BIODIVERSITY PLAN 2023-35

ST ANDREWS BOTANIC GARDEN

FOREWARD

St Andrews Botanic Garden's 2023-35 Biodiversity Plan enables this unique and wonderful place to make a pioneering contribution to the most pressing challenges facing us today, and is welcomed by the University of St Andrews.

Climate change has brought our relationship with nature and plants into urgent focus, and this Plan sets out an approach aimed at not only understanding its impacts but on developing new insights with the potential to build resilience, supporting a more sustainable future. I especially admire the Plan's bold focus on plants that are, or will become, typical of this part of Scotland. Alongside forwarding climate relevant research, it is a Plan that puts people at its heart, and in this mix of research, education and engagement, I can see how the Botanic Garden as 'a place to draw hope' from will flourish. Last year the University made sustainability a theme in our University Strategy 2022-27, and like St Andrews Botanic Garden we will advance both our research and education initiatives in this area. Our theme equally recognises the importance of partnerships in creating a different future and we look forward to finding many more ways to spark activities between the Botanic Garden, the University, and our shared friends.

At the end of On the Origin of Species, Charles Darwin describes a tangled bank — an ecosystem of plants, birds and insects whose evolution is inextricably linked by their dependence on one another for survival – and I am glad to see this metaphor revived in the Biodiversity Plan. The University and the Botanic Garden are part of the tangled bank of this part of the world, and the evolution of each will be furthered together.

Professor Gareth Miles
Assistant Vice Principal, Dean of Science
University of St Andrews

June 2023

PREFACE

We are currently facing serious global challenges, such as the interrelated climate change emergency and biodiversity crisis. Although such challenges are becoming increasingly established in public consciousness, what is not as transparent is how such global challenges can be addressed at different levels of scale. In other words, we require mechanisms for social inclusiveness if such challenges are to be addressed meaningfully at local level.

Botanic gardens play an important role in not only addressing pressing global challenges, but also in providing a mechanism for public understanding and social inclusiveness. The St Andrews Botanic Garden is no exception, and our contribution is nicely captured in our comprehensive Biodiversity Plan, which will underpin all elements of the garden going forward.

The Biodiversity Plan is scientifically based and includes multiple strands that will inform biodiversity management, both within the garden and beyond its borders across Fife. At the same time, the climate-based perspective of the Plan, and its impact on acquisition strategy and display design, will connect what is happening locally in Fife to other parts of the world that share similar climates and similar challenges of impacts of climate change on biodiversity.

As noted above, the Plan is socially inclusive. Not only will visitors to the garden become more aware of the challenges being addressed through this plan (and thus learn more about the world of plants and how they respond to different and changing environments), there will be volunteer roles arising that will provide first-hand opportunities to contribute to response to global challenges on a local scale, bringing to action the phrase coined by a past Professor of Plant Biology at the University of St Andrews (Queens College Campus), Sir Patrick Geddes: “Think globally, act locally”.

Professor Thomas Meagher
Chair, St Andrews Botanic Garden Trust
Director, Global Challenges Forum, University of St Andrews

June 2023

EXECUTIVE SUMMARY

Our understanding of plants and their ecosystems have developed in ways that the founders of the St Andrews Botanic Garden in the nineteenth century could hardly have imagined, and the questions that botanists ask now are different to the questions that were asked when many of the Garden's plants were first planted. Plants are on the move as populations adapt to the changing climate (Sharma et al., 2022) but botanists know that not all plants move as quickly as each other, or in the same direction. The processes of plant migration and accelerated evolution hold significant implications for Fife as plant communities re-assemble, physiologies adapt and new niches emerge.

However, alongside the massive losses of biodiversity we have seen in the recent past, we are witnessing a growing public understanding of the challenges we face, and a greater acceptance of the necessary changes to the status quo. Now is the time to embrace these changes and take advantage of this revitalised passion for the natural world, showing that a gentler and more imaginative approach can be beneficial for humans and for the environment.

The Botanic Garden moved from South Street to the Bassaguard site in the 1960s, with much of its plant collections and building infrastructure being maintained according to the original plans for the past sixty years. Looking forwards over the next sixty years, this Biodiversity Plan identifies the needs and opportunity to refresh the plants, the infrastructure in which they sit, and our ambitions so that we have a framework for research and education that speaks to contemporary botanical challenges.

Our strategic plans set out a vision for the Botanic Garden's role at local, regional and international scales in monitoring, risk assessing, and supporting plants to respond to new conditions. Above all, this vision is rooted in our desire to meet these challenges, pivoting the Botanic Garden from being a place of collection and display to one that identifies and prepares for future challenges by supporting programmes in Fife and temperate regions around the world, and a place where visitors can see locally-relevant examples of the ecological drivers of evolution.

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OUR VISION

Botanic gardens are in a unique position to improve our understanding of the plant kingdom, addressing some of the most urgent issues of our time. Every answer to the challenges presented by climate change and the biodiversity crisis requires a better understanding of how plants function and evolve, and in particular, how they respond to environmental and climatic conditions. To this end, our first steps will be to root the Garden's work in time and space, focussing on the ecological drivers of evolution in temperate zones.

Working with partners in Fife and around the world, St Andrews Botanic Garden will be a window into the habitats where these plants can be found. As part of a network of sites, we will manage the Garden so that it can be used not only as tangible reference to existing and novel habitats but also a place where experiments can be conducted that would not be possible in plants' natural ranges.

The Garden is a highly biodiverse series of constructed habitats, and it is not yet clear to what extent these assemblages influence the physiology of the plants within them, or how these assemblages feedback on their environment and in turn, evolutionary mechanisms (Pausas and Bond, 2022). For this reason, we will ensure that high quality evidence is at the heart of our planning and decision-

Biodiversity Plan 2023-35

making, developing the Botanic Garden as a long-term experiment so that findings can be transparently investigated and shared. In delivering this vision, we will work to six principles:

- The Garden will be managed to maximise ecological resilience, focusing on our niche as a garden of temperate plants but without an exclusive focus on native plants, or any perceived ecosystem integrity. **We find all plants fascinating**, whether they are pavements weeds or canopy trees, and our management will allow multi-trophic interactions and communities to develop and be measured.

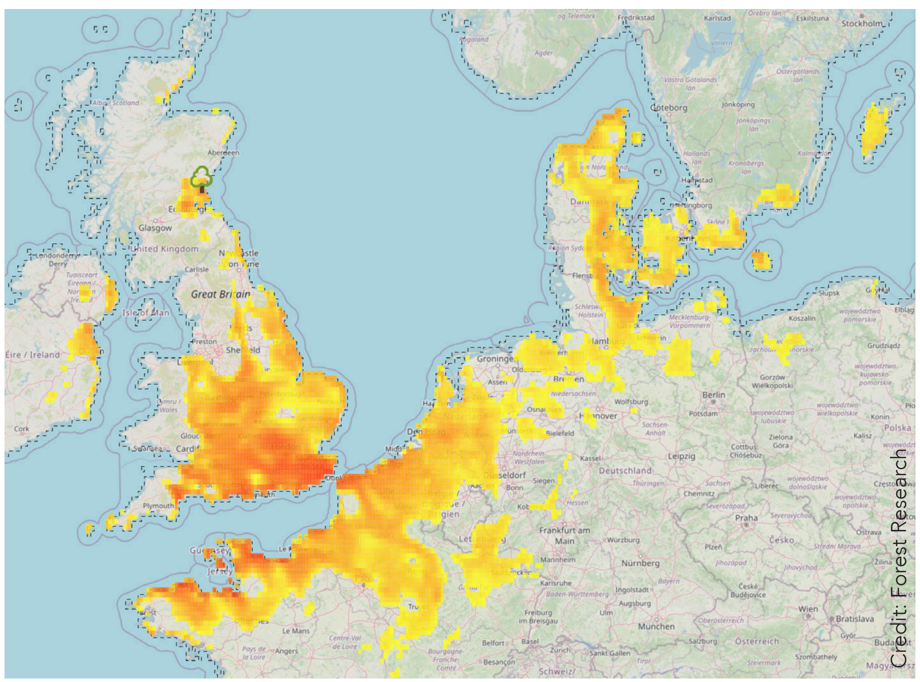
- The Garden aims to demonstrate **sustainable best practice** across all areas of the business, decreasing our footprint whilst inspiring positive change in others. To do this, we will ask climate relevant research questions which allow us to understand how the distributions of plants are changing as a response to climate change and how we can predict likely impacts on their range. This will be an increasingly necessary part of conservation – with associated thorny questions of assisted migration, selective breeding and so on – as the changes become more pronounced.

- To be **a living, dynamic testbed** for trying out new methods and techniques which can be usefully scaled to contribute to the ecological resilience of the ecosystems around us. By working with partners as part of a network of linked sites, we will build detailed and in-depth datasets through biodiversity monitoring, contributing to deeper understanding of eco-evo dynamics and more accurate ecological forecasting.

- To be **a hub for sharing knowledge and skills**, and encouraging people of all backgrounds to develop creative and positive botanically inspired solutions to the problems that we face. We will provide quality information and advice on habitat management and green infrastructure development. The Botanic Garden draws on a combination of academic and practical skill sets, and is excellently placed for developing, testing and scaling management techniques which will contribute to some of the pressing issues facing us. Our environment is coming under increasing pressure to serve multiple purposes (eg carbon sequestration, biodiversity, ecosystem services etc) and a combination of ecological theory and practical vegetation management skills will be vital in balancing these demands.

- Our plant nursery and propagation facilities play an important role. One of our key strengths as a Botanic Garden is the knowledge, skills and facilities to grow a wide range of unusual and specialist plants. We are harnessing this niche by **propogating and sharing locally-fitted, biosecure plants**, as well as developing our capacity to produce stock for conservation projects, ecological restoration and green infrastructure projects. Our ecophysiological research and commitment to benefit sharing will enable us to identify and propagate novel genotypes (Graudal et al., 2022) which will be optimally suited to novel planting conditions.

- The garden must continue to be **a place to draw hope**, where visitors can find peace and inspiration, and where everyone feels welcome. By accepting that we cannot do everything, our focus will remain on doing the things which will have the greatest impact, whilst supporting others to do what we cannot.



Places currently with climates similar to those expected to be seen in Fife in 2073

Building strategic partnerships

St Andrews occupies a very specific climate envelope, being relatively cold (Warmth Index – 46), dry (annual precipitation – 650mm), and coastal (isothermatlity – 39.68%). We will use this climate perspective to prioritise our research, conservation and education work on habitats and plants that occur in places that have similar climates to us in Fife, and places which have climates similar to those we expect to experience in Fife in the medium term (2070-90). This will ensure that not only is there a coherent botanical mission but also a strong motivation for conservation that arises from collaborating on shared challenges and co-developing opportunities for education and training.

Going further, we can use assessments of soils, land uses and depleted habitats (Grantham et al., 2020) to identify locations around the world that have both biotic and abiotic similarities with St Andrews. Through this process of identifying places with similar climates and habitats, we will prioritise partnerships that operate in habitats that can be replicated in the Botanic Garden, as well as the ecotones between them, including urban, grassland, coastal, agricultural, woodland and riparian habitats. These links will be essential not only for research but in creating compelling opportunities for engagement.

At national and international scales, the Botanic Garden will collaborate with researchers to act as a link to best practice for farmers, foresters and community planting groups who have closely aligned strategic goals, as well as organisations that undertake large-scale land use change or management but without conservation as their primary goal (for example housing developers or golf course managers). In these ways, identifying partners where we can add value, share resources and interests, and develop complementary expertise will ensure that we are able to focus on forward-looking initiatives with practical outcomes.

Transition to a more resilient Garden

Managing the Garden primarily as a functioning eco-evo experiment will require careful changes to previous curatorial practices but open exciting new possibilities. Modern botanic gardens must provide a wide number of services that at times can be contradictory but if carefully planned, synergistic, including serving as a visitor attraction, facilities for research and conservation, a resource for education of all kinds, a greenspace resource for local communities, biodiverse habitats and CO_2 sink, underpinned by means of generating income. They must also be managed in a way which secures their long-term health and security, and with finite resources and staff time.

The Botanic Garden has already changed significantly in three years leading up to this Plan, with a substantial reduction in glasshouses and complete redevelopment of several areas to create the Tangled Bank project. Managing the vegetation in an extensive, low-intervention way changes how staff time is allocated, and works effectively in areas of the Garden which have been designed with this management style in mind. Existing areas designed for horticultural display, such as the herbaceous borders, rock garden and entrance area, will need a nuanced design approach to develop an aesthetic language that embraces a lighter, more sustainable, horticultural touch. Over time, these more formal areas will be developed to allow a fuller expression of ecological processes, and to explicitly serve the research and conservation goals of the Trust.

Reflecting findings in recent research, recent bioblitzes in the Botanic Garden suggest that the resilience of the Garden's habitats are constrained by their size, coherence and management regimes (Galiana et al., 2022). Further, a growing body of evidence indicates that the distribution of habitats and biomes at a global scale will change significantly by 2070 (Boonman et al., 2022), presenting a medium-term time frame for the Garden to respond to. To inform decision-making and provide a baseline for measuring change, we will begin with all projects with a mapping exercise to establish a fine-grained baseline understanding of topography, physical conditions and functional phytosociology, and develop habitat management goals for each area that harnessed this evidence to reinforce biodiversity in each area.

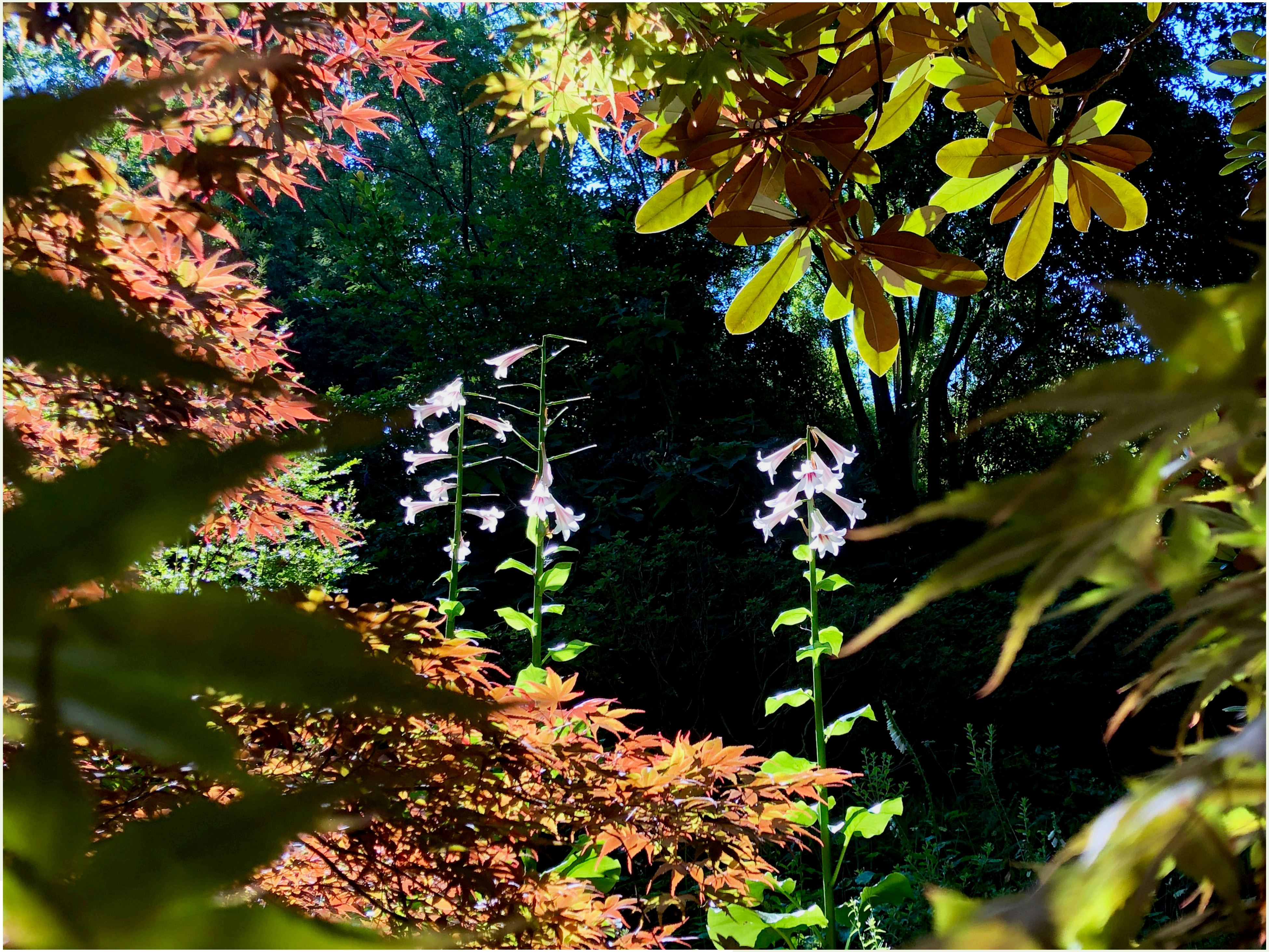
Landscape design principles

Although a relatively small garden of 18 acres, we are part of networks across Fife and around the world, extending our footprint in time and space. The decisions we make today will shape our work for years to come; as curators, we benefit from the decisions taken over the course of the past sixty years, and we set ourselves the same challenge to support future curators. Our Biodiversity Plan responds to the 'Big Here' and 'Long Now': an understanding that the precise moment we're in grows out of the past and is a seed for the future (Eno, 2020). This approach means taking a careful approach with the plants growing in the Garden, prioritising adaptation and selection over wholesale change when taking curatorial decisions.

To communicate our botanical mission, we will develop a landscape language that helps visitors to understand the ecological dynamics that they can see unfolding. Working with populations of plants, rather than individuals, and celebrating ecological systems with a light-touch horticulture will establish a design language that reflects a sense of place, harnessing features that are specific to north east Fife such as the quality of light and the haar to transcend spatial connections, and ensuring that the plants themselves will be the best medium for inspiring visitors to learn more about plants.

An inherent challenge of this approach is that the human experience of a landscape is a window in time, making natural phenomena such as change, novelty and resilience difficult to perceive; a difficulty that is exacerbated by the relatively short growing season in Fife which limits the times when visitors tend to want to visit collections temperate plants.

To overcome this, the principle of 'the medium being the message' will help communicate complex ideas such as plant community dynamics or multi-trophic ecosystems: there is a tractable limit to the level of detail that can be communicated effectively through signs and labels, and harnessing co-design as a tool for sharing complex ideas and changes that operate at different scales will place more of an emphasis on personal, emotional responses to the plants and the places in the Garden. Underpinning this approach, art and play will be used to create opportunities for exploration and reflection, underlining the importance of experience over interpretation.



Policy context

Our Biodiversity Plan is designed to complement existing initiatives, and our work we will support aligned policy goals at international, national and local scales, with core outcomes set out in Table 1 below. Scotland's Biodiversity Strategy and Fife's Biodiversity Action Plan are in development at the time of writing, and we will identify aligned policy goals as these are published.

UN Sustainability Goal 10	• Providing access to the Botanic Garden and high quality learning outcomes, • Supporting in situ and trans situ programmes to ensure equitable access to nature, • Ensuring that meaningful 'Benefit sharing' is prioritised within exchanges of genetic material as part of ABS agreements.
UN Sustainability Goal 11	• Supporting communities in establishing resilient green infrastructure by providing plants and consultancy
UN Sustainability Goal 13	• Reaching ambitious goals for our net carbon footprint • Supporting initiatives that seek to better manage habitats and sequester carbon
UN Sustainability Goal 15	• Support and initiate evidence-led in situ and ex situ conservation • Provide data and guidance to initiatives looking to carry out habitat conservation projects • Undertake research that addresses key conservation challenges
Global Strategy for Plant Conservation Target 8	• Use genetic material from ex situ conservation projects in active research projects so that they can better inform in situ and trans situ initiatives
UK 25 Year Environment Plan	• Taking action to recover threatened, iconic or economically important species and where possible to prevent human-induced extinction or loss of known threatened species (D7). • Making sure that there are high quality, accessible, natural spaces close to where people live and work, particularly in urban areas, and encouraging more people to spend time in them to benefit their health and wellbeing (G4). • Managing and reducing the impact of existing plant and animal diseases; lowering the risk of new ones and tackling invasive non-native species (H1).
Scottish Government Biodiversity Strategy, 2022-45	• Supporting and leading initiatives to halt biodiversity loss • Placing biodiversity at the heart of all areas of our decision making, • Providing good governance and accountability, and using a systems-approach to work with partners
Fife Council Plan for Fife, 2017-27	• Thriving places: Active in conservation initiatives across rural, coastal and urban habitats in Fife • Opportunities for all: Provide high quality learning outcomes and work-place opportunities • Community-led services: Collaborate with and support communities and land managers across Fife and Tayside
University of St Andrews Biodiversity Strategy, 2018-28	• Support data recording and monitoring across the University campus and initiatives • Provide and promote hands-on teaching about biodiversity and sustainable ecosystem management within the University
Climate adaptation for nature (POST Note 679)	• Supporting assisted migration to conserve species genetic diversity and create well-managed, resilient habitats in Fife.

Case study: botanical conservation

Key challenges

- Access to high quality evidence and using it effectively in decision making
- Involving communities in co-design and ensuring long-term commitments are sustained
- Ensuring that benefit sharing is as highly valued as securing access to genetic materials

Our role

- Partnership-based approach to conservation, ensuring that projects are collaborative and support nature connectedness
- Support in situ and trans situ conservation by using habitats in SABG for long term monitoring and Common Garden Experiments and to test interventions before their application in conservation projects
- Plant multiple accessions of plants introduced to SABG, ensuring that representation of genetic diversity within species is maximised and that demographic processes can unfold.

Adding value

- Contribute to plant species conservation assessment programmes
- Support and extend botanical databases through SABG biodiversity monitoring programmes
- Collaborate with research partners to refine management plans through evidence synthesis, consultation, and ecological forecasting

Case study: green infrastructure

Key challenges

- How to optimise ecosystem service delivery in the face of climate change
- Improving habitat resilience to biosecurity and plant health risks
- Managing complex supply chains and reducing variations to contract

Our role

- Providing guidance to partners to optimise plant selection
- Producing climate-fitted plants for high performing landscapes
- Managing plant databases that develop biosecurity preparedness

Adding value

- Help partners to deliver biodiversity and sustainability goals
- Engaging with green infrastructure industry to showcase best practice and provide guidance
- Develop landscape management plans, harnessing insights from SABG biodiversity monitoring

Case study: health and wellbeing

Key challenges

- Nature disconnect and health issues are exacerbated by a shortage of public green space in St Andrews and North East Fife
- Increasing demand for health support creates a constraint on service delivery
- Seasonal variation in weather conditions can make it difficult for some groups to visit year-round

Our role

- Harness diversity of activities in SABG to develop a range of ways of accessing nature, from self-led visits through to formal green social prescribing programmes
- Widen access through infrastructure development and supporting visits by under-served audiences
- Use landscape design as a way of providing a diversity of spaces and habitats that support different ways of engaging with nature

Adding value

- Friends of SABG and volunteering programmes will play a key role in developing informal opportunities for social contact in welcoming settings
- A strong sense of place identity reinforced by botanical development of the Botanic Garden provides high quality setting for green social prescribing
- Development of SABG team to provide support partners to deliver activities and programmes

Case study: education

Key challenges

- In spite of central role of plants in the biodiversity crisis, there is a lack of botanical content in curriculum-based learning
- Shortage of plant-based expertise in teaching and leadership roles
- Horticulture, green infrastructure and conservation industries struggle to recruit students and fill employed positions

Our role

- Create habitats in the botanic garden that are designed to be studied by wide range of audiences, with multiple points of access to botanical content
- Integrative approach to botanical education, collaborating with other STEAM strands
- Provide evidence-based, inspiring examples of solutions to the biodiversity crisis with clear industry applications

Adding value

- Engage with industry to develop employability opportunities, showcase best practice and provide guidance
- Connect with botanic garden networks to support complementary approaches and specialisms in education and research
- Emphasise importance of experience-led learning through exploration and play

CORE PROJECTS 2023-35

To provide the foundations for new botanical programmes and a refreshed visitor experience, we will focus on nine projects over the course of the 12 year plan. These projects are each essential to the Garden's charitable objectives, and are designed to provide high-level goals with considerable scope for co-delivery and partnership development. Identifying botanical projects that are core to our charitable objectives will not only provide clarity to partners about co-benefits and areas of mutual interest, but also create a clear strategic framework for our business activities.

Whilst some of the projects are critical for staff welfare and reinforcing business resilience, the sequence in which the projects are delivered will to an extent be necessarily opportunistic, with partnerships and external support playing a significant role in capacity-building. However, the combination of resources required and the scales at which the projects vary will allow us to undertake selected projects in parallel and incrementally, playing to our strengths of being nimble and forward-thinking, and making full use of the many important plants in the Garden.

The Tangled Bank is a flagship project for the Garden and an example of how these strands can come together, leading to conservation impact beyond the Garden. Taking its name

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from the final pages of On the Origin of Species, which set out a poetic description of how plants and animals interact and evolve (Darwin, 1859), the Tangled Bank exemplifies the ways that ecological dynamics influence evolutionary processes in places we know well in Fife and see in other temperate habitats around the world. In the Tangled Bank we are establishing a long term experiment in the heart of the Botanic Garden that will generate insights into plant adaptation and invasion in response to climate change, and in this way contribute both to science and applied conservation.

The Tangled Bank comprises three grassland habitats which replicate habitats that are found in places around the world with similar climates to Fife: woodland margins, coastal grasslands, and urban landscapes. In each of these parts of the Tangled Bank, we will encourage multi-trophic communities to develop that can be the basis for experimentation, and create clear ways in which people can see how these experiments are unfolding. In this way, the landscape design provides opportunities for visitors to see ecosystems that are accessible to all.

By curating the Garden in such a way that the plants and their assemblages are inspiring and directly relevant to visitors, education programmes and green infrastructure managers, we will have a strong foundation for translating our research into practice. To this end, the curatorial development of the Garden will go hand-in-hand with programmes to record the botanical dynamics in the Garden and in partner sites through our Sentinel Species. Together, this combination of curatorial development and a commitment to long term biodiversity monitoring will enable the Garden to be a place that helps anticipate botanical dynamics under a changing climate, and work with people around the world to create richer, more resilient habitats.

BIODIVERSITY MONITORING PROGRAMME

Objectives

- To better understand the dynamics of temperate plants as they respond to the effects of climate change.
- To build a longitudinal dataset that integrates eco-physiology and life history of plants in temperate regions around the world.
- To use our data as the basis for evidence-led conservation, making it available to researchers and practitioners in industry standard formats.

Actions

- Working with partners in Fife and around the world, we will establish monitoring protocols, grow volunteer networks and build institutional capacity with equipment and facilities.
- In the Botanic Garden, we will encourage the development of multi-trophic habitats in the Tangled Bank that can be the basis for paired studies in partner sites, leading to in situ conservation outcomes.
- Through the monitoring of sentinel species in St Andrews Botanic Garden and partner sites, we will identify co-benefits leading to trans situ conservation outcomes.

Measures for success

- Regular, high quality data assembled and shared with existing programmes.
- Database maintained with permissions as necessary.
- Programmes contribute to University of St Andrews undergraduate teaching and post graduate research, including Vertically Integrated Projects.
- Data used to create iterative near-term ecological forecasts that are the basis for applied conservation, guidance and policy.

TANGLED BANK: WOOD PASTURES AND MARGINS

Objectives

- To monitor the interactions between grasses, forbs and scattered trees in habitats such as such as woodland margins and silvopastoral systems.
- To better understand processes of community assembly and resilience following disturbance events.

Actions

- We will establish permanent quadrats in the Botanic Garden and partner sites, using these as part of the Biodiversity Monitoring Programme.
- Curatorial development of the tree collection, focusing on species with appropriate ecological strategies.
- Open up tree canopy to increase light to ground flora and improve sight lines for visitors.

Measures for success

- Coherent habitat established and conservation outcomes measured.
- Data recorded in Biodiversity Monitoring Programme and shared with existing databases.
- Clear sight lines into the Botanic Garden and a landscape character that takes advantage of the quality of light in this part of the Garden.

TANGLED BANK: COASTAL GRASSLANDS

Objectives

- To monitor the responses of native coastal grassland plants to invasion and disturbance.
- To better understand processes of community assembly and resilience following disturbance events.

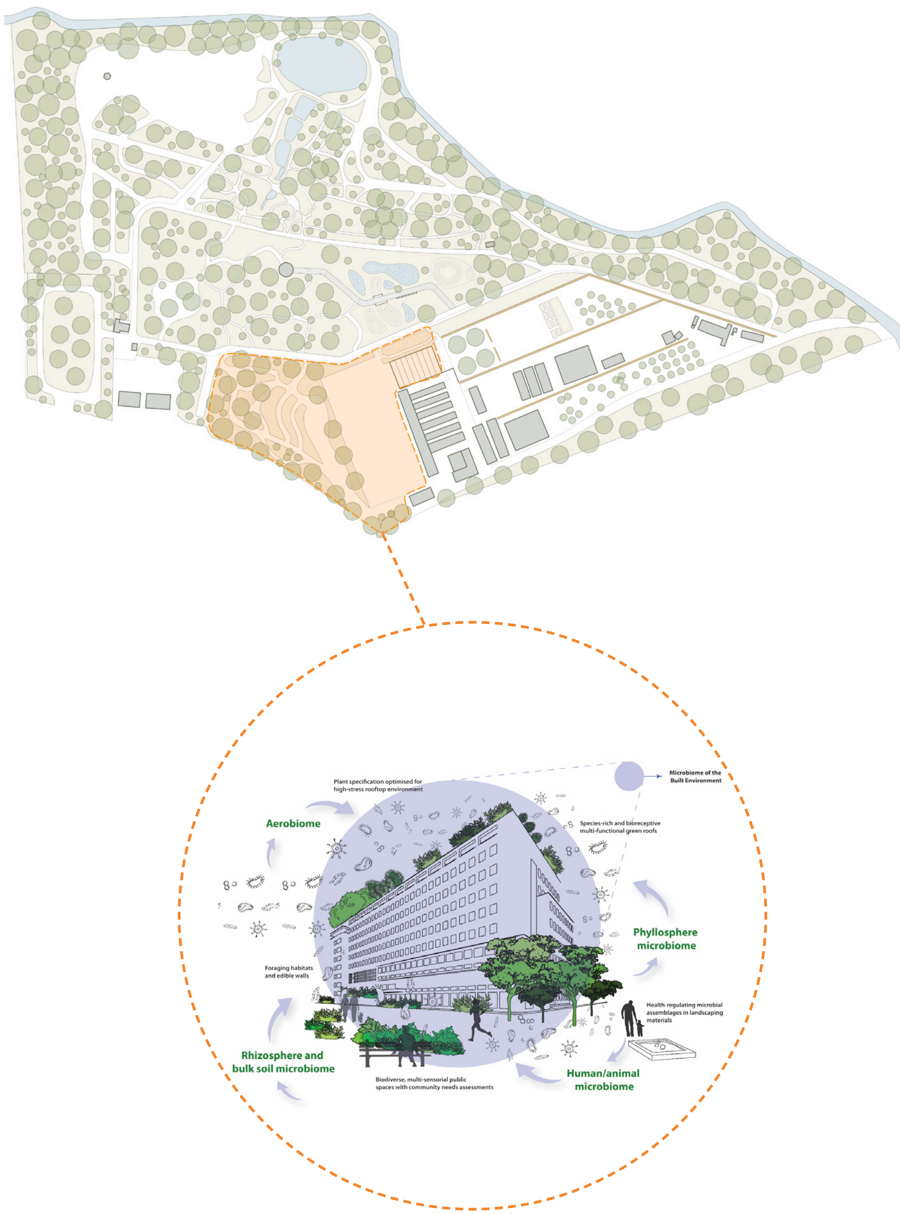
Actions

- We will establish permanent quadrats in the sand dunes and at partner sites, using these as part of the Biodiversity Monitoring Programme.
- Establish coverage of Marram and Lyme grasses throughout the dunes, complemented by dune slack and grey dune assemblages.
- Work with partners to design and undertake tractable experiments that can be conducted amongst the sand dunes.

Measures for success

- Coherent, species-rich dune grassland habitats established and conservation outcomes measured.
- Data recorded in Biodiversity Monitoring Programme and shared with existing databases.
- Sand dunes used in curriculum-based learning, with the boardwalk being used to provide access to habitats for groups and individuals that otherwise struggle to engage with our native biodiversity.

TANGLED BANK: BIOCENE GARDEN



Objectives

- To create a visionary example of how grassland-dominated urban green infrastructure could be adapted to future climate change scenarios.
- To study processes of community assemblage, successional pathways, niche exploitation and resilience in urban environments.

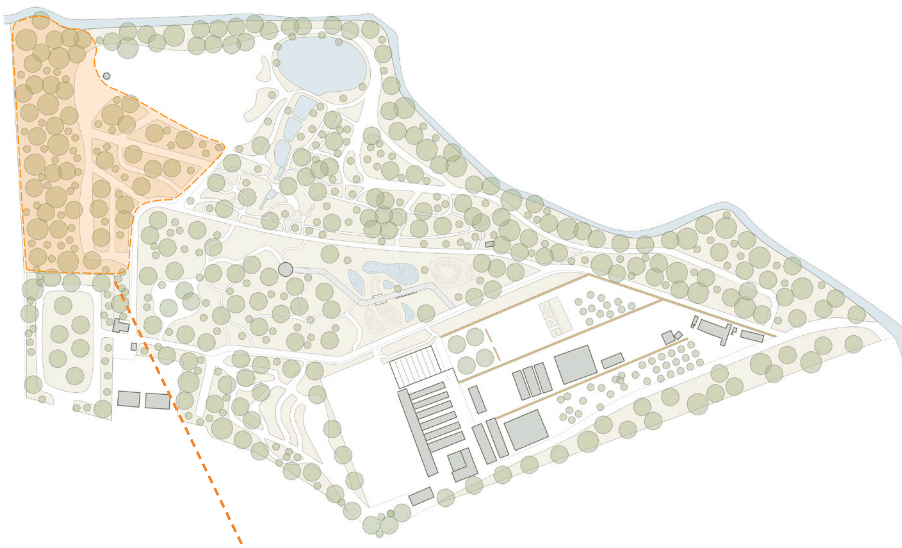
Actions

- Use a co-design methodology to create a new landscape, re-imagining Scotland's green infrastructure.
- Work with stakeholders representing a wide range of interests, including education groups, conservationists, researchers, design professionals and urban landscape managers.
- Share the findings from our research and design processes to leverage change in urban landscapes.
- We will establish permanent quadrats throughout the Biocene Garden and in partner sites, using these as part of the Biodiversity Monitoring Programme.

Measures for success

- Data recorded in Biodiversity Monitoring Programme and shared with existing databases.
- Contemporary design language used to create a landscape that feels welcoming, inspiring and beautiful.
- Highly diverse biotic assemblages arranged in ways that create a locally-relevant demonstration of how our urban landscapes could be developed.
- Biocene Garden regarded as an exemplar site for climate-adapted green infrastructure.

GARDEN OF SEQUESTRATION



Objectives

- To measure how carbon sequestration can be optimised alongside other ecosystem services in existing woodlands and shrub-dominated habitats.
- Extend the Friendly Wood complex to incorporate existing 'A' and 'D' beds, and develop this landscape as a complex of novel habitats with opportunities for accessions, research and education.

Actions

- Use functional phytosociolocial framework to characterise existing plant associations.
- Assess existing carbon sequestration and ecosystem services, and record change in response to habitat curation.
- Remove plants where necessary to create space for new accessions, including Sentinel Species.
- Revise path network, seating and views for visitor enjoyment, along with associated interpretation.

Measures for success

- Mature and over-mature shrub plantings successfully integrated into a coherent network of habitats with diverse canopy layers.
- Sentinel Species plants introduced and monitored in collaboration with partner organisations and initiatives.
- Effective collaboration with partner organisations and sites, leading to optimised CO_2 sequestration with co-benefits for biodiversity.

POND NETWORK AND ROCK GARDEN

Objectives

- Refresh plantings to support a diverse network of habitats that reflect naturally occurring ecosystems.
- To develop the plantings for visitor enjoyment in ways that take advantage of the topography, soils and hydrology.
- Communicate messages about plant evolution and adaptation to conditions that have analogues in urban habitats.

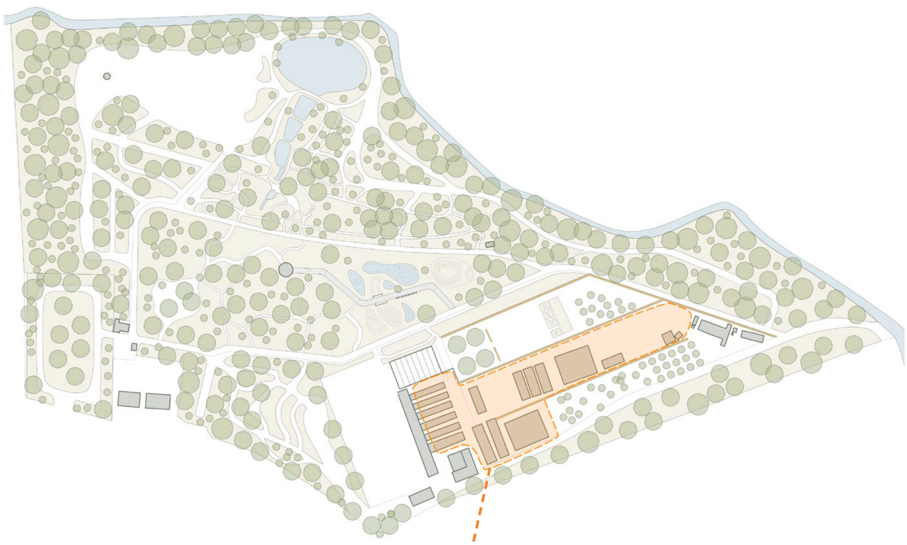
Actions

- Assess current condition of plants, habitats and pedagogical value.
- Remove plants and update access routes where necessary, creating spaces for Sentinel Species and complementary plants to be introduced.
- Future-proof the water infrastructure network, including civil engineering where necessary to repair leaks and pumps.
- Identify partner organisations working with mountain habitats to identify opportunities for conservation and pedagogy.

Measures for success

- Rock Garden and pond network habitats and infrastructure used in teaching and contributing to in situ and trans situ conservation.
- Sentinel Species plants introduced and monitored in collaboration with partner organisations and initiatives.

PLANT NURSERY



Objectives

- To create efficient use of space and resources in the nursery so that high quality plants can be produced for plant sales, habitat creation and restoration projects, and accessions to the Garden.

Actions

- Build a new workshop that can be used as hub for plant propagation, volunteering, and staff mess room.
- Implement appropriate biosecurity measures to ensure safe production of plants.
- Identify and secure plant material of genotypes of interest, working with partners to support benefit-sharing.
- Develop the volunteer programme to support propagation and conservation in the Botanic Garden.

Measures for success

- High quality plants produced using biosecure methods.
- Plant sales makes significant contribution to Trust budget.
- Plants being used for habitat creation and restoration projects within the Botanic Garden and shared with partner sites.

BIODIVERSITY CENTRE

Objectives

- Create a centre where biodiversity records can be stored and accessed by researchers and public (eg digital, film, herbarium).
- The building should embody the Botanic Garden's environmental principles and be an attraction in its own right.

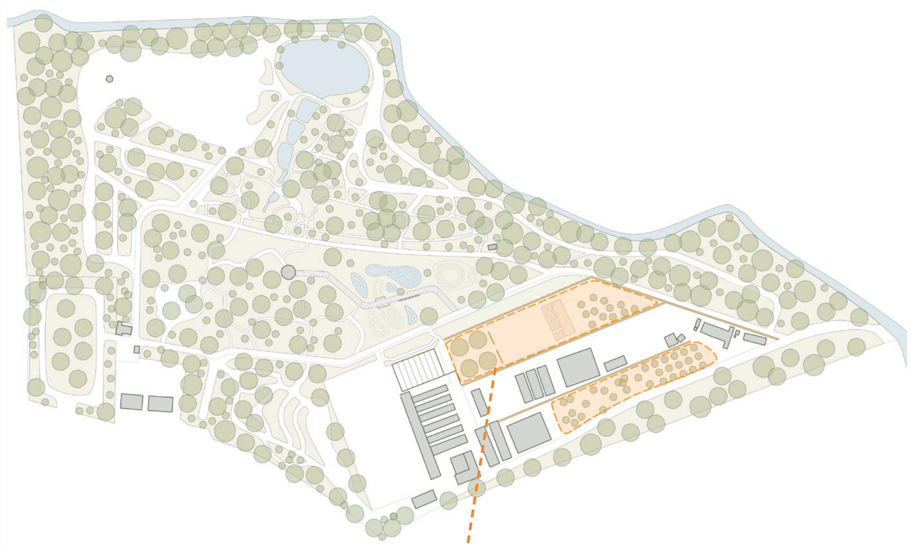
Actions

- Design and secure funding for the new building, including staff resources to oversee consultation, procurement, and construction.
- Develop a volunteer group to reliably accession and digitise herbarium specimens.
- Prepare the herbarium collection for re-location to a new purpose-built facility and decommission herbarium building.

Measures for success

- Building delivered on budget, to high environmental standards, and on time.
- Herbarium collection part of a 'digital extended specimen' network.
- Biodiversity Centre supports conservation in Fife, Tayside and in partner sites internationally and across Scotland.

URBAN FOREST FARM



Objectives

- Building on the experiences of the successful urban farm project, our objective is to create a productive landscape with clear conservation and social outcomes.
- Celebrate the heritage of food production in Fife and Tayside.
- Create a productive landscape dominated by tree species, with multiple canopy layers to optimise food cultivation alongside conservation outcomes.

Actions

- Design the Urban Forest Farm in consultation with Fife and Tayside-based stakeholder groups.
- Carry out groundworks to maximise water retention and soil remediation where necessary.
- Using climate matching and ecological forecasting tools to identify species and genotypes of productive trees that will be well-fitted to future climate scenarios and support native biodiversity in novel assemblages.

Measures for success

- Plants propagated in the nursery and planted out in the Urban Forest Farm.
- Urban Forest Farm a centre for community programmes that deliver aligned Plan for Fife objectives, focusing on Community Led Services and Thriving Places.
- Productive trees integrated into a landscape that is fun to explore and relevant to agricultural heritage of Fife and Tayside.

RESEARCH AND EDUCATION

Botanic gardens are confronted by challenges across many of their core activities: there is a replication crisis in ecology (Filazzola and Cahill, 2021) and horticulture (Watkins et al., 2020) for example, alongside blind spots in plant procurement (Sjöman and Watkins 2021) and biological statistics (Schleicher et al., 2020), compounded by an urgent need for foundational data on the distribution and abundance of species (Gillson et al., 2020).

Most targets for the conservation of genetic diversity operate at the levels of species and genera (Mounce, Smith and Brockington, 2017) but there is an emerging consensus that conserving intraspecific diversity should be incorporated into conservation projects, and to this end, high resolution data gathered consistently over time will allow us to extend existing national and regional initiatives, answer a wide range of practical questions, and place Fife's botany in multi-trophic and international contexts.

The Botanic Garden has advantages in that we can operate outside of the short term windows of postgraduate research, and that our research does not need to prioritise 'novelty' as an outcome, enabling us to undertake the foundational research that is needed for longer term, or global scale research. To address these challenges and recognising the difficulty of unpicking causal dynamics and designing experiments (Kimmel et al., 2021), the Garden will focus its research and education programme on activities relating to the creation of a robust, longitudinal database of plant distributions, fitness and demography so that we can better understand the ways in which species respond to climate change. The data we collect will be gathered by monitoring plants in the Botanic Garden and across Scotland, and working with partners internationally to collect paired data on selected species ("sentinel species") using standardised protocols.

To ensure complementarity with existing initiatives, we will use and adapt industry-accepted monitoring standards such as those used by the National Plant Monitoring Scheme (Pescott et al., 2019) and apply these methodologies to our monitoring programme. Throughout this process, the Herbarium will play an active role. Beginning with a programme to digitise the collection, plant materials will be accessioned to the herbarium (de Lima et al., 2021; Teixeira-Costa et al., 2022) enabling the Botanic Garden to create 'digitally extended specimens' that contribute to international initiatives.

The data assembled in this dataset will have direct, practical outcomes as well as contributing to foundational methodological developments relating to gathering biomarker and plant demography data. These outcomes will be as diverse as the people who want to use the data, and will include:

- Guidance for land managers in Fife and similar habitats around the world based on continuous, near term forecasts (McIntire et al., 2022).
- Contributions to international databases such as GBIF, TRY, and Compadre to widen accessibility and applications (Aubin et al., 2020; Feng et al., 2022) (Hancock et al., 2022).
- Helping to understand the growing divergences between urban and rural habitats (Song et al., 2021) (Swift et al., 2022).
- Understandings of plant adaptation (Royer-Tardif et al., 2021) and evolution under climate change.
- Contributions to conservation assessments.

Using the data we collect, we will produce an annual report that includes near-term forecasts, updated in line with findings as they emerge (Dietze et al., 2018). This process of regular reporting will build trust and engagement with colleagues, as well as provide opportunities to fine tune our models and the guidance that we provide to partners.

Knowledge exchange and employability

The education programme will embrace a broad understanding of education, supporting and reflecting the principles of the biodiversity plan. An active volunteer programme, a commitment to trainee and apprentice positions, and staff development will ensure that as well as curriculum-linked and informal education, the Botanic Garden team support the development of professional skills and benefit from new people regularly joining the team.

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Supporting research

Whilst biodiversity monitoring will be the core of the Botanic Garden's research programme, we will also facilitate investigative or hypothesis driven research, dependent on project funding and staff resources to carry them out. Within the framework of wanting to contribute to understandings of the ecological limits of evolution under climate change, themes of particular interest include:

- Methods for predicting the extent to which species are likely to show intraspecific variation, and the extent to which this influences ecophysiological traits or demography.
- Application of ecophysiological research to plant specification in green infrastructure.
- The invasion debt in botanic garden collections.
- Interactions between species distribution and demography.
- The influence of trait plasticity on community assembly and demography.
- Plant fitness for habitat restoration projects.
- Guidance on transitioning habitat composition through management practices.
- The influence of microbial assembly and diversity on plant fitness.

Data management

To manage the data recorded throughout the botanical programmes, a database will be needed with the capability to handle longitudinal bioinformatic data as well as living an herbarium plant records and accession information. As part of this, key questions will include ensuring that there are sufficient in-house skills to maintain records in a timely manner, reviewing what information we need to record and how we share these data within and outwith the organisation.

Flora of Fife and Tayside

In this workstream we will begin by supporting biodiversity monitoring schemes operating in Fife and Tayside, gathering data that both strategically underpins and extends existing recording initiatives but also facilitates trialling of new sampling methodologies. These data will help address fundamental conservation challenges, such as understanding between & within-patch dynamics, and designing conservation interventions that are locally-specific and evidence based.

The biodiversity data collection process will require the support of volunteers and students, providing opportunities for skills development and social interactions, supporting goals set out in the Plan for Fife and the University of St Andrews Biodiversity Strategy. In turn, the data that are collected in this workstream will support the delivery of national and international policy goals, as well as providing a useful testing ground for in situ conservation projects.

Sentinel species programme

Alongide locally-based biodiversity monitoring, we will identify species that can act as sentinels for the impacts of climate change and biosecurity risk in the Botanic Garden and their natural ranges of distribution. Collaborating with partners to record paired data in their natural ranges and the Botanic Garden, we will plant and manage populations of these taxa in specifically created habitats in the Botanic Garden (Morales-Rodríguez et al., 2021) with a view to supporting trans situ conservation. Our choice of species will help address some of the biases in biodiversity monitoring (Kattge et al, 2020), and build on strengths in taxonomic diversity that the Botanic Garden has already.

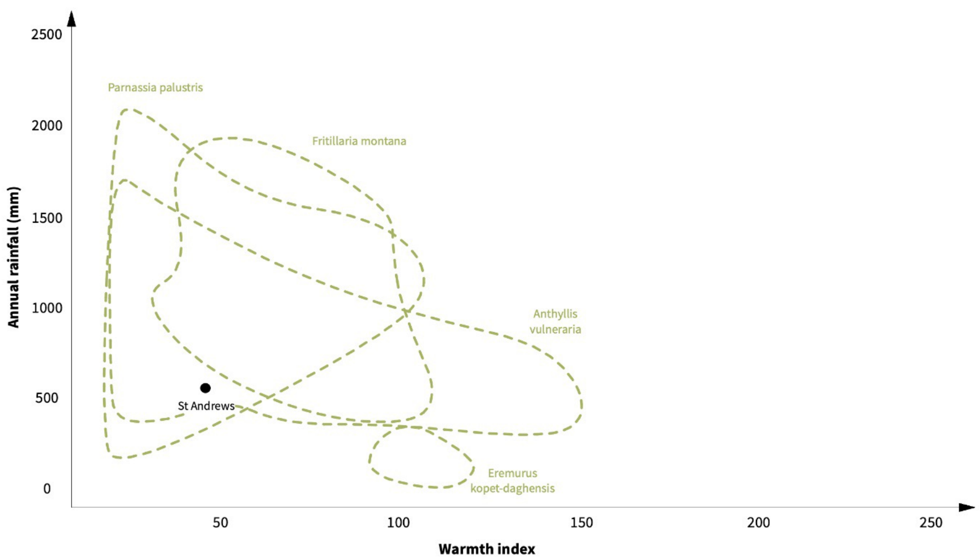
Sentinel species will be selected to meet a range of criteria, including:

- Being naturally distributed across ranges that occupy similar climate niches to north east Fife or the conditions that we might expect to find under climate change scenarios.
- Be under-recorded in existing ecological or botanical databases (eg TRY, Compadre, GBIF).
- Be under-recorded by conservation programmes (eg IUCN Red List).
- Together, represent a diverse range of plant forms and adaptive strategies.

Multiple accessions of each taxon will be made ensuring that the Garden grows an appropriate level of genetic diversity.

Sentinel species: herbaceous plants

We have identified four species of herbaceous plants that offer a range of research and conservation opportunities. Figure 1 below illustrates the range of climate niches occupied by these species, showing how each of these species have populations that are likely to be highly relevant to Fife in future climate scenarios, and yet are mostly treated as 'Data deficient' or 'Not assessed' by the IUCN Red List and are also under-represented or absent from ecological databases.



Kidney vetch (Cas an uain, Anthyllis vulneria L.) and **Grass-of-Parnassus** (fionnscoth, Parnassia palustris L.) are species that are native north east Fife and extend internationally across a range of ecotypes, and given their importance to local biodiversity, offer opportunities for in situ conservation and biogeographical study in trans situ conservation. The **Mountain fritillary** (Fritillaria montana Hoppe ex W.D.J. Koch) is visually similar to the Snake's head fritillary (Fritillaria meleagris L.) that is widely naturalised in damp meadows, yet is less well-known and more drought tolerant, and extends across a range of high altitude in south east Europe, presenting opportunities for trialling in green infrastructure projects. The **foxtail lily** (Eremurus kopet-daghensis Karrer) is very rare both in cultivation and in its natural range, yet similarly offers high potential for green infrastructure projects being unlikely to naturalise, with a strong stem that is adapted to resist to the heavy desert storms (Karrer 1931) and relatively easy to grow.

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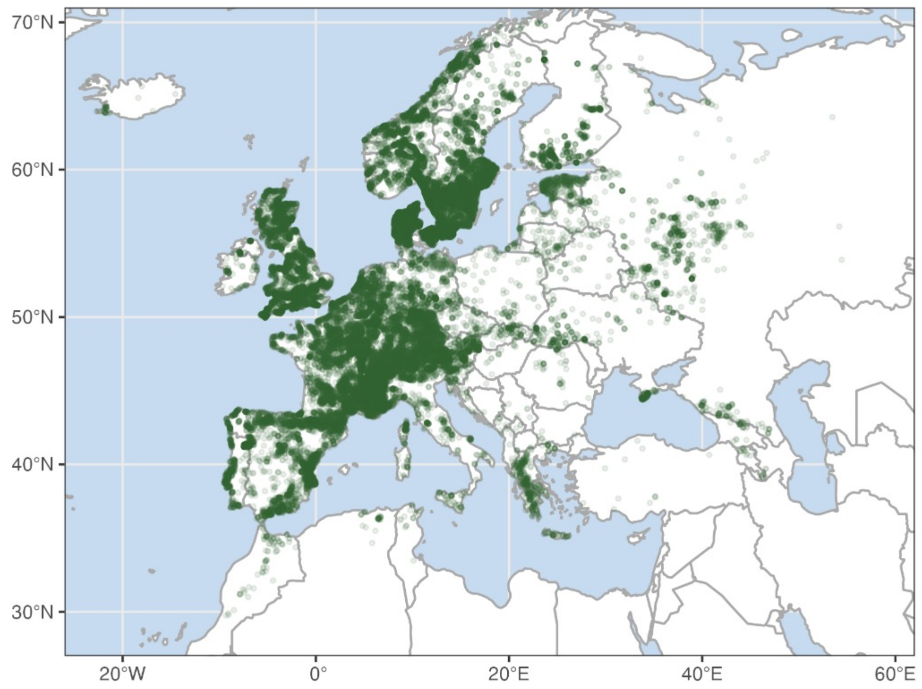
Anthyllis vulneraria L.

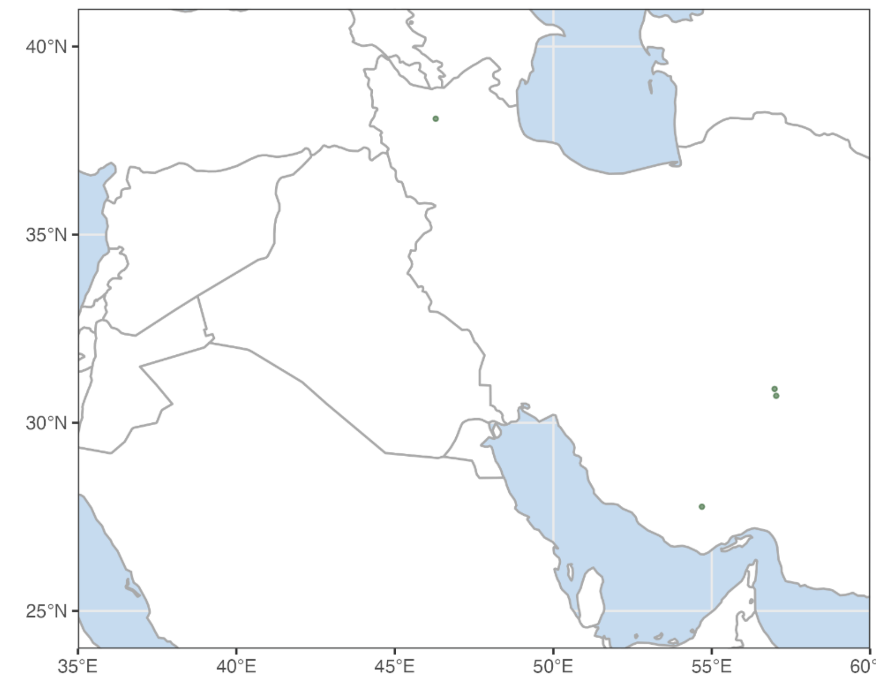


Distribution of *Anthyllis vulneraria* L. Data from GBIF (277,505 populations recorded).

Family	Fabaceae	**Observations in TRY**	776 no.
Conservation status	Not assessed	**Records in Compadre**	3 studies

A very variable species, surviving in drier areas until late summer. It can be found on chalk grassland, sand dunes, rocky banks and cliffs. A variety with red flowers can be found in Pembrokeshire and Cornwall; it is the only source of food for the caterpillars of the Small Blue butterfly.

Eremurus kopet-daghensis Karrer L.

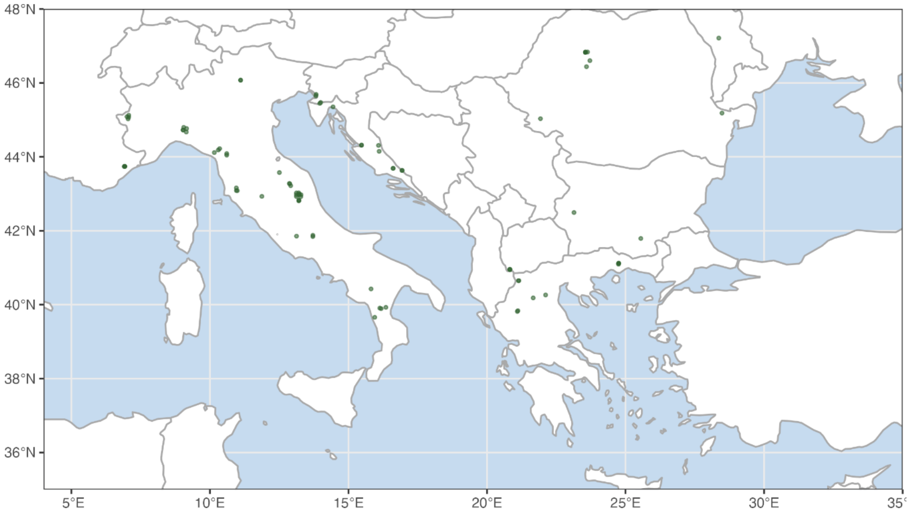


Distribution of *Eremurus kopet-daghensis* Karrer. Data from GBIF (4 populations recorded).

Family	Asphodelaceae	**Observations in TRY**	0
Conservation status	Data deficient	**Records in Compadre**	0 studies

This species has been reported in four ecoregions: Eastern Anatolian montane steppe, South Iran Nubo-Sindian desert and semi-desert, and Eastern Iran montane woodlands, Kopet Dag woodlands and forest steppe. The species is connected to a very unstable environment, influenced by overgrazing in the highest areas of its range, and by habitat loss caused by conversion of land to agriculture.

Fritillaria montana Hoppe ex W.D.J.Koch

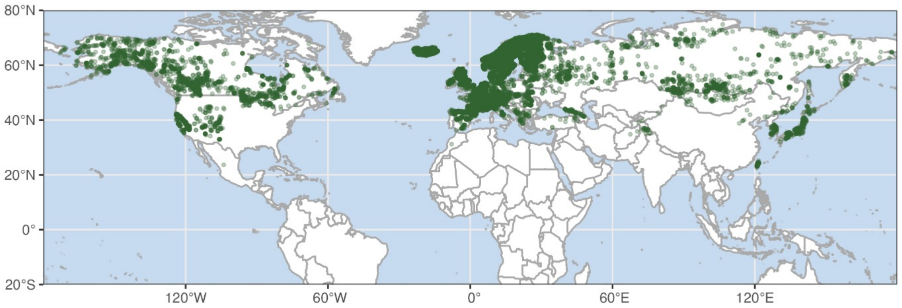


Recorded distribution of *F. montana* Hoppe ex W.D.J. Koch. Data from GBIF (256 populations recorded).

Family	Liliaceae	**Observations in TRY**	2 no.
Conservation status	Data deficient	**Records in Compadre**	0 studies

Found in different habitats ranging from scrub communities and rocky places in openings of deciduous and forest to limestone substrate up to 1,800 m asl. It has been reported that this plant in particular can mix with various types of plant communities across montane and subalpine regions.

Parnassia palustris L.

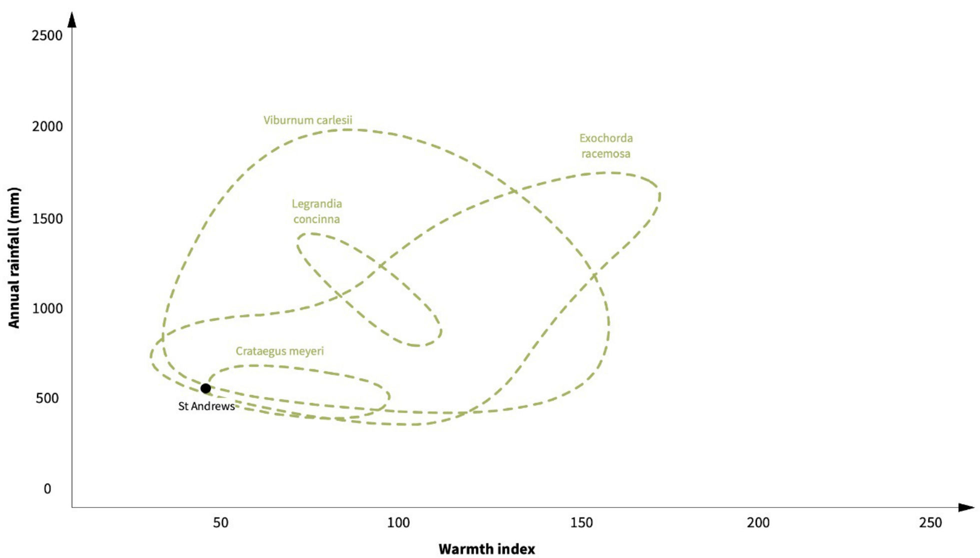


Distribution of *Parnassia palustris* L. Data from GBIF (191,424 populations recorded).

Family	Celastraceae	**Observations in TRY**	703 no.
Conservation status	Least concern	**Records in Compadre**	0 studies

A perennial herbaceous plant with a wide distribution and climate niche, inhabit dune systems, swamps and humid prairies of medium and high altitude mountains. Flowering occurs in summer and autumn (July-October).

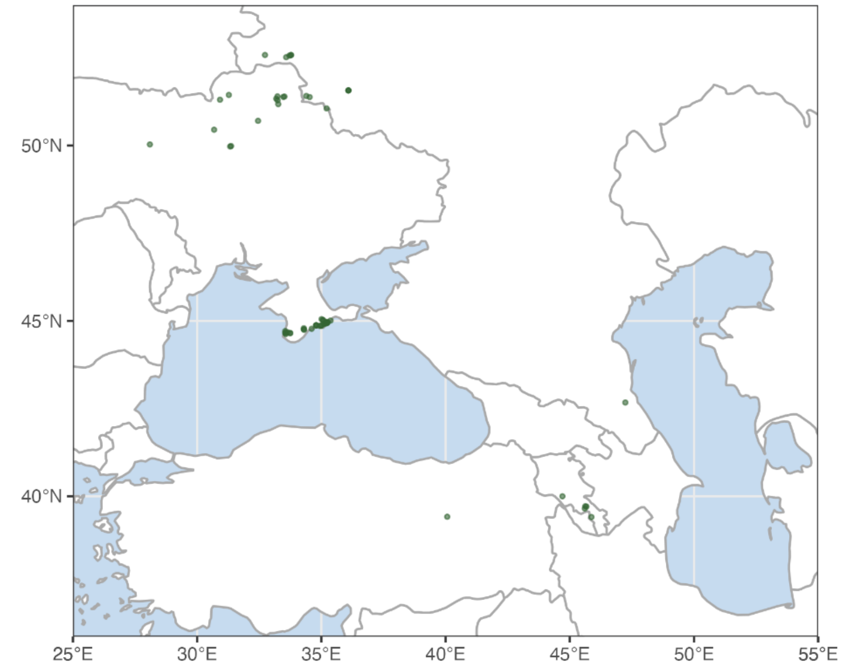
The four shrub sentinel species have been selected primarily with a view to addressing botanical questions and conservation challenges, but also opportunities for trans situ and green infrastructure projects in Scotland. To this end, we have identified charismatic species with high cultural potential that are in different ways under-studied by botanists or conservationists.



Sentinel species: shrubs

Crategus meyeri is closely related to the native hawthorn, C. monogyna but is less widely distributed and occupies a relatively dry climate niche that is similar to St Andrews, although warmer. Rated as ‘Data deficient’ by the IUCN Red List, there are similarly few ecological studies of this species, representing an opportunity to address open botanical and biogeographical questions. **Exochorda** is a small genus that is well-represented in the Botanic Garden at present, although previous attempts to grow the species E. racemosa have met with varying success. It appears to have been the subject of taxonomic debate, having previously been placed in Amelanchier and Spirea, with populations that occupy climate niches similar to St Andrews and posing interesting biogeographical and taxonomic questions. **Legrandia concinna** is little known in Scotland or elsewhere in Europe and is a Critically Endangered species with only five known populations growing in Chile; a highly attractive shrub or small tree in leaf, stem and flower, there is an opportunity to build on the Garden’s Chilean collection and address a gap in knowledge and research that could support conservation of this important species. **Viburnum carlesii** extends across a wide climatic range but a relatively narrow geographic territory in eastern Korea and south west Japan; it is less widely grown than the hybrid V. x burkwoodii (of which it is a parent, with V. utile) and understudied from the perspectives of conservation and ecology.

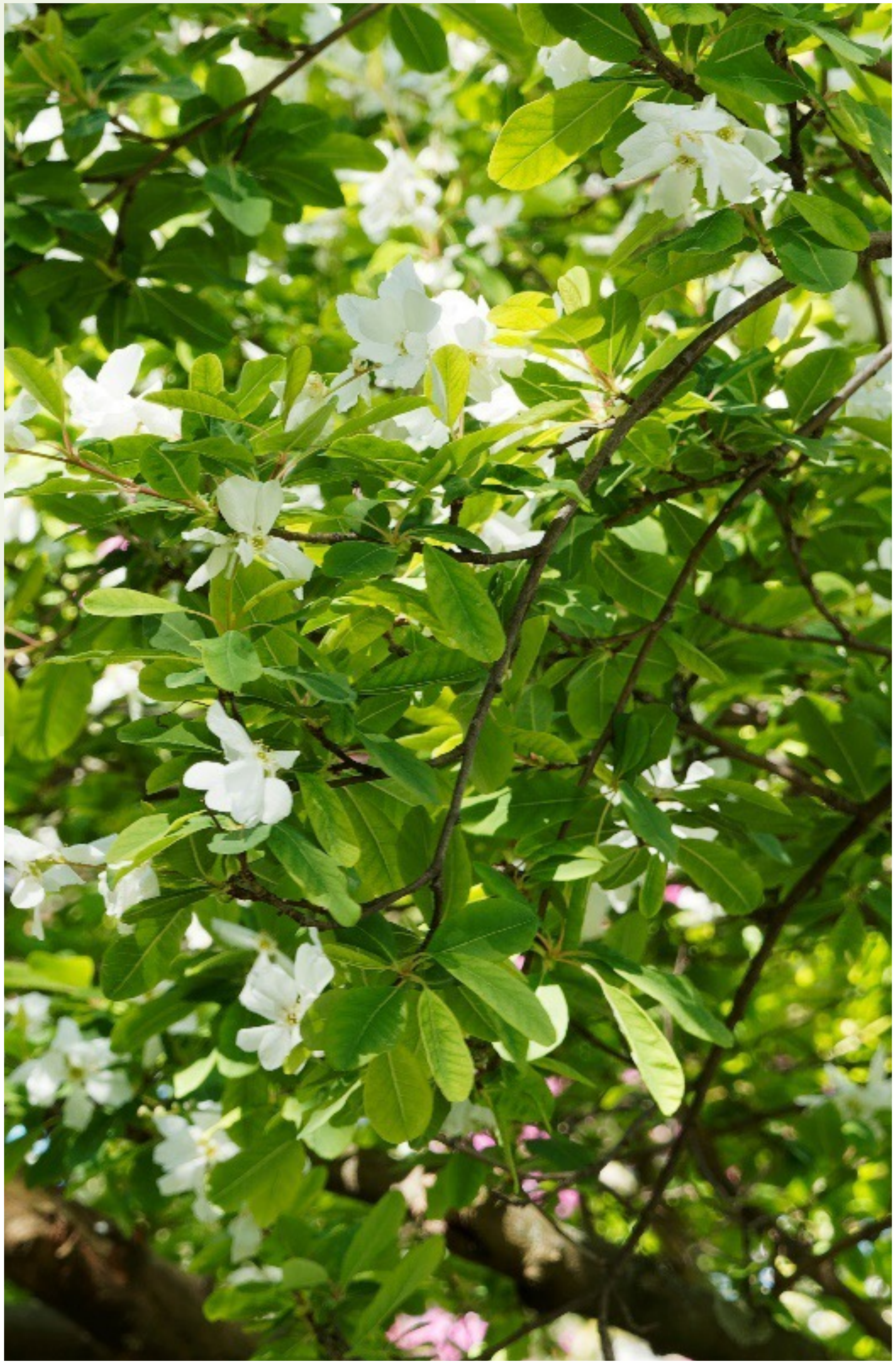
Crataegus meyeri Pojark.



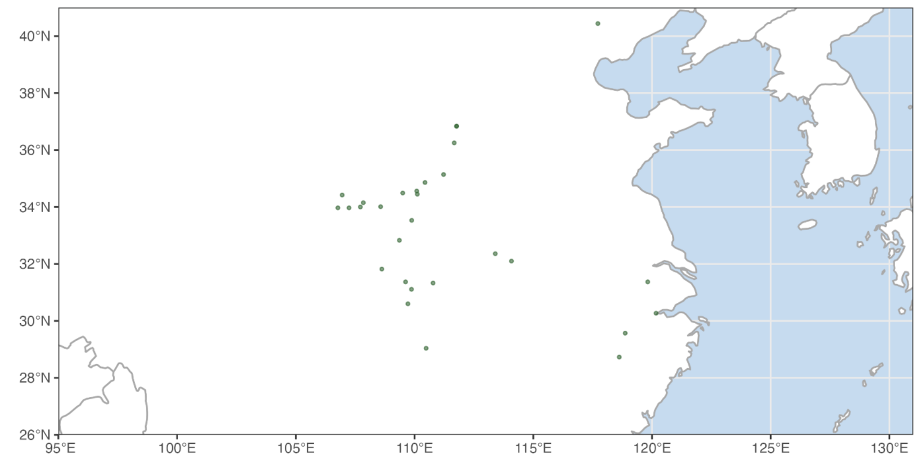
Distribution of Crataegus meyeri Pojark. Data from GBIF (274 populations recorded).

Family	Rosaceae	**Observations in TRY**	1 no.
Conservation status	Data deficient	**Records in Compadre**	0 studies

This species is a shrub or small tree found growing in dry meadows and woodlands (Christensen 1992). The fruit is commonly collected impacting reproduction (Yena and Fateryga 2015). Within Ukraine the threats are grazing by goats and sheep; in Iran increasing fire and drought events may be reducing population numbers (Bakhtar 2013).



Exochorda racemosa subsp. giraldii (Hesse) F.Y.Gao & Maesen

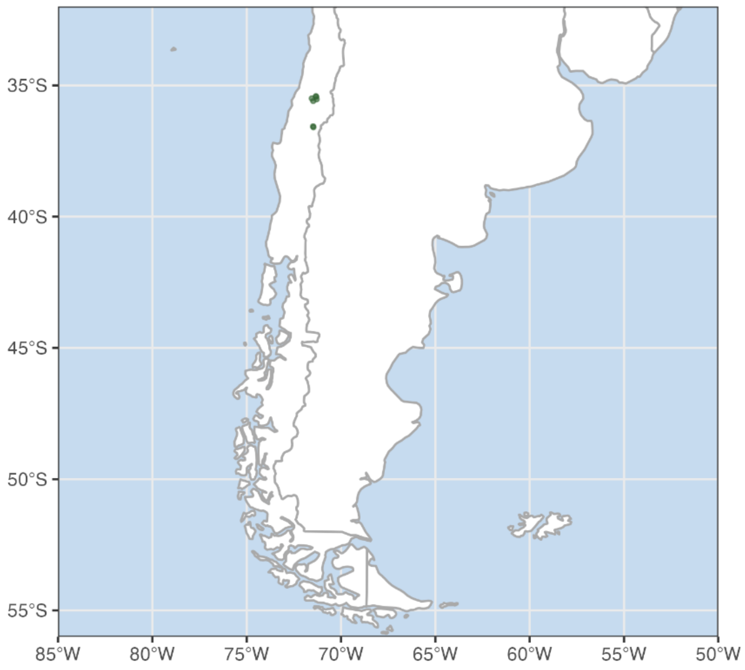


Distribution of *Exochorda racemosa subsp. giraldii* (Hesse) F.Y.Gao & Maesen.
Data from GBIF (34 populations recorded).

Family	Rosaceae	**Observations in TRY**	38 no.
Conservation status	Not assessed	**Records in Compadre**	3 studies

An enigmatic species with significant horticultural value but taxonomically complex and understudied. Occurs across central China and parts of north and south Korea in temperate woodlands with relatively high soil acidity.

Legrandia concinna (Phil.) Kausel

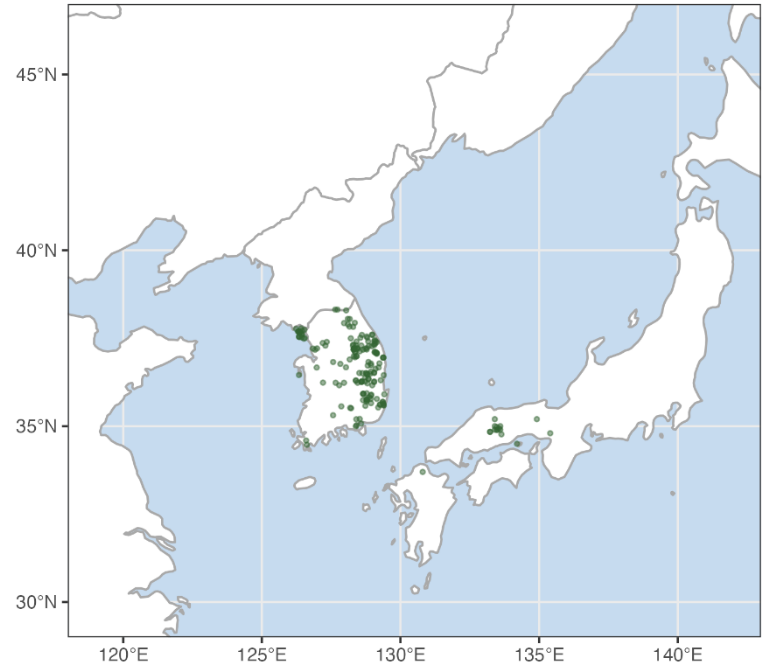


Distribution of *Legrandia concinna* (Phil.) Kausel. Data from GBIF (4 populations recorded).

Family	Myrtaceae	**Observations in TRY**	4 no.
Conservation status	Endangered	**Records in Compadre**	0 studies

Usually occurs in dense forests with poorly drained soils or close to watercourses which are rich in organic soils. It often occurs in forests dominated by Nothofagus glauca, N. obliqua and N. dombeyi. It can also grow in association with Aextoxicon punctatum, Cryptocarya alba, Laurelia sempervirens, Lomatia hirsuta, Luma apiculata, N. nervosa, Persea lingue and Quillaja saponaria.

Viburnum carlesii Hemsl.



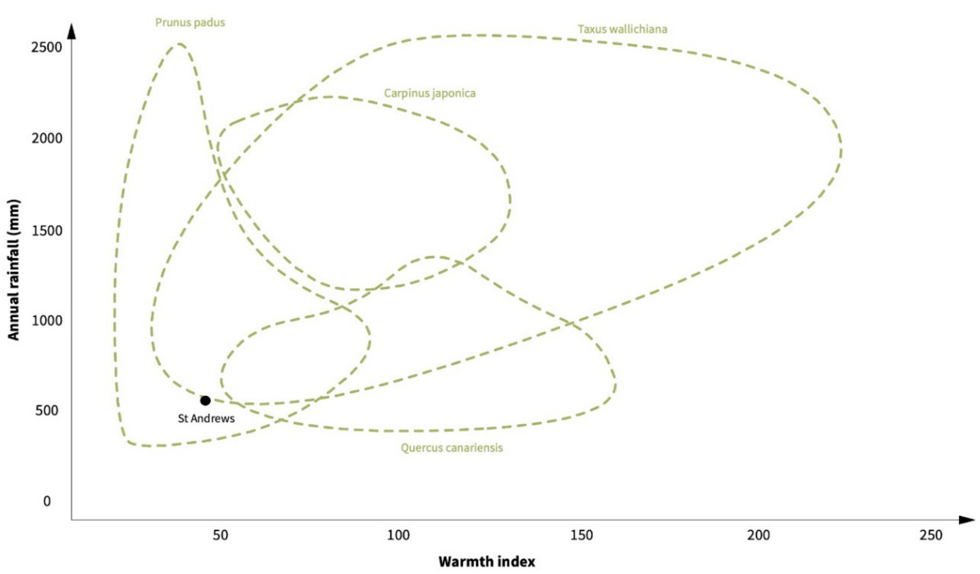
Distribution of *Viburnum carlesii* Hemsl. Data from GBIF (2,093 populations recorded).

Family	Viburnaceae	**Observations in TRY**	44 no.
Conservation status	Not assessed	**Records in Compadre**	0 studies

Native-of Korea and of Tsushima Island, Japan; relatively little is known of its ecology, although it is one of the most recognisable of the viburnums, with highly scented flowers in the spring.

Sentinel species: trees

Our selection of sentinel tree species is intended to meet similar criteria as the other life forms (ie under-studied species of conservation importance or cultural value, and occupying distinct climate niches and ecological strategies) but with an added criteria of responding to biosecurity and climate change challenges facing trees native to north west Europe. Due to their size, longevity and contributions to biodiversity, trees play crucial roles in ecosystem functioning and furthering our understanding of the physiologies and life histories of temperate trees that are closely related to our native species represents a tractable challenge.



Species in the Hornbeam genus appear to be relatively resilient to many of the more impactful pests and diseases currently found in Scotland, and are therefore of significant interest from a biosecurity perspective. As one of the larger species with dense timber and relatively fast-growing, **Carpinus japonica** has potential for green infrastructure projects. Japanese hornbeam occupies a distinctly different climate niche to much more widely distributed **Bird cherry** (Prunus padus) but a similar ecological role and given the wide number of pests and diseases which are likely to affect the genus Prunus in Scotland in the near to medium term future, this represents an interesting counterpoint for paired studies. **Algerian oak** (Quercus canariensis) is known to be capable of hybridising with the native Q. robur and whilst the potential for this to occur will need to be considered, the prevalence and lack of understanding of Acute Oak Decline merits urgent analysis of the Oak genus from multiple perspectives. Yews are famously difficult to distinguish based on morphological characteristics and given the wide biogeographic range occupied by **Taxus wallichiana**, this species represents an opportunity to support phylogenetic as well as ecological and botanical research projects.

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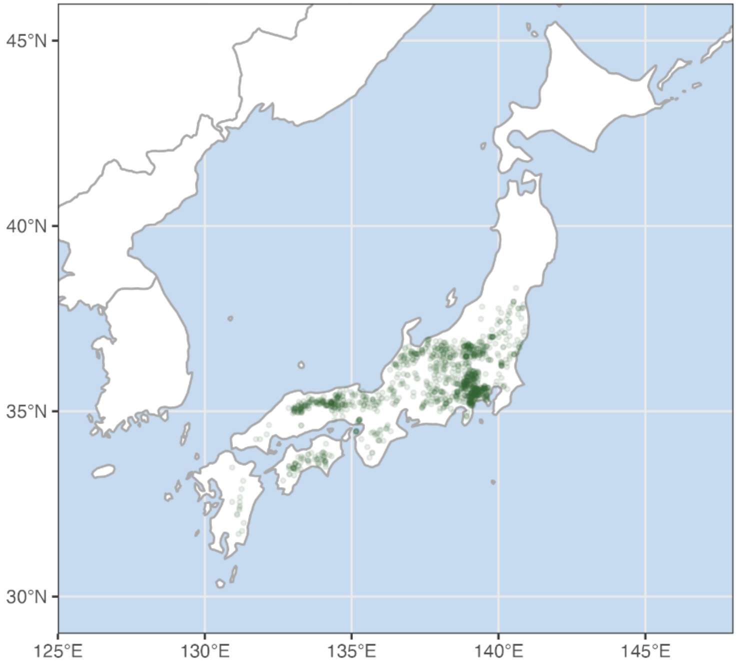
Carpinus japonica Blume.

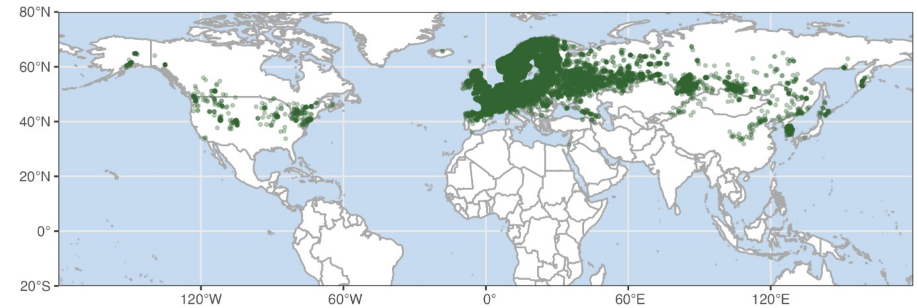


Distribution of *Carpinus japonica* Blume. Data from GBIF (3,884 populations recorded).

Family	Betulaceae	**Observations in TRY**	71 no.
Conservation status	Data deficient	**Records in Compadre**	0 studies

Shade intolerant and therefore disturbance events (e.g. tree fall gap formation) are important for the seedling growth of this species. It is often found in secondary and temperate forests.

Prunus padus L.

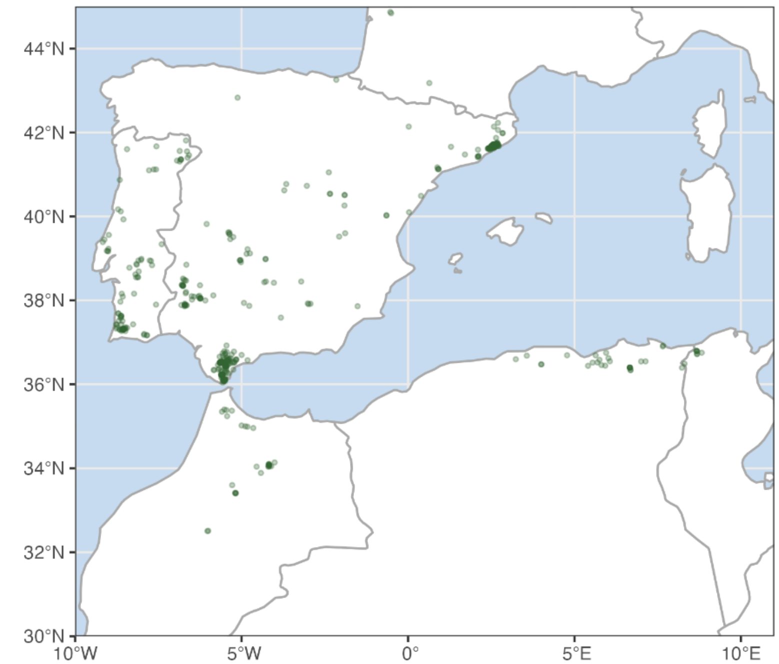


Distribution of *Prunus padus* L. Data from GBIF (339,154 populations recorded).

Family	Rosaceae	**Observations in TRY**	665 no.
Conservation status	Least concern	**Records in Compadre**	0 studies

Often found in forest and scrub in Europe, most frequently on calcareous or base-rich substrates, avoiding very dry or very acidic conditions (Duarte et al. 2011).
It is able to grow in various soil types, preferring damp calcareous or base rich soils in the UK (Preston et al. 2002) and is recorded as occurring on humid, poor, slightly acid soils and also on humid, moderately fertile soils in the Netherlands (Tamis et al. 2003).

Quercus canariensis Willd.



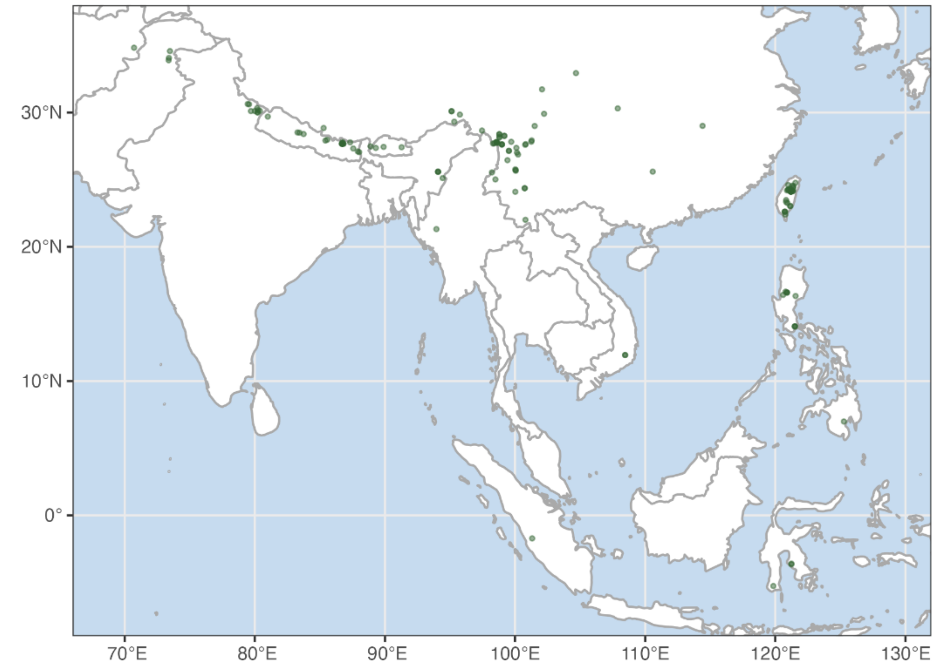
Distribution of *Quercus canariensis* Willd. Data from GBIF (46,865 populations recorded).

Family	Fagaceae	**Observations in TRY**	139 no.
Conservation status	Data deficient	**Records in Compadre**	0 studies

A large tree species growing up to 30 m in height (Arbolapp 2017). It is a fast growing species and grows best in sheltered sites on moist soils, along rivers or in valleys (Arbolapp 2017).

Where the species has been introduced it is able to hybridise with *Quercus robur* (Tree Logic Pty Ltd 2000). Up to 800 mm of precipitation is preferred during the summer season (Pérez-Ramos and Marañón 2009).

Taxus wallichiana Zucc.



Distribution of Taxus wallichiana Zucc. Data from GBIF (1,391 populations recorded).

Family	Taxaceae	**Observations in TRY**	21 no.
Conservation status	Endangered	**Records in Compadre**	0 studies

This species has been reported in four ecoregions: Eastern Anatolian montane steppe, South Iran Nubo-Sindian desert and semi-desert, and Eastern Iran montane woodlands, Kopet Dag woodlands and forest steppe. The species is connected to a very unstable environment, influenced by overgrazing, in the highest areas of its range, and by habitat loss caused by conversion of land to

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MEASURING PROGRESS

It is essential that this is a Plan that is actively used and updated but at the same time operates within a context that is appropriate for long-lived organisms. As such, this 12 year plan takes a view to making decisions with a 40 year perspective:

Annually, the Plan will be refreshed in January to identify priority areas for the year ahead as well as actions which should be postponed or introduced.
Every three years the later stages of the plan should be refreshed. Review work over previous three years and assess to what extent and why actions have been successful or otherwise. Identify actions which remain desirable but have not been completed, and then decide when these should be carried out and what is postponed or removed as a result.
The Biodiversity Plan as whole (in addition to projects) also to be reviewed every three years to ensure it remains relevant, useful and achievable.

There are a range of criteria which will be needed to measure our progress, related to our conservation, research and visitor engagement. These will focus on measuring the impact of our work, and our annual report will include summaries of:

- How many plants were used in research projects,
- The percentage of new accessions which were wild sourced with full provenance data,
- Metrics of people (visitors) that had positive experiences of the garden,
- New plant records that were generated (both on and off site),
- The impacts the Garden has had on in situ and trans situ plant conservation,
- Publications in academic, industry and other journals, and
- Contributions made by plants produced in our nursery to horticulture and conservation.

Recognising the value of external frameworks as a mechanism for inspiring progress, ensuring adherence to a clear plan, and supporting collaboration withing our sector, the Garden will use the IPBES framework to identify process- and results-based targets, against which we can measure our progress. The Garden is already part of the Evidence Champion programme run by Conservation Evidence, which has the value not only of ensuring that our programmes are evidence-led and contribute to conservation but also includes an assessment process to endure that we are able to meet our goals. The Garden will aim for BGCI Garden Accreditation within the next two years, and aim to achieve Plant Healthy accreditation within the next three years.

WHAT SUCCESS WILL LOOK LIKE

Climate adaptation

- We will manage the plants and their habitats to anticipate and prepare for likely climate scenarios.
- Regular, on-going audits will ensure that plants are constantly monitored and used to understand ecological dynamics in the Botanic Garden, and detect early warning signs for plant health risks and climate vulnerability.
- Repeated near-term iterative forecasts will be used as part of our decision making.
- Partnerships with botanic gardens, land managers and conservationists in temperate locations around the world will be developed to prepare robust and collaborative solutions to shared challenges.

A window into a wilder world

- The Botanic Garden's plants will be managed as multi-trophic systems with multiple accessions of taxa to ensure that intra-specific genetic diversity is represented.
- We will use our nurseries to propagate and distribute plants to support trans situ and in situ conservation programmes in Fife and temperate locations around the world.
- We will only accession plants with known provenances.

Improving access to the plants

- Circulation and paths within the Botanic Garden will be improved, with clear information about routes and accessibility.
- Digitisation of the Herbarium collection will be completed by 2035, and the Garden's databases made accessible through portals and emerging digital visualisation tools.
- Citizen science and volunteer programmes will play a central role in skills development, learning from others, and sharing our work.
- Opportunities for engaging with and learning about plants around the year will be developed by increasing the functional and phenological diversity of the Garden's plants.

Botanical innovation

- We will develop data management tools to integrate longitudinal data and individual plant records, treating the Botanic Garden as a long term ecological experiment.
- We will translate findings from our botanical research and databases into evidence-based, tractable, conservation programmes.
- Our projects will seek to anticipate future challenges and prioritise benefit sharing, establishing the Botanic Garden as a trusted partner.

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SUMMARY OF 2020 AUDIT

Since our establishment, the aims of the Botanic Garden have been closely tied to teaching, with a focus on creating a living collection with the widest possible phylogenetic diversity. Ponds, rock garden, a woodland garden, herbaceous beds and a range of glasshouses with different climatic regimes were created in the 1960s, accommodating plants species from biomes across the globe. A recent Garden-wide audit has resulted in a sizeable adjustment to our knowledge of the accessioned plants growing in the Garden.

	2020 audit
Number of accessions	5,668
Number of items	6,153
Number of taxa	4,438
Number of families	209
Number of genera	1,167

The recent audit has greatly improved the accuracy of our records, but our knowledge of what is growing in the garden remains limited. We know little of the plants which have not been accessioned: for example, naturally occurring plants which were not planted, plants used as rootstocks, bryophytes and lichens, and nothing of populations of algae or microorganisms. Infraspecific genetic diversity within the collection is low or uncertain: 3,400 taxa are represented by only one accession, 1,196 represented by two accessions, and 847 represented by three or more accessions. The best represented taxa are Cyclamen hederifolium, Hosta sp, Juniperus communis and Pinus sylvestris with 12, 12, 13 and 18 accessions respectively. Wild collected material makes up 8% of the living collection (489 accessions), but of these, only 5% (301 accessions) have basic provenance information.

Evaluation is important in ensuring current understanding of biodiversity and providing a framework for decision making (Aplin, 2013) but our ambition is to be more than a collection of plants. To this end, we will not just record what exists in the Botanic Garden but also identify and record biomarkers and demographic data that enable us to assess the health, condition and evolving characteristics of our study organisms.

The Garden holds a wide diversity of taxa, developed over time in response to pedagogical and conservation opportunities, amongst which there are five notable collections:

- SBEC – a selection of the 133 plants collected by the 1981 Sino-British Expedition to Cangshan. 15 accessions are currently grown mainly in the China Border but also the Mitchell Climbing garden (formerly Temperate glasshouse). A full set of herbarium specimens is held in the SABG Herbarium, with additional duplicates sets held at other sites.

- Scottish Native plants – with 55 wild collected accessions from Scotland, this group makes up just over 25% of all wild collected accessions that have location data. It includes 12 accessions of Juniperus communis from different parts of Scotland which demonstrate a range of growth forms, and four accessions of Pinus sylvestris representing four distinct genetic lineages. Previous ex situ conservation initiatives include partnerships with local schools to grow Lychnis viscaria, Erigeron acer and Dianthus deltoides, as part of the Aichi Target 4 initiative.

- Rhododendron – this genus is well represented with a good proportion of species represented by more than one accession (176 taxa currently grown, 40 of which are represented by multiple accessions). Around one third of the Rhododendron collection are recorded as wild collected, and 14 of the taxa grown are considered threatened by the IUCN red list. The collection is mainly growing in the woodland garden, but it is becoming increasingly difficult to maintain reasonable levels of soil moisture and humidity in the summer without excessive irrigation.

- Sorbus – a large proportion of this collection was donated from Ness Botanic Garden, and so this acts as a useful insurance for the plants growing there. 59 taxa are grown, of which 17 are recorded as wild collected, and this includes a number of critically endangered microspecies such as S. arranensis, S. bristoliensis and S. pseudofennica. This collection will need to be re-labelled in light of recent taxonomic changes.

- Fritillaria - 116 taxa represented by over 200 accessions, of which 13 are wild collected. 20 of these taxa were considered to be threatened by the 1997 IUCN red list and 9 appear to be held in less than 10 ex situ collections (BGCI Plant Search). Most are grown under glass in a sand plunge and currently these are not visible to gardens visitors nor used for research / conservation.

Herbarium

The Herbarium was established as a teaching resource in the late 1880s, although many of the specimens date from collections made in the 1820s by notable Fife botanists. With over 2000 genera represented in the collection, the Herbarium holds particularly strong collections of bryophytes, lichen and algae; amongst the plant kingdom, the collection is dominated by angiosperms. The Herbarium is in the process of being audited, with a view to identifying the full diversity of the collection and digitising the specimens so that they might become accessible to researchers. At present, the nomenclature used by the Herbarium is split between Cronquist and APG III, and future initiatives will be required to fully update the collection to contemporary systems.

Evidence based conservation

Accessions to natural history collections are declining globally (Rohwer, Rohwer and Dillman, 2022), and pivoting the Garden from being a display-led collection of plants to a proactive centre for research and conservation offers a significant opportunity for diversifying the biological diversity in the botanic garden and trialling management methods. However, to ensure that we accession and manage plants in a responsible and strategic manner, we have begun a process of assessing the plants in the Garden from multiple perspectives, including conservation assessment, condition, biogeography and functional diversity.

Red List assessment

230 species in the Garden are considered threatened according to the 1997 Red List. 57 are considered threatened according to a more recent assessment, and of these species, over half (58%) are woody and almost a quarter (22%) are bulbs. However, given the large number of taxa that are recorded as ‘Data Deficient’ or not assessed in some way, it is difficult to assess the extent to which red listing priorities

reflect the actual degree of threat. The Garden holds 22 EN or CR species (see table), but in all of these cases, the species is also held in more than 5 other ex-situ collections. The collection holds five species thought to be extinct in the wild: Tulipa sprengeri, Ozothamnus selaginoides, Tecophilaea cyanocrocus, Penstemon campanulatus and Wulfenia baldaccii. Most of these species are widely grown in cultivation, but O. selaginoides (a shrub endemic to Tasmania) is held in only one other botanic collection.

Condition

The 2020 audit included an assessment of plant health, form and vigour, allowing a composite condition assessment of the visible parts of the plants to be made. An action for early stages of the Biodiversity Plan delivery will be to identify criteria that can be used in decision-making when suboptimal plants are identified.

Condition	Number of plants	Propotion of accessioned plants
Excellent	1,496	23%
Good	2,565	42%
Fair	267	10%
Poor	201	3%
Unrecorded	1,261	20%

Functional diversity

Alongside the assessment of taxonomic diversity, we carried out a preliminary assessment of the functional diversity of plants in the Botanic Garden. This approach provides a framework for identifying ecological niches in the Garden, with implications for Garden management too. Using publicly-held functional trait data (Kattge et al, 2020), we ordinated species within a CSR framework (Pierce et al, 2017) and calculated the functional diversity of the plants accessioned and growing in the Garden. Further gaps in our knowledge include the extent to which the plants growing in St Andrews are representative of their source populations, or to what extent the plants growing in St Andrews behave in terms of their reproduction, resilience to stresses or disturbance, or population dynamics.

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