



Royal  
Botanic Garden  
Edinburgh

# Biodiversity Duty Report 2021-2023

Our Vision is a positive  
future for plants, people  
and the planet

Our Mission is to  
explore, conserve and  
explain the world of  
plants

## Contents

1. Introduction .....	5
Role and purpose.....	5
Governance and management.....	5
Land and estates.....	5
Key biodiversity impacts.....	6
Biodiversity engagement, education and training.....	6
2. Actions to protect and enhance biodiversity .....	8
Direct actions to benefit biodiversity.....	8
On our sites .....	8
In our local areas .....	9
Across Scotland.....	9
Across the world .....	10
Actions to tackle the main drivers of biodiversity loss .....	11
3. Mainstreaming biodiversity .....	12
Protecting biodiversity through our policies, plans and strategies .....	12
Embedding biodiversity in our work .....	13
Biodiversity leadership .....	13
4. Nature-based solutions, climate change and biodiversity .....	15
Integrating biodiversity into climate action .....	15
Mitigation.....	15
Adaptation.....	16
Green growth.....	17
Health and wellbeing.....	18
Climate change-related challenges for biodiversity.....	18
5. Public engagement and workforce development.....	20
Public Engagement .....	20
Volunteering .....	20
Exhibitions and events .....	20
Early years, schools and outdoor learning .....	20
Professional courses.....	22
Citizen science initiatives .....	22
Community engagement and public outdoor education programmes.....	22
Website, blogs, social media and press.....	23
Workforce development.....	24

Staff training, education and capacity building .....	24
Conferences, exhibitions and events.....	24
Collaborative working and sharing best practice .....	25
Opportunities available to staff to take part in practical actions .....	25
6. Research and monitoring .....	26
Research activities .....	26
Understanding plant and fungal diversity.....	26
Global environmental change.....	27
Conservation and sustainability.....	27
Monitoring impact .....	28
Trends and areas of concern.....	28
Sharing data.....	29
7. Highlights and challenges.....	30
Major achievements .....	30
Future challenges.....	30

## 1. Introduction

### Role and purpose

Founded in 1670, the Royal Botanic Garden Edinburgh (RBGE) is a leading botanic garden and global centre for biodiversity science, horticulture and education. We are a registered charity (SC007983) and non-departmental public body sponsored by the Scottish Government's Environment and Forestry Directorate. Our remit is defined by the National Heritage (Scotland) Act 1985.

Current catastrophic biodiversity loss and climate emergency demand urgent and collective action. RBGE's mission is to explore, conserve and explain the world of plants, pushing the boundaries of scientific knowledge to identify and apply solutions. We engage nationally and internationally, empowering individuals, communities and partners to protect the botanic world, helping us build a positive future for plants, people and the planet.

RBGE is the custodian of Scotland's national botanical collections including a Herbarium of three million preserved plant specimens, an extensive botanical Library and Archive, and one of the world's richest Living Collections held across our four Gardens at Edinburgh, Benmore, Dawyck and Logan. Our research has a strong focus on protecting and restoring Scotland's unique and globally important flora, alongside a renowned international programme with active projects in more than 40 countries.

Our established partnerships with individuals, institutions, governments and organisations across the world, particularly in Scotland, South America, Southeast Asia, sub-Saharan Africa, the Middle East, the Himalayan region and China, help document and protect species and ecosystems, support sustainable livelihoods, and build global capacity in plant science and conservation. Our learning programmes cater for those from early years to professional and postgraduate training, as well as recreational courses, and we are a major visitor attraction with over a million visitors each year.

### Governance and management

RBGE is governed by a Board of Trustees appointed by Scottish Ministers. The Regius Keeper and Chief Accountable Officer is Simon Milne MBE, who reports directly to the Scottish Government and the Board of Trustees. Formal reporting is via quarterly board meetings with reports to the Board and government, along with the statutory annual report and accounts.

The organisation is managed by an Executive Team comprising the Regius Keeper and five Directors: Science; Horticulture and Visitor Experience; Development and Communications; Resources and Planning; and Innovation.

Our primary source of funding is Grant-in-Aid and capital support from the Scottish Government. In addition, we receive financial support from trusts, foundations, individuals, corporate supporters, donations from the public, income from admission charges, our membership and patrons programme, research grants, retail sales, educational courses, events and exhibitions, investments and consultancy.

### Land and estates

The RBGE estate includes c. 109 ha across four Garden sites. Our property portfolio comprises nearly 30,000 m<sup>2</sup> of built environment across 100 assets, including administrative offices, scientific laboratories, education facilities, visitor centres and heritage glasshouses. These assets underpin our research to understand the natural world, education and engagement activities, and our conservation and restoration of rare and threatened species. Our Living Collection contains 13,300 species from over 160 countries, including over 1,000 threatened species and the vast majority of Scotland's rare and threatened vascular plants.

Our estate is managed to minimise negative environmental impacts, protect the biodiversity in our collections, support the wider natural capital value of our sites for wildlife and nature-based solutions to climate crisis, and to embed environmental sustainability as a central priority into every aspect of our development and decision-making. The ongoing Edinburgh Biomes programme directly addresses our biggest source of carbon emissions – glasshouse heating – while safeguarding the National Botanical Collection and improving the efficiency of multiple listed buildings within our historic estate.

## Key biodiversity impacts

RBGE is a key contributor to Scotland’s response to the linked crises of climate change and biodiversity loss, guided by the Environment Strategy for Scotland:

### One Earth. One home. One shared future

Globally, we work in partnerships across the world to support the protection, restoration and sustainable use of plant biodiversity, promoting planetary health and green recovery.

We recognise that maintaining our Living Collections and built estate has an impact on the natural environment. This impact – which is measured and submitted to the Scottish Government each year as part of our accounting procedures – occurs largely through the use of energy, water and other resources required to run our buildings and cultivate our world-class plant collections, as well as the air travel required to share our expertise internationally. The emissions from these activities contribute to climate change, which in turn impacts on global biodiversity. We are currently working on a ten-year Environmental Sustainability Strategy which will support our path to Net Zero by 2045, to decarbonise our heating by 2038, and to reduce overall emissions by 35% by 2030 compared to our 2019/20 baseline of 3,043 tCO<sub>2</sub>e. Strategies to achieve these targets include:

- Close monitoring and management of heating using building management systems and half-hourly data to reduce wastage;
- Upgrading glasshouses and buildings to increase efficiency and support adoption of low-carbon heating systems;
- Constructing an energy centre to provide low-carbon heat to the Edinburgh estate;
- Uptake of electric cars and horticultural vehicles where possible, with installation of further electric charging points and investigating electric vehicle hire opportunities for staff;
- Purchasing energy-efficient equipment and appliances and LED lighting upgrades throughout estate;
- Increased on-site renewables generation;
- Reviewing our travel policy to reduce flights and encourage rail travel;
- Encouraging video calls and remote working as an alternative to travel;
- Working to facilitate green and active travel to site for both staff and visitors.

## Biodiversity engagement, education and training

Our education and engagement programmes deliver learning opportunities around the biodiversity and climate crises to a wide range of audiences. These include school sessions from early years to secondary, tertiary provision of HND, BSc and MSc programmes in partnership with Scotland’s Rural College and the University of Edinburgh, in-house certified programmes including practical horticulture, herbology and botanical illustration, delivery of Royal Horticultural Society (RHS) qualifications, a range of short courses, and a large online programme.

Public engagement occurs both through formal events and exhibitions and self-guided tours and interpretation materials. Community learning takes place on-site and off-site through a wide range of activities and events (See [Public Engagement](#)).

Note that many of our projects and programmes incorporate multiple outcomes such as biodiversity protection and restoration, climate solutions, training and engagement. While we have tried to designate entries to a single section below to avoid repetition, many activities will have crossover with other sections.

## 2. Actions to protect and enhance biodiversity

### Direct actions to benefit biodiversity

Our actions to benefit biodiversity extend from our own sites to the city of Edinburgh, across Scotland and around the world, in partnership with numerous other organisations.

#### On our sites

Our Living Collection is of global conservation importance, safeguarding many rare taxa, including over a thousand globally threatened species (16% of accessions) and 12 species extinct in the wild; we continue to identify, verify and accession additional threatened species. The Living Collection contributes to the Scottish Government's Environment Strategy by providing a resource for research, education and outdoor amenity. Our wild-collected examples of threatened species, in particular, are a vital resource for global conservation.

We also manage our four Garden sites, their landscapes and Living Collections to support native biodiversity, as required by the Nature Conservation (Scotland) Act 2004. Specific actions include:

- Maintaining a diversity of plant forms to provide habitat for a range of animals, insects, fungi and lichens, with mixed, naturalistic and multi-species plantings;
- Conducting all daily horticultural tasks (e.g., pruning, weeding, grass cutting) with awareness of the life cycles of associated species, such as bird nesting times and orchid growth habits;
- Reducing the use of chemicals and harmful management techniques;
- Widespread use of biological (instead of chemical) control against glasshouse pests and in some outdoor situations – for instance at Dawyck we are using a small predatory beetle, *Rhizophagus grandis*, to treat an infestation of great spruce bark beetle (*Dendroctonus micans*) on a century-old Brewer's weeping spruce (*Picea breweriana*);
- Monitoring biodiversity across all sites, with data being used to identify how and where management of the Living Collection and our estate can enhance its value to biodiversity.

Site-specific examples of management for biodiversity include:

**Edinburgh:** We maintain an annual 'pictorial meadow' of c. 40 native wildflower species, new plantings of nectar-rich perennials, and large areas of grass converted to 'living lawns' sown with a mix of low-growing, native, perennial wildflowers, providing increasing habitat quality and nectar sources for native species; reducing mowing to enable more species to reach flowering stage; retaining deadwood where possible; and creation of a demonstration 'bug hotel' to support overwintering invertebrates.

**Benmore:** We are increasing native flora in areas of the Garden with turf-management practices and altered mowing regimes; reduced herbicide usage and increased use of organic mulches; placement of bird and bat boxes, and control of non-native invasive species, particularly *Rhododendron ponticum*.

**Dawyck:** Here we care for a unique Cryptogamic Sanctuary where native species – especially bryophytes and fungi – thrive undisturbed. Reduced grass cutting in meadow areas to once per year has led to increased, naturalised populations of *Dactylorhiza fuchsii* (common spotted orchid). We also carry out regular grey squirrel control to support populations of native red squirrels.

**Logan:** We work with the Solway Firth Partnership to protect local flora, and provide displays and interpretation on native plants including a specialised area focused on conserving local coastal plant



species. We also work with Luce and Rhins Red Squirrel Group and offer guided nature walks of the local area for visitors.

### In our local areas

RBGE supports the activities of the Local Biodiversity Action Plans (LBAPs) relevant to each site. The Edinburgh Garden has been a member of the Edinburgh Biodiversity Partnership since 1997, implementing the [Edinburgh Biodiversity Action Plan](#), in which we are committed to multiple strategic actions across the built environment, green and blue infrastructure and networks, and species-specific actions. We are founding members of the [Edinburgh Living Landscape](#) consortium and members of the [Edinburgh Nature Network Working Group](#), creating the first Nature Network in Scotland, an initiative which will be followed in every local authority. Benmore supports Argyll and Bute's LBAP with the cultivation of LBAP-listed species. We also contribute to partner plans such as the Cairngorms National Park's Nature Action Plan, helping to shape programmes of recovery for species in decline.

### Across Scotland

We conduct extensive research programmes with a special focus on mountain and temperate rainforest biodiversity. Our work helps build understanding of how Scotland's plant species are affected by climate change, and how to protect biodiversity by ensuring we retain microclimatic refugia through appropriate habitat management (see also [Research](#)). Our results underpin practical action through the Alliance for Scotland's Rainforest.

Elsewhere in woodlands, we are collaborating with Forestry and Land Scotland to explore critical topics including how to manage recovery of native woodland from non-native plantations, and how we might offset the negative effects of devastating tree diseases by deploying substitute tree species into Scotland's landscape to support biodiversity.

**Scottish plant restoration:** Our Scottish Plant Restoration programme draws upon our broad expertise in genetics, conservation horticulture and plant health, and works closely with local landowners and conservation organisations to lead evidence-based management strategies for species facing extinction in the UK (i.e., rare, nationally threatened, and/or listed on the UK Biodiversity Action Plan, Wildlife and Countryside Act, or Scottish Biodiversity List). This includes *in-situ* protection and ecological study, education and engagement, and *ex-situ* conservation and reintroduction.

Our conservation-genetics approach to restoration is summarised in recent publications on *Cicerbita alpina* (alpine-blue sowthistle; [Finger, et al., 2023a](#)), montane willows ([Finger, et al., 2022](#)) and marsh saxifrage (*Saxifraga hirculus*; [Finger, et al., 2023b](#)), and has been applied to multiple rare species in Scotland including *Salix lapponum* (downy willow) and *Salix myrsinites* (whortle-leaved willow) in the Cairngorms National Park in partnership with Mar Lodge, Glenfeshie and Abernethy Estates, National Trust for Scotland (NTS) and Cairngorms Connect. Working with NatureScot, NTS, and Glenlochay and Glenfeshie Estates we have now translocated 900 individuals of *C. alpina* at five new sites to safeguard the species from extinction in the UK. This flagship programme – which won the 2022 Holyrood Green Giant Nature and the Environment Award – is also a test of whether genetic rescue can help increase the success of conservation translocations, and progress will be monitored annually.

Our current, Nature Restoration Fund-supported project aims to translocate 1,000 individuals of ten species (including the unique Arran whitebeams (*Hedlundia arranensis*, *H. pseudofennica* and *H. pseudomeinichii*), wild apples (*Malus sylvestris*), wych elm (*Ulmus glabra*), oblong woodsia (*Woodsia*

*ilvensis*), small cow-wheat (*Melampyrum sylvaticum*) and marsh saxifrage, to the wild, ensuring appropriate genetic diversity in new populations and paying particular attention to site suitability in terms of ecology and potential for natural spread. Seed, spores, cuttings and rootstock have been collected from all ten species in Scotland and overseas, and are now being propagated in RBGE's nursery using innovative horticultural techniques.

Plant health and biosecurity are of key importance here, and the project is following the Garden's best practice guidelines for conservation translocations, including adhering to 'Plant Healthy' standards (see [Embedding biodiversity in our work](#)). Working at landscape-scale with (currently) 43 partners including landowners, voluntary and nature-protection organisations, the programme is adding value to several nature-restoration projects around Scotland by introducing species that would be unlikely to colonise naturally. The first plantings of wych elm will take place during winter 2023/24 and all species will be restored to new wild sites over the next three years.

We also applied conservation-genetic methodology to analysis of over 60 *Zostera marina* (common eelgrass) meadows around the UK and further afield, building the first UK genetic database for this species, informing multiple planned translocation projects in collaboration with Project Seagrass, NatureScot and many other contributors. A similar database has been started for *Zostera noltii* (dwarf eelgrass).

A new programme initiated with NatureScot will collect, cultivate and translocate populations of rare ephemeral bryophytes from Bavelaw Marsh near Edinburgh. We are also working more widely with NatureScot to develop a strategic approach to prioritising species of both plants and animals that would most benefit from conservation translocations.

## Across the world

Internationally, we manage genetically diverse and representative collections of threatened species to support active conservation programmes, including leadership of the Global Conservation Consortium for *Rhododendron* which brings together scientists, horticulturists and conservationists to prioritise and facilitate *in-situ* and *ex-situ* conservation of these iconic and often threatened species, and our pioneering International Conifer Conservation Programme (ICCP).

With over a third of conifer species globally threatened, the ICCP maintains vital genetically diverse *ex-situ* conservation collections at a network of over 200 sites across the UK and Ireland, safeguarding them from extinction. It also carries out *in-situ* protection and restoration as well as baseline taxonomic work. The ICCP team is responsible for maintaining the IUCN *Red List* of threatened conifers, assessing all taxa every decade and any newly described taxa as soon as possible.

We also have a focus on raising awareness of the importance of grassland, savanna and dry forest species and habitats (e.g., [Lewis, et al., 2022](#); [Silveira, et al., 2021](#)), from Brazil's *cerrado* (e.g., [da Conceição Bispo, et al., 2023](#); [de Barros, et al., 2023](#)) to the grasslands of sub-Saharan Africa and Madagascar (e.g., [Lehmann, et al., 2021](#); [Tiley, et al., 2023](#)). Their biodiversity, soils, and the livelihoods of people dependent on these habitats are threatened by development, climate change, and often planned or unplanned encroachment by trees (e.g., [Wieczorkowski & Lehmann, 2022](#)). We work with local organisations and communities to explore the best ways to manage these ecosystems, including managing fire regimes, and to guide global standards for reforestation which take account of biodiversity ([Andres, et al., 2022](#)).

In Nepal, we are partners in a long-term DEFRA Darwin Initiative-supported programme led by our collaborators ForestAction ([DAR26022](#), [DAR29028](#)). Here, we are restoring community forests

through training in plant identification, removing invasive species, and promoting sustainable agroforestry systems such as cardamom and goat-production, fertilised by low-carbon biochar made from the biomass of the invasive species removed.

Knowledge and skills transfer, and capacity building, are central to our biodiversity conservation work in regions with rich floras which often face the greatest threats. Recent examples include our work to build capacity and community resilience for grassland conservation in Bhutan ([DARCC002](#)), to enable sustainable, profitable and equitable community-based forest management in Tanzania ([DAR25019](#)), and to support sustainable plant use in Tajikistan ([DAR26010](#)).

Further projects and programmes providing the evidence base for biodiversity protection, restoration and monitoring may be found in the [Research](#) section.

## Actions to tackle the main drivers of biodiversity loss

We tackle the main drivers of biodiversity loss, as [identified by IPBES](#), including:

**Land-use change:** Our work to protect biodiversity extends to the land-use policy level. For instance, our high-resolution approach to mapping deforestation in southeast Asia – in partnership with Kunming Institute of Botany, Chinese Academy of Sciences, and CIFOR-ICRAF China Country Program – enabled us, for the first time, to quantify the extent of deforestation due to natural rubber plantations (published in *Nature* [\[Wang, et al., 2023\]](#)). Rubber is now included in the recent EU deforestation-free commodity regulation. We are working with farming cooperatives and certification bodies including the Forest Stewardship Council (FSC) and the Global Platform for Sustainable Natural Rubber, to ensure that a transition to deforestation-free rubber does not disadvantage smallholder producers.

**Pollution:** With the UKRI-GCRF [South Asian Nitrogen Hub](#), we are using lichens as indicators of nitrogen pollution and impacts on biodiversity in the Himalayas, as part of a larger programme helping improve nitrogen management in agriculture and develop the policy conversation on nitrogen in the region.

**Climate change:** In addition to our extensive work in Scotland and overseas to develop, share and provide training in nature-based solutions for climate change mitigation and adaptation, detailed under [Integrating Biodiversity into Climate Action](#), and our Edinburgh Biomes programme, covered under [Biodiversity Leadership](#), we are reducing carbon emissions wherever possible at all our Gardens. For instance, Logan has recently installed a 32 kWh solar PV array and Benmore is upgrading its courtyard heating to include air-source heat pumps.

**Natural resource use and exploitation:** Our work is helping protect and monitor several plant groups at risk of overexploitation, including frankincense (*Boswellia* spp.), and yew (*Taxus* spp.), which in some areas are illegally harvested for their rich content of paclitaxel, a broad-spectrum anti-cancer compound.

**Invasive species:** Aside from our work restoring forests threatened by invasive plants in Nepal (see [Across the world](#)), we play a leading role in protecting Scotland's horticultural industry and natural environment from the growing problem of emerging pests and pathogens (see [Integrating Biodiversity into Climate Action](#)).

Note that actions to 'achieve wider outcomes for nature and people' are reported throughout subsequent sections of this report.

### 3. Mainstreaming biodiversity

#### Protecting biodiversity through our policies, plans and strategies

The Royal Botanic Garden Edinburgh's [Corporate Strategy](#), which runs from 2021-2026, puts responding to the biodiversity crisis and climate emergency at its core. It is supported by a ten-year [Science and Biodiversity Strategy](#). Both Strategies centre around three strategic pillars:

- Unlocking knowledge and understanding of plants and fungi to benefit society;
- Protecting and developing the National Botanical Collections as a global resource;
- Enriching and empowering individuals and communities through learning and engagement with plants and fungi.

Our fourth, enabling pillar is Sustaining RBGE – ensuring a sustainable organisation.

The Science and Biodiversity Strategy expands our first pillar further into three strategic themes:

- Discovery Science: Understanding plant and fungal diversity;
- Global Environmental Change: Understanding biodiversity and ecosystem change;
- Conservation and Sustainability: Delivering science to enable the conservation and sustainable use of biodiversity.

An annual (from 2024/25, five-yearly) Operational Delivery Plan defines our activities in line with these pillars and themes, and includes targeted Key Performance Indicators to monitor progress.

We have recently published supporting five-year (2023-2028) Digital and People Strategies which will help us meet our aims and objectives for biodiversity and people, whilst building our capacity and nurturing our workforce. A new Living Collections Policy is at an advanced stage of development, and will guide the future curation and management of our Living Collection to maintain healthy, diverse and well-documented plants in landscapes which are safe for users and local biodiversity, in compliance with national and international laws and conventions, ensuring that our plants, estates and landscapes are of maximum value to the local and international community. Key objectives of the Living Collections Policy in the context of biodiversity include:

- Increasing representation of the world's plant diversity in botanic gardens;
- Enhancing the conservation value of our Living Collections;
- Increasing the number and diversity of threatened plant species held, to protect against extinction;
- Increasing the number of threatened plant species used as a resource for restoration programmes;
- Capturing maximum information about each collection;
- Building resilience to changing conditions;
- Researching and developing horticultural protocols to support conservation;
- Protecting the Living Collections from emerging pests and disease with biosecure practices, including maintaining Plant Healthy certification;
- Managing the Living Collections to support biodiversity in our Gardens.

An Environmental Sustainability Strategy is in preparation, to expand on our Carbon Management Plan and ensure our transition to Net Zero by 2045. We have Sustainable Procurement, Ethical Fundraising and Ethical Investment policies in place, to ensure that all our operations are in-line with environmental and other ethical principles. The principles of biodiversity conservation extend

throughout our other Strategies and Policies, such as our Arts Manifesto, Research Ethics Policy, Data Management Policy and Travel Policy.

Our Executive Team and Board of Trustees have final sign-off on all strategies, plans and policies. All our staff engage in biodiversity protection and restoration in some way, either directly or through sustaining our organisation. Of note, our estates team and curators are responsible for maintaining biodiversity and minimising climate impact across our estates, including our dedicated head of the Edinburgh Biomes programme and our Sustainability and Energy Manager. Within Science, our Cryptogams Section is responsible for most of our work to protect and restore Scotland's biodiversity. Our two nature-based solutions posts are joint appointments between Science and Horticulture, reflecting the cross-disciplinary nature of this work, and our Scottish Plant Restoration team also includes staff from both disciplines working closely together.

## Embedding biodiversity in our work

Aside from our direct research and conservation work, biodiversity is embedded throughout our horticulture, visitor offer, education and engagement programmes. A key paper ([Hughes & Foulkes 2022](#)) documents our actions to reduce environmental impacts across our horticultural and visitor activities and helps to inform other similar organisations of actions they may be able to take.

Three of our four Gardens are members of the Green Tourism Scheme and have achieved its highest (Gold) award. At Edinburgh, our certified organic market garden supplies all our catering outlets with seasonal, nature-friendly produce.

In 2022 RBGE became the first public garden in the UK to be [Plant Healthy](#) certified, applying the Plant Health Management Standard to all activities across our organisation to promote biosecurity and reduce the risk of introduction and spread of unwanted organisms, one of the main drivers of biodiversity loss. Processes are internally and externally audited annually to ensure continued adherence to the Standard. Maintaining Plant Healthy accreditation requires continual improvement, so in 2023 we provided an online biosecurity training module for all Horticulture staff, and aim to roll this out to all relevant staff. A new Plant Health and Biosecurity Policy describes the importance of this area to RBGE and where responsibility for actions lies.

Our Education team integrate an awareness of biodiversity into every course and deliver CPD sessions for teachers through the ENFOR partnership in conjunction with Education Scotland, and with City of Edinburgh Council and the Edinburgh Outdoor Learning Network. In addition, our new engagement programme – Planting Connections – supported by the National Lottery Heritage Foundation, has set up three new advisory groups to help shape our programming to meet community needs. The project has already trained six community biodiversity ambassadors to deliver free community workshops on- and off-site, covering aspects of biodiversity conversation, from seasonal eating to plant biology and nature art to tackling climate change in the home. For more on our education and engagement activities see [Public Engagement](#).

## Biodiversity leadership

Our Senior Leadership, Science Management and policy teams have contributed to the development of the Scottish Biodiversity Strategy, National Planning Framework 4, Scotland's new National Performance Framework and the Natural Environment Bill, in conversation and collaboration with partners across the SEFARI institutes, NatureScot, the Environment and Economy Leaders' Group, and others.

We have taken the lead with NatureScot in developing – with all relevant stakeholders – a [Plant Biodiversity Strategy](#) and Delivery Plan for Scotland, aligned to the Scottish Biodiversity Strategy and Global Strategy for Plant Conservation (GSPC).

At international level, we sit on the Consortium of Scientific Parties advising the Subsidiary Body On Scientific, Technical and Technological Advice to the Convention on Biological Diversity. In this context, we helped develop a new GSPC in response to the invitation of the Kunming-Montreal Global Biodiversity Framework. We also contributed to the development of the IUCN Global Ecosystem Typology – a conceptually robust, scalable, spatially explicit framework placing all Earth’s ecosystems into a unifying theoretical context to guide the transformation of ecosystem policy and management from global to local scales ([Keith, et al., 2022](#)), and the bringing together of over 70 natural history collections from 28 countries to create a global database of over a billion specimens to facilitate solving problems such as biodiversity loss, climate change and pandemic preparedness ([Johnson, et al., 2023](#)).

Landmark projects in which we show leadership for biodiversity include the [World Flora Online](#), a unique, coordinated global effort to produce a comprehensive online resource of authoritative baseline knowledge on all known plants, a key tool for botanical research, conservation policy and practice, and the sustainable use of plant resources. RBGE plays a leading role in this through our Taxonomic Expert Network Manager who develops the network of taxonomic experts and coordinates the input of taxonomic data into the Flora. Since the start of 2022, RBGE has also been responsible for directly hosting and managing the Flora’s taxonomic backbone – a dynamic, hierarchical list of all plant names and relationships, via the bespoke management system *Rhakhis*.

RBGE co-leads (with Naturalis, Netherlands) an important pan-European consortium, [Biodiversity Genomics Europe](#) (BGE). Comprising 33 partners across 20 nations, the consortium aims to drive the comprehensive application of genomic science to biodiversity research, supporting fundamental advances in conservation science and policy, by bringing together communities involved in both genome sequencing and DNA barcoding to build capacity, increasing the production of genomic data across communities and borders, and improve the efficacy of management interventions and biomonitoring programmes with sound genomic tools.

On site, our ambitious Edinburgh Biomes plan, supported by investment from the Scottish Government’s Low Carbon fund, will be realised over the next seven to ten years. It includes replacing our old heating system with a sustainable energy centre and district heating system featuring ground-source heat pumps, and renovating or replacing our heritage and research glasshouses to minimise heat losses and maximise energy efficiency. We are working with the principal contractor – Balfour Beatty – to trial the delivery of an industry-leading zero-carbon construction site. This involves examining every element of the project – materials, transport and all activities that take place on site during construction until handover – to find lower-carbon options and solutions, integrating carbon into decision-making and making it a priority alongside cost, quality, time and safety.

## 4. Nature-based solutions, climate change and biodiversity

### Integrating biodiversity into climate action

In all our activities, we promote a biodiversity-rich environment crucial to carbon sequestration, and ecosystem and human resilience. As a major centre of public engagement we support individuals and organisations to reduce their carbon emissions via nature-based solutions.

### Mitigation

Understanding the impact of the climate emergency is fundamental to instigating positive change. We work to establish the status of plant and fungal species in our most climate-threatened landscapes, such as the snow beds of the Cairngorms National Park. This enables us to monitor changes as the environment heats up and habitats shrink, and to identify focal areas for protection. A particular focus is on cryptogams. 'Cryptogamic crusts' of bryophytes and lichens account for a substantial proportion of carbon capture and more than 50% of terrestrial nitrogen fixation, and Scotland is a hotspot for these vulnerable communities. Our cryptogam research includes long-term monitoring, field sampling, translocation experiments and statistical modelling, to understand how climate change is affecting their ability to survive, grow, and reproduce.

Seagrass (*Zostera* spp.) beds are a key nature-based solution, combining biodiversity benefits with remarkable levels of carbon storage and climate adaptation. Forming dense meadows in shallow waters and intertidal areas, they stabilise coastlines, act as nurseries for many fish, including commercially important species, and are also excellent carbon sinks: occupying just 0.1 percent of the sea floor, they hold 11 percent of all organic carbon stored in the oceans. However, they are one of the most threatened ecosystems on the planet, declining at a rate of seven percent every year as a result of pollution, disturbance and disease. The three-year [Restoration Forth](#) programme, initiated in 2022, is part of a national seagrass-restoration project, working with local communities to restore coastal habitats and strengthen connections between nature and community. Together, we aim to restore 30 km<sup>2</sup> of seagrass meadows by 2030, with four ha in the Firth of Forth, alongside reintroducing 30,000 native oysters which have been locally extinct for over a century.

Our conservation genetics team is informing this work, analysing the DNA of seagrass populations around the British Isles to identify the best and most diverse source populations to maximise the likelihood of successful restoration programmes – work which won the 2022 Nature of Scotland Innovation Award. Successful seagrass germination has since been achieved at all three trial sites. We also contributed chapters to a new [Seagrass Restoration Handbook](#), guiding best practice for seagrass restoration programmes around the world.

Internationally, we document the identity, distribution, and conservation status of plant species in biodiverse and economically important groups including forest trees, conifers, gingers (Zingiberaceae), begonias, the potato family (Solanaceae), and grasses (Poaceae), to monitor threats and identify priorities for conservation. Our forest plot data, accumulated over decades in Africa and South America, contribute to regional assessments of changing forest biodiversity and carbon cycling, many of them published in extremely high-impact publications (e.g., [Bennett, et al., 2021](#); [Bennett, et al., 2023](#); [Mo, et al., 2023](#); [Forestplots.net, et al., 2021](#)), providing evidence to support forest management for both biodiversity and climate mitigation.

Globally, many climate change mitigation programmes rely on tree planting. This can have negative consequences for biodiversity if non-native trees are planted or if the existing natural vegetation of the site is disturbed, damaged or destroyed. Our work in savannas and grasslands, particularly in

Africa and Madagascar, addresses this problem by working with ecologists, policymakers, local communities and NGOs to seek best practice for management of biodiversity, carbon, fire and livelihoods (e.g., [Phelps, et al., 2022](#); [Stevens, et al., 2022](#)).

## Adaptation

Climate change adaptation is ongoing at all our sites as we deal with changing temperatures, increasingly frequent extreme weather events, and emerging pests and diseases.

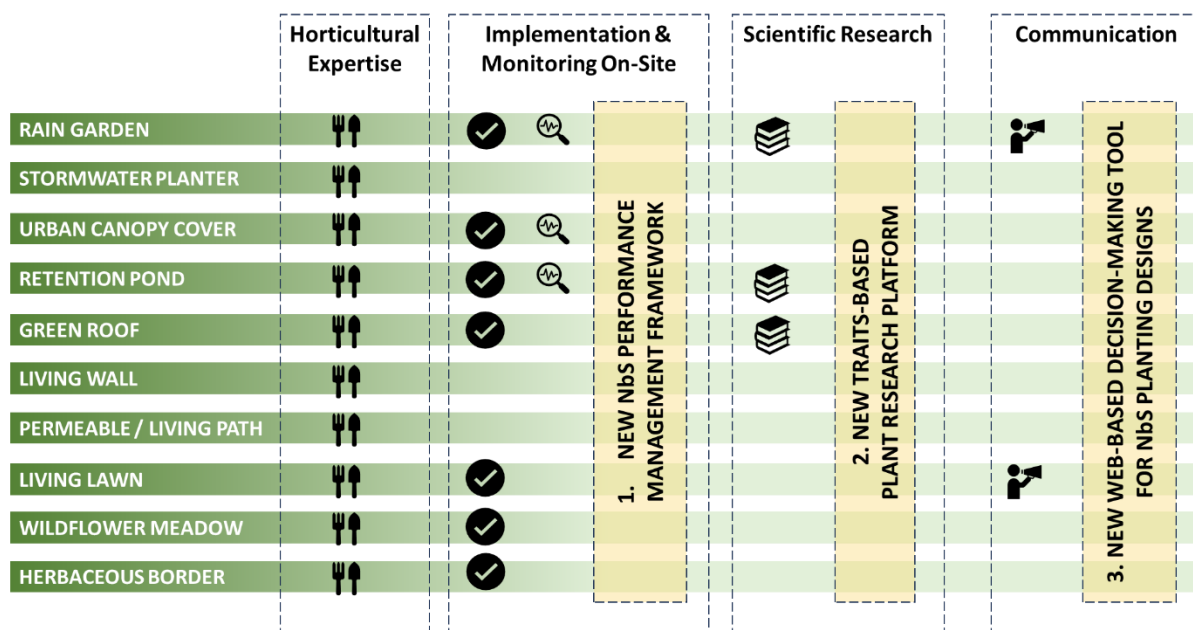
We are working with Leadership Fellows from our partner organisation, Longwood Gardens, USA, to shape our response in this area. Their most recent research report in 2023 helped clarify our role, and the wider role of botanic gardens in climate adaptation, recommending gardens deliver practical demonstrations, develop planting lists and lead research into plant performance, provide training and skills-building for planners, landscape architects, grounds maintenance and landscape teams, guide and educate the public, and develop climate-adaptation product lines for sale – all recommendations which have been approved for action by our Board.

We have recently established a nature-based solutions team to expand our work with urban greening and blue-green infrastructure for biodiversity and climate resilience, from our own sites to across Edinburgh and beyond. Many of our buildings, such as the Dawyck Visitor Centre and Edinburgh's John Hope Gateway, have green roofs on which plants help insulate the building and regulate the temperature throughout the year, at the same time providing a biodiverse habitat for plants and pollinators.

Increasingly intense rainfall events are becoming problematic for managing our estate. At Benmore we are improving drainage infrastructure with larger pipes and ditches, and have successfully aerated the soil under our iconic redwood avenue using an innovative system of geo-injection to protect from compaction, waterlogging, and consequent vulnerability to disease, with results already apparent in healthier trees. This system is now being used to beneficial effect elsewhere across the site.

Our Edinburgh demonstration raingarden, created in 2019 in partnership with the Water Academy at Heriot-Watt University as part of 'Edinburgh Adapts – Driving Adaptation Actions for the Capital,' is regularly monitored to document its performance as a nature-based solution to extreme weather events. It showcases plants as a tool for flood mitigation, provides a research setting for ongoing evaluation of species' climate-ameliorating performance, and has benefits for biodiversity, greenspace, recreation and education. The mix of plants grown in the raingarden is designed to attract a greater diversity of wildlife to the area: a range of flowers supply nectar for insects, and leaving stems of the perennials and grasses standing over winter provides habitat for invertebrates and food for seed-eating birds. Interpretation materials and regular demonstration events make this a valuable tool for encouraging wider uptake of nature-based solutions. Additional demonstration blue-green infrastructure solutions in the Edinburgh Garden include new stormwater planters and a bioretention pond, with interpretation around green walls and vertical planting coming soon.





**Above:** Summary of RBGE expertise, monitoring, research and communication activities across blue-green infrastructure for climate adaptation.

Offsite, during the current reporting period, we carried out an inventory of green roofs across Edinburgh to support future research and policymaking ([Miller, et al., 2021](#)), two detailed studies of the ecosystem services provided by urban SuDS ponds and surrounding greenspaces at Blackford ([Krivtsov, et al., 2022](#)) and Granton ([Krivtsov, et al., 2021a](#)), Edinburgh, to promote the benefits of blue-green infrastructure, and a study of the potential synergistic benefits of combined SuDS ponds and green roofs ([Krivtsov, et al., 2021b](#)).

Our Scottish Plant Restoration programme (described under [Direct actions to benefit biodiversity](#)) is ensuring that all rare and threatened plants we reintroduce across Scotland are genetically diverse, to give populations the best possible chance to adapt to a changing climate and emerging pests and pathogens. Climate change exacerbates the spread of new plant diseases, putting the natural environment, horticulture, agriculture and forestry sectors at risk, alongside threats to food security. RBGE is Natural Environment and Horticulture Lead in Scotland’s [Centre of Expertise in Plant Health](#), which brings together experts from all these sectors to co-ordinate plant health knowledge, skills, needs and activities across Scotland, and works with Scottish Government, public bodies and stakeholders to provide scientific evidence to tackle plant pests and pathogens. RBGE is also a member of the [International Plant Sentinel Network](#), providing a global early-warning system of emerging pest and disease risks.

As a member of BGCI’s [Climate Change Alliance of Botanic Gardens](#), we work with other gardens across the world to prepare and plan for the need to move rare and threatened species from warmer to cooler sites as their current locations become less climatically suitable, putting them at risk.

## Green growth

We work in multiple public and private partnerships to create the conditions and trained individuals to support green growth in Scotland.

Examples include a ‘Partnership Ecosystem’ network with Scottish Water, NatureScot, Green Action Trust, Hydro Nation, Edinburgh City Council and SEPA, working to demonstrate the feasibility of

retrofitting private and public assets with blue-green infrastructure, initially using the example of Craigleith Retail Park.

We provide support to other organisations around urban greening. For example, we have an ongoing partnership with the National Museum of Scotland, developing ways to add blue-green infrastructure to their rooftops and identifying suitable species to incorporate, including rare and threatened Scottish plants – a win-win scenario for biodiversity and climate adaptation. We work with Fife Council and NHS Fife on the design and implementation of natural flood management schemes on their estates.

We are members of the [Scottish Forum on Natural Capital](#), aiming to bring natural capital into mainstream decision-making. Nature-based solutions are an integral part of our in-house horticulture courses, we deliver training in nature-based solutions in partnership with universities (Edinburgh, St Andrews and Heriot Watt), and we regularly provide advice to landscape architects on planting schemes. Our free online course '[Botany for the built environment](#)', developed with Leeds University, explains the value and function of urban plants and green infrastructure.

### Health and wellbeing

We support physical, emotional and social wellbeing by fostering connections between people, plants and each other. Our Edinburgh Garden provides 28 ha of accessible greenspace within the urban landscape. All four of our Gardens offer a dedicated [Silent Space](#) for peaceful engagement with nature, and at Edinburgh our Garden of Tranquillity is a calming and engaging space for those living with dementia and their families.

Following our successful response to meet changing community needs during the covid pandemic, we continue to offer a range of health and wellbeing activities to help local communities access the benefits of biodiversity in Gardens and other local greenspaces. The focus is our Engaging Gardens programme, centred around Edinburgh's Botanic Cottage. Here, we connect health and wellbeing with environmental sustainability through a range of activities including family drop-in sessions, a community Edible Garden project (currently involving groups including Adoption UK, Edinburgh and Lothians Regional Equality Council, and Networking Key Services), 'Meet the Gardener' sessions and free, tailored, community skills-share workshops supporting local groups to develop green spaces in their own areas.

We help deliver improvements in physical health (our 'Move More' regular gardening group provides gentle exercise for those experiencing cancer), mental health (regular drop-in sessions at the Botanic Cottage include Thrive North West, Empathy in Mind and VOCAL) and overall wellbeing and reducing social isolation through monthly 'Food Socials', providing a supportive and social environment for people to cook and share a meal together, and dementia-friendly 'Garden Socials'. 'Social Capital' networking events have recently focused on building connections in community growing across regions and developing green health and wellbeing in North Edinburgh.

In 2022/23 RBGE scientists working on the '[Good City](#)' project engaged with more than 400 young people across Edinburgh to explore the value of nature in their urban neighbourhoods, analysing their access to nature, identifying areas in need of nature-based solutions, and connecting them and their ideas with decision-makers.

### Climate change-related challenges for biodiversity

The themes of biodiversity and climate crisis are central to all our present and future activities. We are currently developing a five-year implementation plan for our Science and Biodiversity Strategy, to maximise our impact on these challenges. We evidence local and global threats to biodiversity, and

deliver practical actions to restore species and habitats in the face of environmental change. Our education, engagement and outreach programmes play a key role in raising awareness around biodiversity loss and climate change and guiding positive behavioural shifts.

In our Gardens, key climate-related challenges include direct loss of plants in the Living Collection due to changing climate, extreme weather (storm damage, heatwaves and flooding) and emerging pests and diseases. Infrastructure programmes such as Edinburgh Biomes will help protect our collections. We have monitoring in place to capture the impacts of pests and pathogens, and a research programme to understand their impact on our plant collections, working in partnership with others through initiatives such as the International Plant Sentinel Network and Scotland's Centre of Expertise in Plant Health. Our long-term phenology monitoring programme helps us track plants' responses to a changing climate, as does analysis of herbarium collections from multiple years.

As part of the [Climate Change Alliance of Botanic Gardens](#), we are working with institutions across the UK and beyond to secure the global 'meta-collection' of living plants, modelling future scenarios and, where necessary, considering moving specimens from sites that have become unsuitable to those that may now be safer for them. We are also working in partnership with other key UK organisations, including the RHS, National Trust and NTS, Royal Parks, English Heritage and Royal Botanic Gardens, Kew, to identify areas where we can collectively meet climate-related challenges in the management of our plant collections.

Offsite, we continue to support the management of Scotland's unique habitats, such as rainforest, by studying and modelling species and community responses down to the microclimate level (e.g., Ellis & Eaton 2021[a](#), [b](#)).

Globally, impacts of climate change related to our work include the spread of non-native invasive species, which we are tackling in our work with community forest user groups in Nepal (see [Across the world](#)); food security, on which we are working in Solanaceae (potato family); and tree encroachment in grasslands, which we are helping to raise awareness of and mitigate through sustainable ecosystem management (see [Adaptation](#)).

## 5. Public engagement and workforce development

### Public Engagement

Biodiversity is a key theme underpinning RBGE's public engagement programmes including community engagement, interpretation, creative programmes and events, and of course our education and training courses. Ensuring that these programmes are inclusive and accessible to diverse audiences is a key priority. We have engaged a Community Advisory Group to help us reach a diverse range of voices, and we partner with organisations such as RNIB and Sight Scotland to improve accessibility and inclusivity.

### Volunteering

RBGE has as many volunteers as staff, and they provide a vital, valued and respected contribution to our work, playing a significant role in the welcome, experience and learning of our visitors, including as our popular Garden Guides. Found across the organisation, from science to horticulture, events and exhibitions, the Herbarium and Library, many have been with us for a decade or more. Supported by a Volunteer Coordinator, our volunteers gain satisfaction from their contribution and often build knowledge and skills such as in horticulture and public engagement, including through training courses. See also [Citizen science initiatives](#) for examples of our volunteer activities.

### Exhibitions and events

RBGE's creative programmes are unique within the Scottish cultural and heritage sector in linking scientific research, art and community engagement. Centred around the '[Climate House](#)' gallery in the Edinburgh Garden, our exhibitions and events are designed to spark the imagination, nurture a culture of interest in the natural environment, inspire connections among a wide variety of audiences, and catalyse action. For example, acclaimed recent exhibitions such as [Shipping Roots](#) and [In the Eddy of the Stream](#) addressed the impacts of colonialism relating to invasive non-native species transported, and effects on the local flora of Palestine, respectively.

Our extensive programme of events covers all four Garden sites (for example, Logan hosts more than 70 events annually). Twice yearly we deliver family-focused trails around biodiversity in the Edinburgh Garden, with around 10,000 people engaging each time. We also run a programme of biodiversity-themed events for all ages as part of the annual Edinburgh International Science Festival, and host or contribute to Edinburgh Festival Fringe events in the summer, such as 2023's *1,000 Miniature Meadows*, providing an immersive experience to participants via soundscapes from pollinator-rich meadows. Our self-guided Lichen Trails celebrating some of Scotland's most overlooked organisms are available at all four Gardens, with additional Moss and Fern Trails at Benmore.

For members and supporters we provide additional events to inform, engage and inspire, such as exhibition previews, book launches, expert public lectures and guided tours.

### Early years, schools and outdoor learning

Having piloted an outdoor nursery as a response to the covid pandemic in 2020, we have continued to evaluate the importance of biodiversity engagement among early-years learners. Three core early-years programmes have now been established: *Seedlings*, *Sprouts* and *Sunflowers*. The latter is a 'stay and play' outdoor session aimed at encouraging children (and parents/carers) to connect with nature and promote a love of the outdoors. Feedback to date has been extremely positive, with many of the youngest learners (from five months) progressing through the different sessions as they grow. Most importantly there is also anecdotal evidence indicating that parents/carers attending the sessions

have formed a stronger connection with nature and increased awareness of biodiversity loss and climate emergency.

For schools, RBGE offers a range of primary sessions at the Edinburgh Garden, all focused on biodiversity education with a STEAM-based approach including:

- *Life of plants;*
- *Rainforests;*
- *Wild words;*
- *Our senses, our stories.*

Educational delivery at Dawyck, Logan and Benmore is delivered through a free, annual, regional outreach programme supported by the players of the People's Postcode Lottery. This programme ensures we reach learners across Scotland with a strong message and call to action around biodiversity. Logan also holds family activities twice weekly throughout the summer.

Young people with additional support needs are engaged via a dedicated project – *Living Roots* – which enables and supports connection with biodiversity through gardening and observing wildlife. These sessions encourage nature-positive practices, and we also provide advice to schools on their own sites through a 'roving gardener' service.

We have recently recruited a dedicated Secondary Schools Officer to help reach young people, working across the curriculum and engaging in discussions around green careers, subsequently encouraging a greater awareness and interest in biodiversity. We also work with local schools, such as Stranraer Academy near Logan, to develop their biology programmes.

From 2023, through funding from the National Lottery Heritage Fund, we increased capacity to provide schools' outreach programmes in-person and virtually, focused on the importance of plant biodiversity, the threats facing it, and accessible actions to protect it, with four new biodiversity-themed sessions:

- *Soil secrets* (in-classroom, for primary) exploring soil biodiversity. This activity was also shared with school groups and other visitors at St Abbs Science Festival and the Royal Highland Show;
- *Rainforest protectors* (live virtual workshop, for upper primary) exploring plant adaptations and uses. This activity was delivered as part of Orkney Science Festival and also to Edinburgh pupils learning from home during school strikes;
- *Rainforests in your PLAYGROUND* (in-classroom/school grounds, for upper primary) exploring plant identification and field work skills;
- *Field skills for biology* (in-classroom/school grounds, for lower secondary) exploring fieldwork skills.

An estimated 1,500 pupils from 25 learning settings engaged in these activities in 2023, from Barra to the Borders and Stromness to Stranraer.

Working with partners in the Scottish Government Outdoor Learning Group including NatureScot, Forestry and Land Scotland, and Scotland's National Parks, RBGE contributes to Scotland's [Outdoor Learning Directory](#), a resource for teachers, parents and carers to find outdoor activities encouraging connection with nature. RBGE is also a member of [the Learning for Sustainability](#) group at Education Scotland, ensuring that current guidelines around biodiversity are fed into programme development in line with the Curriculum for Excellence.

## Professional courses

We deliver a wide range of biodiversity-related professional courses, including a new online provision, the *RHS Level 2 Certificate in Principles of Plant Growth and Development*, which includes a detailed *Biodiversity* topic covering plants and biodiversity, the impact of climate change, creating habitats, citizen science and species surveys, and biodiversity action plans. It is currently accessed by 150 online learners.

Our *Horticulture with Plantsmanship* HND/BSc (Hons) programme promotes the use of horticultural practices in the conservation and management of biodiversity. The 2023 introduction of Next Generation Higher National Qualifications has seen an increased focus on biodiversity, ecology and conservation in contemporary horticultural practices, and the revalidation of the BSc (Hons) course in 2024 will include a dedicated conservation horticulture module, with biodiversity conservation embedded in all other modules. These curriculum changes recognise the vital role that horticulturists play in mitigating biodiversity loss, and the technical skills required to develop and maintain nature-based solutions.

RBGE's MSc in *Biodiversity and Taxonomy of Plants* has trained world-class botanical researchers since 1992, with over 400 graduates from 47 countries so far progressing to careers in botanical research and conservation at institutions around the world. The programme offers in-depth modules in global angiosperm, cryptogam and fungal biodiversity, evolution, conservation, and applied biogeographical and molecular research methods, giving graduates the skills to undertake cutting-edge biodiversity research and to make evidence-based conservation decisions. The course includes a three-month thesis project developing students' experience and practical skills, often resulting in published, peer-reviewed papers. Graduates are uniquely placed to work at the forefront of biodiversity and conservation research.

## Citizen science initiatives

As part of our involvement in the [Darwin Tree of Life](#) genome-sequencing programme (see also [Research and Monitoring](#)), three citizen-science plant-recording projects have been carried out with local recording groups and the public: in [Skye](#), the [Scottish Borders](#) and at [Little Sparta](#) near Edinburgh. On Skye, the aim was to improve recording of two rare and overlooked ferns – *Ophioglossum azoricum* (small adder's-tongue) and *Polypodium x mantoniae* (Manton's polypody). In the Borders, the focus was on finding surviving large wych elm trees, which may be resilient to Dutch elm disease (*Ophiostoma novo-ulmi*), to provide a genetic resource with potential to assist the recovery of the species. At Little Sparta (a garden developed from sheep pasture) we ran a two-day 'bioblitz' event – the first concerted effort at biological recording of this diverse site. All three events generated new biological records.

Other citizen scientist initiatives include participation in [Observatree](#), an important plant health project which trains volunteers to recognise and report plant health issues. In our herbarium-based programmes – either stand-alone or as part of wider, often global, initiatives – citizen scientists help harness the vast quantities of data held in herbarium specimens via transcribing labels, whilst engaging with our historic botanical collections. These include 'virtual expeditions', run through the [Digivol](#) and [Zooniverse](#) citizen science platforms, may take the participant anywhere from the UK to Australia or Myanmar (for example, see [this blog post](#)).

## Community engagement and public outdoor education programmes

Our Gardens are demonstration sites for nature-positive gardening and land management, engaging communities with plant conservation and the maintenance and creation of species-rich habitats. Seasonal British Sign Language tours are an accessible way for visitors to connect with our

collections, explore the changing seasons and history of the Garden, and we are also developing live audio-described tours to provide more inclusive engagement with biodiversity.

Many of our community engagement programmes combine biodiversity with health and wellbeing (see [previous section](#)). Additional community engagement contributions include a programme of one-off creative workshops around our biodiversity-linked exhibitions, bringing together community groups with a shared interest in the arts; and youth biodiversity-engagement programmes including regular visits from Adoption UK's kinship-care project and the Rock Trust, with many more *ad-hoc* users including Multi-Cultural Family Base and Children First.

Our collaborative [Restoration Forth](#) programme (see also [Integrating biodiversity into climate action](#)) has a large community-engagement component, focused on educating, inspiring and upskilling local residents. Volunteers engage in activities throughout the oyster and seagrass restoration process, from practical reintroduction work and monitoring in the field, through to creative input into an oyster mural.

Our wide range of short courses includes the free, five-hour online course *Plants and Climate Change*, developed in 2022, which incorporates biodiversity and its relationship to a changing climate. In the past year, over 500 people from 51 countries have enrolled on the course, with 100 completing it to-date. In 2024/25 we plan to develop a complementary online short course in *Biodiversity*, raising awareness of the biodiversity crisis, encouraging participants to take action to help biodiversity, and contributing to RBGE's mission and strategies regarding biodiversity conservation, climate change and education.

In our online *Getting Started with Planting Design* course we added a new topic, *Designing for Nature* in 2023, covering creating a community of plants that contributes positively to biodiversity by providing habitats for other species. This includes a lesson on *Designing Communities*, exploring garden design for nature and maximising species richness in our Gardens, for example through layering and the use of both native and non-native plant species.

Plant health is a key area where public engagement and education can support biodiversity. As part of Scotland's Plant Health Centre, RBGE has employed a specialist Plant Health Communications Officer to communicate the importance of plant health and biosecurity to audiences across Scotland and beyond.

We also host the Chartered Institute of Horticulture's annual Scottish *Grow Careers* day, taking place both online and in-person at our Edinburgh Garden. This day-long conference led by a range of horticulturists is aimed at anybody who is interested in starting or developing their career in horticulture.

## Website, blogs, social media and press

Online public engagement makes use of a wide variety of media, including using social media to drive traffic to our website and [Botanics Stories](#) blog, both of which continue to grow audiences.

While we produce frequent [press releases](#) each year on biodiversity-related issues, these are just a small part of our regular contact with the media. Working on a daily basis with regional, national and international media and with partner organisations we continue to reach fresh audiences. For example, from September 1 to December 11, 2023, alone, RBGE news was covered in 16 countries outwith the UK, most frequently in the USA, Germany, India, Ireland and France, with a publications and broadcast reach of 63.6 million and online views of 5.5 billion. Coverage included communications on international research papers, such as our rubber-related deforestation work

(see [Actions to tackle the main drivers of biodiversity loss](#)); Scottish research and conservation initiatives; the refurbishment and replacement of public and research glasshouses as part of the Edinburgh Biomes initiative, and myriad pieces relating to education, events and exhibitions.

Our social media channels communicate the work for biodiversity happening across our organisation, engaging a worldwide audience of over 256,000 followers across [Facebook](#), [Instagram](#), [LinkedIn](#), [X](#), [YouTube](#) and [TikTok](#). Focusing on producing informative and interesting content, the average engagement rate across social media channels for 2021-2023 was 4.4%, which is over twice as high as the industry average as of December 2023. For example, our [video](#) of herbaceous supervisor Kirsty Wilson giving audiences top tips on how to encourage wildlife into their garden as part of the *Get Planting with Nature* campaign had over 10,000 views. This ran alongside our social media campaign supporting No Mow May, encouraging audiences to let their lawns grow over the month of May.

Weekly 30-minute Instagram Live tours of our Edinburgh Garden hosted by science communicator Max Coleman started in early 2023 and have a total audience of over 100,000 (typically around 200 live viewers per tour and a further 1,000 on-demand within one week). With topics including the Scottish Plant Restoration project, plant health and biosecurity, nature-based solutions and Scotland's Climate Week, international audiences are invited to take a closer look at the biodiversity in our Living Collection across the seasons, engaging virtually with nature.

Our Scottish Plant Restoration team also carried out an Instagram '[Takeover](#)' and regularly publish accessible blog posts about their work on a dedicated [Botanics Stories](#) channel. The project has also been featured on NatureScot's '[Nature Heroes](#)' webpage, in print media, and on BBC Radio Scotland's *Out of Doors*.

We continue to publish richly illustrated popular books. During the reporting period these included *Herbology, A Physic Garden Pharmacy*; *Planting with Nature*; *Scottish Plant Names*; *The Hidden World of Mosses*; *The Yew Hedge*; and *World of Plants, Stories of Survival* as well as exhibition catalogues such as *Shipping Roots: Plant Journeys Through Empire*. Our two journals, [Edinburgh Journal of Botany](#) and [Sibbaldia: the International Journal of Botanic Garden Horticulture](#), are published on a diamond open-access model (free to read and free to publish).

## Workforce development

### Staff training, education and capacity building

All staff and volunteers are encouraged to benefit from personal and professional development, and have access to a wide range of courses and resources, such as our new internal Plant Health and Biosecurity online training course, rolled out to raise awareness of the risks from introduced plant pests and diseases.

We run apprenticeship schemes at Edinburgh and Benmore providing training, mentorship and the opportunity to study for an SVQ Level 2 in Horticulture and Landscaping, and a work placement programme at Logan. In addition, the 'Planting Connections' programme (see [Embedding biodiversity in our work](#)) has funded one apprenticeship, four student placements and two places on our Certificate of Practical Horticulture course.

### Conferences, exhibitions and events

We regularly host conferences, seminars and workshops, to which staff and students alike are welcome, and these are often jointly organised with other organisations. These include the annual [Scottish Botanists' Conference](#), the [2023 British Lichen Conference](#), the Society for the Preservation of Natural History Collections' [2022 conference](#), the [European Conservation Genetics Meeting 2022](#),



and a BGE day as part of the [Biodiversity Genomics 2023](#) online conference. Recent standalone events included a panel discussion: *Golden Monkey: Creativity, Conservation and Flagship Species* with artist Lisa Roet, Helen Senn of the Royal Zoological Society of Scotland, and RBGE's Martyn Dickson and Emma Nicolson, as well as speaker evenings with [Professor Sandra Díaz](#) and [Angela Saini](#).

Our staff are also supported to attend and present at biodiversity conferences elsewhere, including Scotland's annual Plant Health Conference, the RESAS Science, Evidence and Policy Conference, CITES COP19 meeting and UNFCCC COP26 meeting in Glasgow, where we co-hosted a nature-based solutions stand in the Blue Zone with NatureScot, and created displays for the meeting rooms comprising plants grown at RBGE.

### Collaborative working and sharing best practice

Our Education Department is part of several networks which ensure opportunities for sharing best practice, including the Heritage Environment Forum, Scottish Science Centre Educators Group, Edinburgh Outdoor Learning Network Working Group and ENFOR Education Group.

Science staff attend networking and learning events with organisations such as Edinburgh Plant Science (which has a particular focus on early-career researchers), Edinburgh Conservation Science, the British Ecological Society, Systematics Association and Linnean Society. We also sit on the Executive Committees of the Scottish Consortium for Rural Research and SEFARI.

### Practical opportunities

The day-to-day work of our staff and volunteers is fully aligned with practical action for biodiversity. Beyond this, we encourage a range of staff to participate in biodiversity fieldwork both in Scotland and overseas. One key example during the current reporting period was our conservation translocations of alpine-blue sowthistle at Glenfeshie, Glen Lochan and Mar Lodge in autumn 2021, in which staff from across the organisation took part, successfully planting out 900 young plants (see also [Direct actions to benefit biodiversity](#)).

## 6. Research and monitoring

### Research activities

We carry out a huge range of collaborative biodiversity research at varying scales from our Garden sites to globally. We published approximately 130 peer-reviewed papers per year over the reporting period, with around 70 papers published in the last five years cited over 50 times. We also described around 50 species new to science per year. We aim to make all publications available on the [Research Scotland Repository](#), which to date includes almost 3,500 of our journal articles plus many other items. We also contribute data and analysis to major reports such as the fifth [State of the World's Plants and Fungi](#) and the UK [State of Nature](#) reports, as well as detailed analyses of the diversity and threats facing particular regions, such as Madagascar ([Antonelli, et al., 2022](#); [Ralimanana, et al., 2022](#)).

### Understanding plant and fungal diversity

We have a strong focus on biodiversity discovery, characterisation and mapping as a basis for further research and conservation, in particular for the plants of south and southeast Asia, understudied Scottish taxa (bryophytes, fungi and lichens), and economically and ecologically important plant groups such as Solanaceae (potato, tomato and aubergine family). For example, during the reporting period we produced checklists to the large Gesneriaceae genus *Cyrtandra* in Sumatra ([Wang, et al., 2022](#)), the Philippines ([Olivar, et al., 2022](#)) and New Guinea ([Bramley, et al., 2023](#)) as well as a full taxonomic revision of the genus for Sulawesi ([Atkins & Kartonegro, 2021](#)). Similarly, we published a floristic account of the genus *Begonia* in Peru ([Moonlight, et al., 2023](#)), a checklist for Kalimantan ([Randi, et al., 2022](#)), and multiple new species descriptions in the genus, taking the number of known species to over 2,000 (reported [here](#)). Our genomic study ([Li, et al., 2022](#)) sheds light on the evolution of this mega-diversity. In 2022, our journal *Edinburgh Journal of Botany* produced a [special issue](#) on *Begonia* with papers by 68 authors from 21 countries.

For Zingiberaceae (ginger family, including many economically important species) we contributed to the new volume of the *Flora of Thailand* and in Solanaceae we published a revision of the South American species of the Moreloid clade ([Knapp, et al., 2023](#)), a detailed study of trait evolution ([Hilgenhof, et al., 2023](#)), a monograph of a new genus, *Doselia* ([Orejuela, et al., 2022](#)), and an important genomic study of deleterious mutations in potato to facilitate hybrid crop breeding ([Wu, et al., 2023](#)).

RBGE is a leading centre for the development of genomic techniques to discover, identify, understand and monitor biodiversity, including pioneering new methods such as extracting DNA from herbarium specimens and other museum collections ([Ferrari, et al., 2023](#)). As a Genome Acquisition Lab for the [Darwin Tree of Life Programme](#) coordinated by the Wellcome Sanger Institute, we contribute to sequencing the genomes of all 70,000 known species of animals, plants, fungi and protists in Britain and Ireland, with implications for biodiversity conservation and sustainable use of species, and potential to be scaled up to the flora and fauna of the world. In 2023, this project published its milestone 1,000<sup>th</sup> genome. Our focus has been on sampling bryophytes and rare Scottish vascular plants, both from our Living Collections and field research across Scotland, and on curating genomes such as that of [mistletoe](#) (*Viscum album*) the largest genome sequenced to-date.

Making biodiversity data accessible is a key step towards conservation, and RBGE plays a leading role in an important resource, the [World Flora Online](#) (WFO), created to meet Target 1 of the first GSPC. A collaborative, curated database of plant names, classification and data, the WFO is a vital tool for biodiversity conservation. It currently contains over 1.5 million plant names for 383,000 accepted species of the estimated 400,000 vascular plant species on Earth. RBGE manages the WFO network

of taxonomic experts and coordinates the input of taxonomic data, as well as hosting and managing the online 'taxonomic backbone' of the WFO via our bespoke management system *Rhakhis*. We also contribute data for ten plant groups, including all conifers.

## Global environmental change

We document how species and habitats are changing in response to human pressure on the environment, supporting conservation prioritisation, protection, restoration and sustainable use. Crucial to this is the assessment of species' 'Red List' status according to criteria defined by the IUCN. As well as evaluating the Red List status for every species we describe or revise, with a focus on species-rich *Begonia*, Gesneriaceae, Sapotaceae, Solanaceae, Zingiberaceae and cryptogams (bryophytes and lichens), RBGE chairs the IUCN Species Survival Commission (SSC) Conifer Specialist Group, reviewing the status of all the world's conifer taxa – over a third of which are threatened with extinction – every decade. We also co-chair the IUCN SSC Lichen Specialist Group. We have recently established a project to re-assess the conservation status of all UK lichens with Natural England, the British Lichen Society and the Centre for Ecology and Hydrology.

Beyond the species level, we work to assess the richness and endemism of, and threats to, communities and ecosystems, such as in AlUla, Saudi Arabia, where we are providing evidence to support the creation and siting of new conservation areas and nature reserves.

Monitoring species' and communities' responses to global environmental change is increasingly efficient thanks to the development of DNA-based biomonitoring technologies. We co-lead the Horizon-2020-funded [BGE](#) consortium programme (see [Biodiversity Leadership](#)) to build capacity and supporting reference libraries for DNA barcoding and genome sequencing across Europe. This will enable more efficient and effective species identification and monitoring of whole communities such as soil microbes, freshwater organisms, and pollinators. BGE brings together the European DNA-barcoding community ([Bioscan Europe](#)) and genome-sequencing community ([European Reference Genome Atlas](#)) to achieve economies of scale and share sampling and methodologies for biodiversity monitoring across the continent.

Pollinators are a key focus of the BGE programme, which is conducting pan-European DNA-barcoding of bees, butterflies, moths and hoverflies to create a barcode reference library supporting ongoing monitoring efforts and rapid eDNA assessment of pollinator community health. Within this, RBGE is using metabarcoding to compare pollinator communities among urban gardens and agricultural fields across Europe. In 2023, malaise traps ran for five weeks at Edinburgh and Logan, each paired with a trap in a local agricultural field. This case study will expand to more sites in 2024. Edinburgh and Benmore are also among c. 100 sites across the UK where monthly malaise-trap collections are made to support DNA-based characterisation of insect diversity through space and time.

At ecosystem level, we document changes such as those occurring in grassland and savanna undergoing encroachment by woody species ([Raymundo, et al., 2023](#); [Wieczorkowski & Lehmann 2022](#)), drought and fire ([Trotter, et al. 2022](#)) or overgrazing ([Hempson, et al., 2022](#)); and forest degradation ([Ahrends., et al. 2021](#)).

## Conservation and sustainability

Our research provides an evidence base for protection and restoration of habitats in Scotland and overseas. In Scotland's rainforest, our work – which contributes to the Scottish Government Strategic Research Programme – has elucidated species' responses to microclimate and demonstrated how microclimates are crucial to forest management for ecological guilds including functionally-important nitrogen-fixing epiphytes ([Ellis & Eaton, 2021a](#)) and epiphytic communities ([Ellis & Eaton, 2021b](#)). We

highlighted the particular role of riparian woodland in climate change adaptation, and informed the recent British Ecological Society [report](#) on the importance and conservation of riparian woodlands.

We have multiple strands of research in Scotland's mountains, including genomic characterisation of biodiversity in threatened habitats such as late-lying snowbeds, managing and curating data from a set of transects to monitor long-term effects of climate change on mountain lichens and arctic-alpine plants, monitoring indicator species in the Cairngorms National Park and leading on updating species risk assessments (e.g., for lichens) across the UK, in-line with IUCN guidance.

More information on our linked research and conservation projects in Scotland can be found under [Direct actions to benefit biodiversity](#) (e.g., Scottish plant restoration programme) and [Integrating biodiversity into climate action](#) (e.g., developing nature-based solutions).

Overseas, our programmes incorporate research with conservation action, support to sustainable livelihoods and building in-country capacity. For example, our work in Nepal combines baseline biodiversity discovery and documentation for the [Flora of Nepal](#) with production of user-friendly field guides, identification and removal of invasive non-native plant species, and development of sustainable livelihoods based on agroforestry techniques.

## Monitoring impact

Our species reintroduction and management programmes across Scotland are all monitored in the long term by ourselves or partners including NatureScot and local landowners, to ensure that populations of rare and target species remain healthy and are not impacted by factors such as disease or herbivory. Monitoring activities provide excellent training opportunities for students, and opportunities for engagement with volunteers and citizen scientists.

Overseas, long-term relationships with in-country partners ensure that the legacy of our international programmes is monitored and assessed. Often, one project follows another to build upon past successes. This is particularly true of our Darwin Initiative programmes such as in Nepal and Tajikistan.

As an organisation, we are currently undergoing an independent Economic and Social Impact Assessment which will establish the five-year impact of our operations from 2018/19 to 2022/23. We monitor our outcomes quarterly via Key Performance Indicators and narrative deliverables, and report these annually to the Scottish Government. Many of our externally funded programmes also require us to report on our impact and legacy – including the People's Postcode Lottery and the Darwin Initiative (all reports to the latter can be found [here](#)).

## Trends and areas of concern

The Botanical Society of Britain and Ireland (BSBI) [Plant Atlas 2020](#), the most in-depth survey of the British and Irish flora ever undertaken, was published in 2023, with its Scotland launch at RBGE. This comprehensive atlas indicates that over half of native plants have declined over the last 20 years as a result of human activity. Incredibly, non-native plant species now outnumber non-native species in the wild. The spread of some species – such as Sitka spruce (*Picea sitchensis*) is particularly worrying as it can invade peatlands important for both native biodiversity and carbon sequestration. In Scotland, mountain plants reliant on late-lying snow – such as alpine lady-fern (*Athyrium distentifolium*), alpine speedwell (*Veronica alpina*), and snow pearlwort (*Sagina nivalis*) – are being significantly impacted by climate change.

The UK [State of Nature](#) 2023 report also identifies a continuing decline in native species, with one in nine Scottish species threatened with extinction. Over 60 percent of bryophytes and 57 percent of lichen species have decreased in distribution since 1970.

The fifth [State of the World's Plants and Fungi](#), to which we also contributed, focused on knowledge of the diversity and distribution of plants and fungi. Our data helped determine that there are still extensive gaps in scientific knowledge of what plants exist and where, identifying 32 global 'darkspots' with significant numbers of unnamed and unmapped species, including Colombia, New Guinea and south-central China ([Ondo, et al., 2023](#) [preprint]). This work helps identify priorities for biodiversity discovery programmes to document the world's species in order to protect them.

Our work on rubber as part of the UKRI-GCRF [TradeHub](#) indicates that deforestation for production of commodities remains a problem (see [Action to tackle the main drivers of biodiversity loss](#)); however, working with policymakers such as in the EU, certification schemes such as FSC, and local farmers and cooperatives, we are positive that a way forward can be found that is beneficial to livelihoods and biodiversity, while maintaining world supplies.

Closer to home, our monitoring suggests increasing risks to the Living Collections from extreme weather events linked to climate change (intense rainfall, high winds and flooding) as well as from emerging pests and pathogens. We are undertaking remedial work and forward-looking infrastructure works (e.g., Edinburgh Biomes – see [Biodiversity leadership](#)) to protect our collections from climate-related losses, and with other members of the Climate Change Alliance of Botanic Gardens to protect the global 'meta-collection' of threatened species (see [Looking Ahead](#)). We work with partners in the International Plant Sentinel Network, Scotland's Centre of Expertise in Plant Health, and other parties such as Forestry and Land Scotland, to identify and manage plant health risks when they occur.

## Sharing data

RBGE is a member of the National Biodiversity Network (NBN). All databased UK collections in our Herbarium are represented in the NBN Gateway, and we provide data on Scotland's conservation-priority species to the *National Biodiversity Atlas*. In addition, all databased collections are accessible on GBIF, where our data are recognised as a 'colossal database.' We contributed data to the seminal *BSBI Plant Atlas 2020*.

We are part of the Scottish Biodiversity Information Forum, aiming to improve Scotland's infrastructure for recording, managing, sharing and using wildlife data. We also contribute to the [Better Biodiversity Data project](#), developing the first steps in a strategic approach to the collection, collation and sharing of biological data across Scotland.

One key facet of making our biodiversity data available and accessible is the digitisation of our Herbarium. Over 750,000 of our c. three million specimens can now be viewed in full, and images downloaded in high resolution, via our [catalogue](#), and we are on-target to digitise one-third of the collection by summer 2024.

## 7. Highlights and challenges

### Major achievements

We are proud of our work to protect, restore and enhance biodiversity across Scotland and the world, which is integrated across all our strategic aims. A few example highlights are listed below, focusing on our work in Scotland.

On site, management of our four Gardens to promote native biodiversity has gone from strength to strength, with the conversion of lawns to meadows, revised mowing regimes, reduced chemical control and the practice of peat-free horticulture. We have become a leader in plant health and biosecurity, gaining (in 2022) and retaining (in 2023) Plant Healthy certification, and ensuring biosecurity is front and centre of all our work through a programme of staff and volunteer awareness and training.

The start of the first phase of the Edinburgh Biomes programme to protect our Living Collection, restore our heritage glasshouses and reduce our carbon emissions is a huge achievement, taking place in 2021 at the height of the covid pandemic. Staff worked round the clock in team 'bubbles' to decant plants from the historic palm houses, storing them safely on-site, [at our other Gardens](#), and off-site, and propagating many larger specimens by taking cuttings (see report on our blog [here](#)). More stories from the Biomes can be read [here](#) as this landmark project progresses.

We were delighted to be awarded over £725,000 from the Scottish Government's Nature Restoration Fund to expand our work to restore genetically diverse, adaptable populations of some of Scotland's rarest plants, supporting other species on a landscape scale. This project commenced earlier this year and has extended strong collaborations with multiple partners, developed innovative techniques to cultivate specialised species in our nursery (such as our [marsh saxifrage 'cascade'](#)), built *ex-situ* collections of thousands of seed, cuttings and seedlings from its ten target species, and identified sites for planting in the coming years. Project progress can be followed on our blog [here](#) and on X [@PlantsRbge](#).

Internationally, our renowned research programme continues to deliver evidence on biodiversity characterisation, threats, management and sustainable use, with a total of 386 papers published over the reporting period, alongside extensive capacity-building partnership programmes in Nepal, the middle East, and elsewhere.

### Future challenges

Our institutional strategies clearly identify the biodiversity crisis and climate emergency as the most important challenges we aim to tackle. Beyond the continuing impacts of the main drivers of biodiversity loss, significant accelerating challenges likely to impact our work to protect and restore biodiversity in Scotland are globally include extreme weather events (see [Adaptation](#)) and emerging pests and pathogens.

Pests and disease are already having a profound impact on our Gardens. Recently we had to remove the oldest tree in the Edinburgh Garden due to disease, and are in the process of felling 350 larches at Benmore and many iconic conifers at Dawyck. We continue to audit and improve our biosecurity practices and procedures to counteract this threat, both within our Collections and across the wider landscape.

Our new Risk Management Policy (2022) embeds risk management into day-to-day activities across the organisation, and has proved effective in dealing with events posing a risk to the Collections, such as sudden flooding.



**Royal Botanic Garden Edinburgh**

Inverleith Row, Edinburgh EH3 5LR

0131 552 7171

[info@rbge.org.uk](mailto:info@rbge.org.uk)

**Benmore Botanic Garden**

Dunoon, Argyll PA23 8QU

01369 706261

[benmore@rbge.org.uk](mailto:benmore@rbge.org.uk)

**Dawyck Botanic Garden**

Stobo, Scottish Borders EH45 9JU

01721 760254

[dawyck@rbge.org.uk](mailto:dawyck@rbge.org.uk)

**Logan Botanic Garden**

Port Logan, Stranraer, Dumfries & Galloway DG9 9ND

01776 860231

[logan@rbge.org.uk](mailto:logan@rbge.org.uk)

[rbge.org.uk](http://rbge.org.uk)

The Royal Botanic Garden Edinburgh (RBGE) is supported by the Scottish Government's Rural and Environmental Science and Analytical Services Division.

The Royal Botanic Garden Edinburgh is a Charity registered in Scotland (number SC007983).

Text and images © Royal Botanic Garden Edinburgh or reproduced with kind permission.