***.

***In situ* conservation**: (1) At the habitat level, creating protected areas of various types for the conservation of ecosystem diversity and biological diversity or important or significant species diversity; and (2) at the species/population level, conserving individual target species or small groups of target species (threatened or not) through *in situ* management and monitoring.

Management interventions: The actions taken to help achieve the recovery of the species or populations. These include assisted pollination, habitat protection, fencing, restrictions on wild-collecting, control of disease, control of invasive species, augmentation of populations and monitoring, amongst many others. Also known as **recovery actions**.

Outplanting: The transfer of *ex situ* plant material to an *in situ* location, as in recovery and reintroduction programmes.

Protection: The choice and implementation of measures necessary to halt the further decline of a threatened species or population.

***Quasi in situ* conservation**: A term used to describe an approach that acts as a bridge between *ex situ* and *in situ* conservation whereby *ex situ* collections are maintained in a natural or semi-natural environment while preserving both neutral and adaptive genetic diversity.

Recovery: The procedures whereby species, or targeted populations of species, that have become endangered are recovered in their present habitat to a state whereby they are able to maintain themselves without further human intervention. Recovery is also used to refer to the outcome or recovered end-state of the process (also known as **recovered state**). The terms **recovery actions**, **recovery goal**, **recovery criteria**, and **recovery objectives** are also used.

Recovery actions: The steps taken to manage the species so as to achieve the recovery goals(s). Also known as **management interventions**.

Recovery criteria: The measures used to determine that the recovery goals have been achieved.

Recovery goal: The specific qualitative or quantitative condition that it is hoped to achieve through a recovery programme.

Recovery objectives: Recovery objectives link the recovery goal and criteria, thus recovery objectives are the parameters of the goal, and criteria are the measures of those parameters.

Recovery plan/Recovery action plan: A document stating the research and management actions necessary to stop the decline, support the recovery and enhance the chance of long-term survival in the wild, of a stated species or community.

Reintroduction: The deliberate movement of individuals of a species to parts of its natural range from which it has been lost with the aim of establishing a new population. The IUCN restoration guidelines definition is: the intentional movement and release of an organism inside its indigenous range from which it has disappeared. Reintroduction aims to re-establish a viable population of the focal species within its indigenous range. It should be noted that usage of the term reintroduction varies from country to country and is often used as a general term for any controlled translocation of material including population augmentation in species recovery. We recommend adopting a strict definition as given here to avoid confusion.

Release site/location/population: The place in which translocated organisms are released.

Restoration: The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. In conservation, restoration is a general term that is used in many ways, including: ecological restoration, habitat restoration, species restoration, population restoration, etc. Its use without qualification is best avoided.

Source population: The place where translocated organisms are taken from (the donor site).

Target species: The species that is the subject of conservation or recovery action. Also known as **focal species**.

Translocation: The transfer of material from one part of the existing species' range to another. See also **conservation translocation**.

Note that the IUCN reintroduction guidelines use the term 'translocation' in a broad sense and distinguish between **conservation translocation** which they define as 'the intentional movement and release of a living organism where the primary objective is a conservation benefit: this will usually comprise improving the conservation status of the focal species locally or globally,..' and **population restoration** through reinforcement or reintroduction within a species' indigenous range as well as **conservation introductions** outside a species' indigenous range.

Rocla silica sand extraction and Banksia habitat restoration (Image: Barney Wilczak).

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