Creating a biophilic Wales: increasing the health and wellbeing of people, biodiversity and the environment

Natasha de Vere[1]

Abstract

The National Botanic Garden of Wales (NBGW) is dedicated to the research and conservation of biodiversity, sustainability, lifelong learning and the enjoyment of our visitors. NBGW's Conservation and Research programme includes four major themes: 'Saving Plants and Fungi', 'Saving Pollinators', 'International Conservation and Research' and 'Science and Society'. This article describes some of NBGW's activities in three of these core areas, focusing on our work within Wales: conserving Welsh plants, fungi and habitats; conserving pollinating insects; and promoting the importance of plants and gardens for the health and wellbeing of people, wildlife and the environment. NBGW takes a multidisciplinary approach that involves research, education, engagement, advocacy and direct conservation action. It aims to create a biophilic Wales by increasing our understanding of the natural world and inspiring people to protect it. Wales is used as a study system to develop models that can be applied globally.

Introduction

Humans are part of the Earth's intricate ecosystem processes, belonging to the community of living things with which we share our world. But in the current geological epoch, the Anthropocene, humans have caused a biodiversity and climate crisis of unprecedented magnitude. The issues that have led to this planetary emergency are multifaceted, so the solutions also require a multidisciplinary approach. The Conservation and Research programme at the National Botanic Garden of Wales (NBGW) attempts to make a contribution to solving the biodiversity crisis, using Wales as a study system to develop models that can be used throughout the world. The approach taken involves research, education, engagement, advocacy and direct conservation action. We aim to understand the natural world and inspire people to protect it.

NBGW opened in 2000 to create a national institution for the biodiversity, environment and people of Wales. The research and conservation of biodiversity is at the heart of NBGW's mission statement: 'The National Botanic Garden of Wales is dedicated to the research and conservation of biodiversity, to sustainability, lifelong learning and the enjoyment of our visitors'. NBGW's Conservation and Research programme includes four major themes: 'Saving Plants and Fungi', 'Saving Pollinators', 'International Conservation and Research' and 'Science and Society'. Here we focus on three of these core areas: (1) conserving and understanding Welsh plants, fungi and

[1] Natasha de Vere is Head of Conservation and Research at the National Botanic Garden of Wales.
Address: Llanarthne, Carmarthenshire, SA32 8HG, UK.
Email: natasha.devere@gardenofwales.org.uk

DOI 10.24823/Sibbaldia.2021.314

habitats; (2) conserving pollinating insects and understanding pollinator ecosystem services; and (3) understanding and promoting the importance of plants and gardens for the health and wellbeing of people, wildlife and the environment.

Unlike many botanic gardens around the world that are located within urban areas, NBGW is set within an agricultural landscape in Carmarthenshire, South Wales (UK) (Ritchie, 2021). The site covers over 202 ha, containing the formal botanic garden and Waun Las National Nature Reserve (NNR), which is managed as an organic farm. The Science Centre, overlooking the formal botanic garden, contains a suite of genomics research labs, teaching labs, a library, a herbarium and the National Seed Bank of Wales. The combined resources of the Science Centre; staff expertise in science, horticulture, education and marketing; plant collections; and a National Nature Reserve allow effective multidisciplinary conservation action.

Saving plants and fungi: conserving and understanding Welsh plants, fungi and habitats

In Wales, plant species are facing increasing threats from climate change, development and the intensification of farming practices. Over half of plant species have declined in their abundance and distribution in Wales over the period 1970–2013, and 256 of these species are threatened with extinction (Dines *et al.*, 2008; Hayhow *et al.*, 2016).

The NBGW Science and Horticulture teams carry out conservation and research on threatened species and habitats throughout Wales, investigating the genetics, propagation, reproduction and restoration of species (Table 1).

Species conservation in the National Seed Bank of Wales

The National Seed Bank of Wales was established in 2018 to ensure that plant material of Welsh provenance was seed banked for long-term conservation and research. NBGW works closely with the Millennium Seed Bank (MSB) at the Royal Botanic Gardens, Kew, and collected seed is stored in both institutions. The first priority for collection is the threatened plants of Wales which will then be followed by collections of all Welsh native flowering plants. To maximise genetic diversity, multiple accessions are collected from throughout the species range in Wales. As well as safeguarding these species in the long term, the seed bank is used for immediate conservation action by ensuring that seed of Welsh provenance is available for habitat creation and restoration projects.

Habitat conservation in Waun Las National Nature Reserve

Occupying over 150 ha, Waun Las NNR has been managed as a Soil Association certified organic farm since the late 1990s and was designated a National Nature Reserve in August 2009. It contains a wide range of valuable habitats including rhos pasture, lowland hay meadows, wet woodland and internationally important grasslands for waxcap fungi. Research, training and engagement within Waun Las NNR aim to show the links between biodiversity and regenerative agriculture.

Grassland restoration is a particular area of interest. Species-rich grasslands support endangered species and habitats, store carbon, clean air and water, and provide pollination services. They allow sustainable livelihoods and a vital connection with the natural world. Grassland is the most extensive

DOI 10.24823/Sibbaldia.2021.314

Table 1 Examples of conservation projects on plants, fungi and their habitats at the National Botanic Garden of Wales.

Species / Habitat	Conservation research action
Grassland restoration in Waun Las NNR	Testing different management regimes, green hay transplantation, rhos pasture translocation.
Quarry restoration: Breidden Hill SSSI	Growing assemblages of plants for restoration of quarry faces at Breidden Hill SSSI.
Grassland monitoring using DNA barcoding	Soil samples from grassland sites throughout Wales have been DNA metabarcoded to improve monitoring and understand grassland resilience.
Hawkweed – *Hieracium* restoration	Growing endangered hawkweeds for restoration at sites throughout Wales.
Whitebeam trees – *Sorbus* spp.	Investigating the reproductive biology and genetics of these trees and working with a group of partners throughout Europe on their taxonomy and conservation (Ennos *et al.*, 2012; Hamston *et al*., 2017; Hamston *et al.*, 2018).
Devil's bit scabious – *Succisa pratensis*	Growing plants of *Succisa pratensis* for reintroduction. Examining the ecology and genetics of *S. pratensis* populations in order to support the endangered marsh fritillary butterfly.
Deptford pink – *Dianthus armeria*	Growing plants for reintroduction into the wild.
Spreading bellflower – *Campanula patula*	Researching genetic variation in current and historic samples of *Campanula patula* to inform conservation efforts.
Meadow thistle – *Cirsium dissectum*	Research on the ecology and genetics of *Cirsium dissectum* to inform the conservation of both the species and the rhos pasture habitat it is found within (de Vere *et al.*, 2009).
Wild cotoneaster – *Cotoneaster cambricus*	Investigating the impact of this rare species hybridising with more common relatives and improving propagation protocols for *ex situ* support.
Meadow clary – *Salvia pratensis*	Growing plants for reintroduction of this species back into the wild. Investigating the ecology of *Salvia pratensis* to support conservation efforts.
Arctic-alpine saxifrages – *Saxifraga* spp.	Assessing the genetic relationships within these rare arctic-alpine species.
Ash dieback pathogen *Hymenoscyphus fraxineus*	NBGW is a site for research into the ecology and pathology of ash dieback disease.

DOI 10.24823/Sibbaldia.2021.314

habitat in Wales, covering 1.3 million ha (62 per cent of the land area) with most of this (1.1 million ha) being lowland grasslands. Less than 10 per cent of lowland grasslands consist of species-rich, semi-natural grassland, and these remaining areas are increasingly under threat (Stevens *et al.*, 2010).

In Waun Las NNR controlled grazing with Welsh black cattle and Balwen sheep, mowing, green hay transplantation and rhos pasture translocation have been used to increase the conservation value of the grasslands. Seed harvesting and green hay are used to provide a sustainable source of organic wildflowers for gardeners, landowners and farmers. In 2020 NBGW launched its Saving Pollinators wildflower seed and meadow mixes.

Barcode Wales and Barcode UK: creating a national DNA barcode resource of flowering plants

DNA barcoding is a worldwide, open science initiative that uses short sections of DNA for species identification. NBGW led the project that made Wales the first nation in the world to DNA barcode all of its native flowering plants (de Vere *et al.*, 2012). The project has continued, with NBGW working with the Royal Botanic Garden Edinburgh to DNA barcode the rest of the UK's native flora (Jones *et al.*, 2021b).

DNA barcoding has a wide range of applications, providing a means to identify a sample of plant from the tiniest fragment of leaf, seed or pollen grain. It also provides DNA sequence information that can be used in phylogenetic reconstruction and community ecology (Lim *et al.*, 2014; Ito *et al.*, 2017; Wang *et al.*, 2018). A NBGW research project, initiated in 2019, aimed to investigate grassland ecosystem processes and resilience by DNA metabarcoding the plants, animals, fungi and microbial communities found in Welsh grassland soils. Soil samples were collected from 42 grassland sites throughout Wales, ranging from NNRs and amenity grasslands to colliery sites.

A particular area of specialism at NBGW is the use of DNA metabarcoding to identify pollen. Applications range from identifying pollen in the atmosphere to help asthma and hay fever sufferers (Brennan *et al.*, 2019) to understanding the foraging preferences of honeybees and wild pollinators (Hawkins *et al.*, 2015; Bell *et al.*, 2016; de Vere *et al.*, 2017; Potter *et al.*, 2019).

Saving Pollinators: conserving pollinating insects and understanding pollinator ecosystem services

Saving Pollinators is a core theme of NBGW's Conservation and Research programme due to the severity and impact of pollinator declines worldwide (Wagner *et al.*, 2021). Habitat loss, climate change, pests and diseases, insecticides and agricultural intensification have created a perfect storm which has caused ill health in honeybees and a decline in wild pollinators (Potts *et al.*, 2010). NBGW takes a multidisciplinary approach within the Saving Pollinators programme, including research on which plants pollinators visit along with advocacy, training and engagement on gardening for pollinators and ethical beekeeping.

Saving Pollinators research focuses on which plants are important for honeybees and wild pollinators in gardens, amenity areas and farmland. DNA metabarcoding is used to identify pollen retrieved from the bodies of insects or from samples of honey.

For example, Lucas *et al.* (2018a; 2018b) studied the role of hoverflies as pollinators in rhos pastures. Hoverflies are likely to be

DOI 10.24823/Sibbaldia.2021.314

important pollinators; however, relatively little is known of the role they play in pollen transport. Lucas *et al.* (2018a; 2018b) investigated the range of pollen carried by hoverflies and showed the most frequent pollen included members of the Apiacieae, such as *Carum verticillatum* (whorled caraway) and *Angelica sylvestris* (wild angelica), as well as *Rubus fruticosus* (bramble), *Succisa pratensis* (devil's bit scabious) and *Filipendula ulmaria* (meadowsweet). The results give an insight into flower choice by individual hoverflies, and the role these insects play in pollinator ecosystem services.

Jones *et al.* (2021a) DNA metabarcoded 441 honey samples from throughout the UK to show the changes in the UK floral landscape over the last 65 years. The plants foraged on by honeybees in 2017 were compared to a survey of 855 honey samples conducted in 1952. *Trifolium repens* (white clover) was the most important plant for honeybees in 1952, but the reduction of flowering white clover within improved grasslands meant that by 2017 *Rubus fruticosus* (bramble) had become the most foraged plant. The data also show the emergence of oil seed rape as an important plant for honeybees (it was first grown as a crop in the 1960s) and the spread of the invasive species *Impatiens glandulifera* (Himalayan balsam). Honeybees now rely on *I. glandulifera* as an important nectar source at the end of the season, but it is a non-native invasive species that outcompetes other plants and blocks watercourses.

With fewer nectar and pollen resources available in the landscape, gardens are becoming increasingly important refuges for pollinating insects (Salisbury *et al.*, 2015; Staab *et al.*, 2020). NBGW, with its extensive plant collections set within an agricultural landscape, provides an excellent study site for investigating the importance of gardens and horticultural plants for pollinators (Fig. 1). Research focuses on the foraging behaviour of hoverflies, bumblebees, solitary bees and honeybees within the garden landscape. Annual seed mixes are created and tested to investigate their utility for different pollinator groups.

Saving Pollinators Assurance Scheme

There is significant public support for gardening for pollinators, with 96 per cent of survey participants in garden centres in the UK more likely to buy a plant with a pollinator-friendly label compared to one without (Wignall *et al.*, 2019). Whilst there is a wealth of information available on the best plants for pollinators, only a small number of plant recommendation lists are based on empirical evidence (Garbuzov & Ratnieks, 2014). Garbuzov *et al.* (2017) showed that most ornamental plants on sale in garden centres are unattractive to pollinators. Horticultural plants labelled as pollinator-friendly may also have been grown using peat compost and treated with synthetic insecticides, which can harm pollinating insects (Lentola *et al.*, 2017).

The Saving Pollinators Assurance Scheme was launched in 2020 to address these issues. NBGW works with nurseries throughout the UK that grow plants without the use of peat or synthetic pesticides. It reviews the supply lists of these nurseries to identify species that are beneficial to pollinators based on our scientific research. The Saving Pollinators Assurance Scheme logo (Fig. 2) can only be displayed on plants shown to be attractive to pollinators based on NBGW research and grown without peat and synthetic pesticides.

DOI 10.24823/Sibbaldia.2021.314

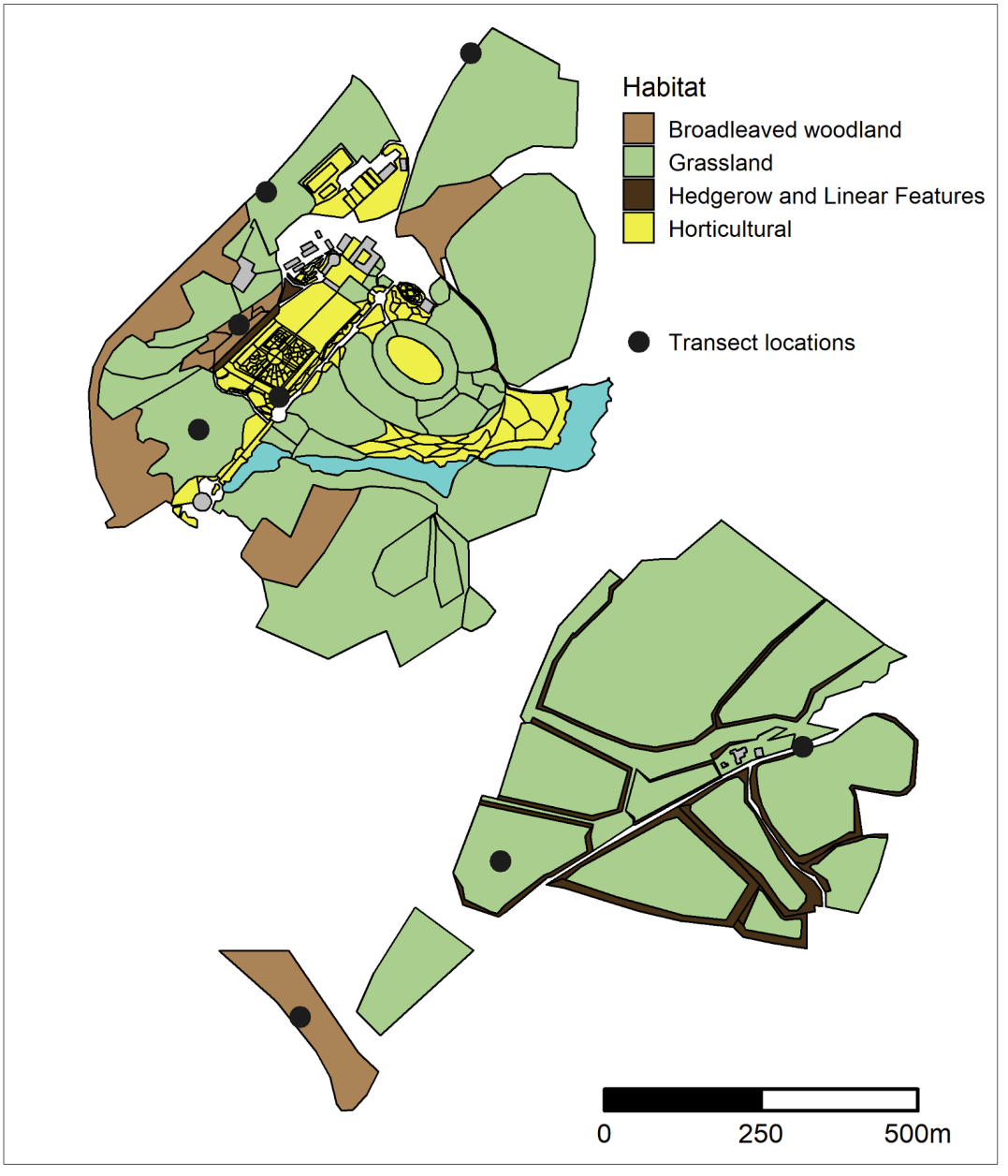

Fig. 1 Map of the habitats within the National Botanic Garden of Wales and Waun Las National Nature Reserve showing location of transects where pollinators are surveyed. Maps created by Abigail Lowe in QGIS v. 3.6.1 and R v. 3.5.1 from OS data © Crown Copyright (2018) licensed under the Open Government Licence.

DOI 10.24823/Sibbaldia.2021.314

Fig. 2 The Saving Pollinators Assurance Scheme logo. Only plants that are shown to be beneficial to pollinators based on NBGW research and that are grown without peat and synthetic pesticides are eligible to display the logo.

Science and society: understanding and promoting the importance of plants and gardens for the health and wellbeing of people, wildlife and the environment

> '*Biophilia is the innately emotional affiliation of humans to other living organisms*' (Wilson, 1984)

Biophilia is the principle that humans possess an innate tendency to seek connections with the natural world and that this is vital to our health and wellbeing. Connecting with nature in our everyday lives can make us happier and healthier (Bragg *et al.*, 2015; Buck, 2016; Lovell *et al.*, 2018). Strengthening connections with the natural world may also make people more prepared to take greater action to protect it. At NBGW two projects investigate the importance of plants and gardens for the health and wellbeing of people, wildlife and the environment: Growing the Future and Biophilic Wales.

Growing the Future

Growing the Future (GTF) was a five-year, £2.3 million project delivered through the Welsh Government Rural Communities – Rural Development Programme 2014–2020, funded by the European Agricultural Fund for Rural Development and the Welsh Government. GTF provided training and engagement to adults and children in the value of plants and gardens for growing food, keeping fit, conserving biodiversity and helping the environment. It also showcased the diversity and quality of Welsh horticultural produce and made connections between science and horticulture (for example, the Saving Pollinators Assurance Scheme was part of the GTF project). Training and engagement took place at NBGW and at partner hub sites established throughout Wales. From 2017 to 2020 the project provided 11,520 training days to 35,737 participants and engaged with 107,292 people at 331 events (Fig. 3). Courses and engagement activities ranged from sustainable horticulture, plant sciences and plant-inspired arts and crafts to ethical beekeeping and products of the hive.

Biophilic Wales

Biophilic Wales was a three-year, £1.3 million project, funded by the Welsh Government's Enabling Natural Resources and Well-being in Wales Grant Scheme. Led by NBGW, the main partners were Swansea Bay University Health Board, Natural Resources Wales and Swansea University. A core work package of the project, 'Inspiring Spaces', had a focus on 40 sites within the Swansea Bay University Health Board estate. The sites surround hospitals, health centres, and mental health

DOI 10.24823/Sibbaldia.2021.314

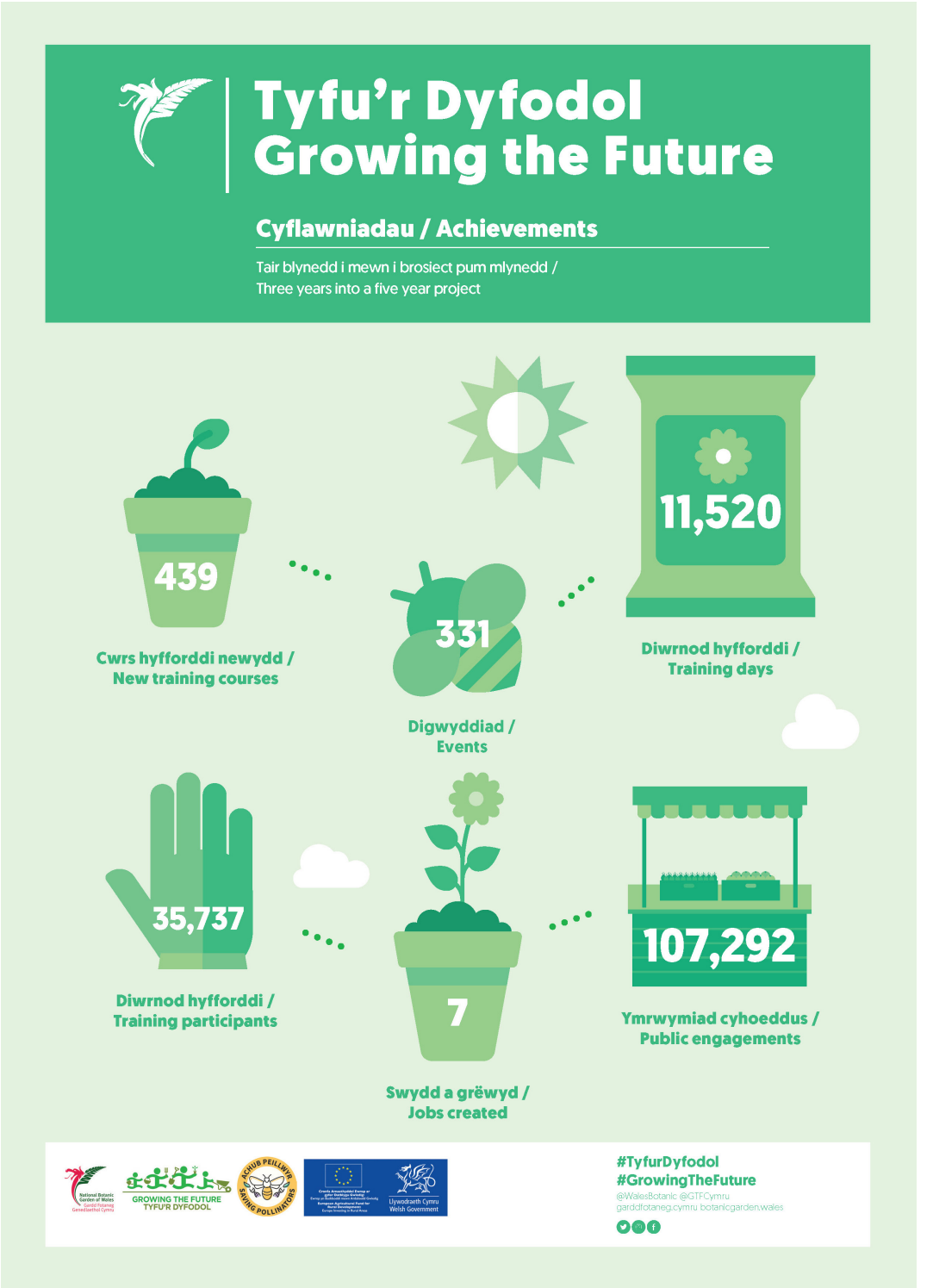

Fig. 3 Outputs of the Growing the Future project. Image: NBGW.

DOI 10.24823/Sibbaldia.2021.314

Fig. 4 Join Our Growing Team wildflower packs posted to participants as part of the Biophilic Wales project. Photo: Elliot Waters.

and residential facilities. The aim was to create inspirational green spaces for people to connect with nature by increasing accessibility, biodiversity value, ecosystem services and habitat connectivity.

Interventions on health board sites varied, ranging from creating relaxation areas for people, changing grass management regimes to create meadows, and planting hedgerows and orchards to putting up bird and bat boxes. Smaller sites, with negligible green infrastructure, were provided with planters containing native wildflowers. Art installations based on biophilic design principles were installed outside and inside health board sites.

A key feature of the project is that volunteers helped to deliver the biodiversity and wellbeing improvements. The lockdowns made necessary by the coronavirus pandemic during March 2020 meant that project work needed to move online. A 'Join Our Growing Team' campaign was initiated that invited people to grow wildflowers at home for planting out at health board sites (Fig. 4). A total of 1,637 Join Our Growing Team packs were sent out and many participants reported that growing plants had positive effects on their wellbeing. Participants returned grown plants to NBGW and these were planted throughout the health board sites, mostly in planters in hospital grounds.

References

BELL, K.L., DE VERE, N., KELLER, A., RICHARDSON, R., GOUS, A., BURGESS, K. & BROSI, B.J. (2016). Pollen DNA barcoding: current applications and future prospects. *Genome*, 59(9): 629–640. doi: https://doi.org/10.1139/gen-2015-0200

DOI 10.24823/Sibbaldia.2021.314

BRAGG, R. *ET AL*. (2015). Wellbeing benefits from natural environments rich in wildlife: a literature review for The Wildlife Trusts. University of Essex.

BRENNAN, G.L., POTTER, C., DE VERE, N., GRIFFITH, G.W., SKJØTH, C.A., OSBORNE, N.J., WHEELER, B.W., MCINNES, R.N., CLEWLOW, Y., BARBER, A., HANLON, H.M., HEGARTY, M. *ET AL*. (2019). Temperate grass flowering season defined by spatio-temporal shifts in airborne pollen communities. *Nature Ecology and Evolution*, 3: 750–754. doi: https://doi.org/10.1038/s41559-019-0849-7

BUCK, D. (2016). Gardens and health – implications for policy and practice. The Kings Fund. Available online: https://www.kingsfund.org.uk/publications/gardens-and-health (accessed January 2021).

DE VERE, N., JONES, L.E., GILMORE, T., MOSCROP, J., LOWE, A., SMITH, D., HEGARTY, M., CREER, S. & FORD, C.R. (2017). Using DNA metabarcoding to investigate honeybee foraging reveals limited flower use despite high floral availability. *Scientific Reports*, 7: 42838. doi: https://doi.org/10.1038/srep42838

DE VERE, N., JONGEJANS, E., PLOWMAN, A. & WILLIAMS, E. (2009). Population size and habitat quality affect genetic diversity and fitness in the clonal herb, *Cirsium dissectum*. *Oecologia*, 159: 59–68. doi: https://doi.org/10.1007/s00442-008-1203-y

DE VERE, N., RICH, T.C.G., FORD, C.R., TRINDER, S.A., LONG, C., MOORE, C.W., SATTERTHWAITE, D., DAVIES, H., ALLAINGUILLAUME, J., RONCA, S., TATARINOVA, T., GARBETT, H., WALKER, K. & WILKINSON, M.J. (2012). DNA barcoding the native flowering plants and conifers of Wales. *PLoS ONE*, 7(6): e37945. doi: https://doi.org/10.1371/journal.pone.0037945

DINES, T. (2008). *A Vascular Plant Red Data List for Wales*. Plantlife International, Salisbury.

ENNOS, R.A., WHITLOCK, R., FAY, M.F., JONES, B., NEAVES, L.E., PAYNE, R., TAYLOR, I., DE VERE, N. & HOLLINGSWORTH, P.M. (2012). Process-based species action plans: an approach to conserve contemporary evolutionary processes that sustain diversity in taxonomically complex groups. *Botanical Journal of the Linnean Society*, 168(2): 194–203. doi: https://doi.org/10.1111/j.1095-8339.2011.01206.x

GARBUZOV, M., ALTON, K. & RATNIEKS, F.L.W. (2017). Most ornamental plants on sale in garden centres are unattractive to flower-visiting insects. *PeerJ*, 5: e3066. doi: https://doi.org/10.7717/peerj.3066

GARBUZOV, M. & RATNIEKS, F.L.W. (2014). Listmania: The strengths and weaknesses of lists of garden plants to help pollinators. *BioScience*, 64(11): 1019–1026. doi: https://doi.org/10.1093/biosci/biu150

HAMSTON, T.J., DE VERE, N., KING, R.A., PELLICER, J., FAY, M.F., CRESSWELL, J.E. & STEVENS, J.R. (2018). Apomixis and hybridisation drives reticulate evolution and phyletic differentiation in *Sorbus* L.: implications for conservation. *Frontiers in Plant Science*, 9(1796). doi: https://doi.org/10.3389/fpls.2018.01796

HAMSTON, T.J., WILSON, R.J., DE VERE, N., RICH, T.C.G., STEVENS, J.R. & CRESSWELL, J.E. (2017). Breeding system and spatial isolation from congeners strongly constrain seed set in an insect-pollinated apomictic tree: *Sorbus subcuneata* (Rosaceae). *Scientific Reports*, 7: 45122. doi: https://doi.org/10.1038/srep45122

HAWKINS, J., DE VERE, N., GRIFFITH, A., FORD, C.R., ALLAINGUILLAUME, J., HEGARTY, M.J., BAILLIE, L. & ADAMS-GROOM, B. (2015). Using DNA metabarcoding to identify the floral composition of honey: a new tool for investigating honey bee foraging preferences. *PLoS ONE*, 10(8): e0134735. doi: https://doi.org/10.1371/journal.pone.0134735

HAYHOW, D.B., BURNS, F., EATON, M.A., BACON, L., AL-FULAIJ, N., BLADWELL, S., BROOKMAN, E., BYRNE, J., CHEESMAN, C., DAVIES, D., DE MASSIMI, S., ELDING, C. *ET AL*. (2016). State of Nature 2016: Wales. The State of Nature Partnership. Available online: https://nbn.org.uk/wp-content/uploads/2019/09/State-of-Nature-2019-UK-full-report.pdf (accessed January 2021).

ITO, Y., TANAKA, N., BARFOD, A., KAUL, R., MUASYA, A.M., GARCIA-MURILLO, P., DE VERE, N., DUYFJES, B. & ALBACH, D. (2017). From terrestrial to aquatic habitats and back again: molecular insights into the evolution and phylogeny of *Callitriche* (Plantaginaceae). *Botanical Journal of the Linnean Society*, 184(1): 46–58. doi: https://doi.org/10.1093/botlinnean/box012

JONES, L., BRENNAN, G.L., LOWE, A., CREER, S., FORD, C.R. & DE VERE, N. (2021a). Shifts in honeybee foraging reveal historical changes in floral resources. *Communications Biology*, 4(37): 1–10. doi: https://doi.org/10.1038/s42003-020-01562-4

JONES, L., TWYFORD, A.D., FORD, COL R., RICH, T.C.G., DAVIES, H., FORREST, L.L., HART, M.L., MCHAFFIE, H., BROWN, M.R., HOLLINGSWORTH, P.M. & DE VERE, N. (2021b). Barcode UK: A complete DNA barcoding resource for the flowering plants and conifers of the United Kingdom. *Molecular Ecology Resources*. doi: https://doi.org/10.1111/1755-0998.13388

LENTOLA, A., DAVID, A., ABDUL-SADA, A., TAPPARO, A., GOULSON, D. & HILL, E.M. (2017). Ornamental plants on sale to the public are a significant source of pesticide residues with implications for the health of pollinating insects. *Environmental Pollution*, 228: 297–304. doi: https://doi.org/10.1016/j.envpol.2017.03.084

LIM, L., CRAWLEY, M.J., DE VERE, N., RICH, T. & SAVOLAINEN, V. (2014). A phylogenetic analysis of the British flora sheds light on the evolutionary and ecological factors driving plant invasions. *Ecology and Evolution*, 4(22): 4258–4269. doi: https://doi.org/10.1002/ece3.1274

LOVELL, R., DEPLEDGE, M. & MAXWELL, S. (2018). Health and the natural environment: A review of evidence, policy, practice and opportunities for the future. DEFRA, Defra Project Code BE0109.

LUCAS, A., BODGER, O., BROSI, B.J., FORD, C.R., FORMAN, D.W., GREIG, C., HEGARTY, M., NEYLAND, P.J. & DE VERE, N. (2018a). Generalisation and specialisation in hoverfly (Syrphidae) grassland pollen transport networks revealed by DNA metabarcoding. *Journal of Animal Ecology*, 87(4): 1008–1021. doi: https://doi.org/10.1111/1365-2656.12828

LUCAS, A., BODGER, O., BROSI, B.J., FORD, C.R., FORMAN, D.W., GREIG, C., HEGARTY, M., JONES, L.E., NEYLAND, P.J. & DE VERE, N. (2018b). Floral resource partitioning by individuals within generalised hoverfly pollination networks revealed by DNA metabarcoding. *Scientific Reports*, 8(5133). doi: https://doi.org/10.1038/s41598-018-23103-0

POTTER, C., DE VERE, N., JONES, L.E., FORD, COL R., HEGARTY, M.J., HODDER, K.H., DIAZ, A. & FRANKLIN, E. (2019). Pollen metabarcoding reveals broad and species-specific resource use by urban bees. *PeerJ*, 7(22). doi: https://doi.org/10.7717/peerj.5999

POTTS, S.G., BIESMEIJER, J.C., KREMEN, C., NEUMANN, P., SCHWEIGER, O. & KUNIN, W.E. (2010). Global pollinator declines: trends, impacts and drivers. *Trends in Ecology and Evolution*, 25(6): 345–353. doi: https://doi.org/10.1016/j.tree.2010.01.007

RITCHIE, W. (2021). Botanic Garden Profile: The National Botanic Garden of Wales at 20. *Sibbaldia*, 19: 5–16. doi: https://doi.org/10.24823/Sibbaldia.2020.305

SALISBURY, A., ARMITAGE, J., BOSTOCK, H., PERRY, J., TATCHELL, M. & THOMPSON, K. (2015). Enhancing gardens as habitats for flower-visiting aerial insects (pollinators): should we plant native or exotic species? *Journal of Applied Ecology*, 52(5): 1156–1164. doi: https://doi.org/10.1111/1365-2664.12499

STAAB, M., HELENA, M., PEIXOTO, P. & KLEIN, A.M. (2020). Exotic garden plants partly substitute for native plants as resources for pollinators when native plants become seasonally scarce. *Oecologia*, 194(3): 465–480. doi: https://doi.org/10.1007/s00442-020-04785-8

STEVENS, D.P., SMITH, S.L.N., BLACKSTOCK, T.H., BOSANQUET, S.D.S. & STEVENS, J.P. (2010). *Grasslands of Wales: A Survey of Lowland Species-rich Grasslands 1987–2004*. University of Wales Press, Cardiff.

WAGNER, D.L., GRAMES, E.M., FORISTER, M.L., BERENBAUM, M.R. & STOPAK, D. (2021). Insect decline in the Anthropocene: death by a thousand cuts. *PNAS* 118(2): 1–10. doi: https://doi.org/10.1073/pnas.2023989118

WANG, X., GUSSAROVA, G., RUHSAM, M., DE VERE, N., METHERELL, C., HOLLINGSWORTH, P.M. & TWYFORD, A.D. (2018). DNA barcoding a taxonomically complex hemiparasitic genus reveals deep divergence between ploidy levels but lack of species-level resolution. *AoB Plants*, 10: 3. doi: https://doi.org/10.1093/aobpla/ply026

WIGNALL, V.R., ALTON, K. & RATNIEKS, F.L.W. (2019). Garden centre customer attitudes to pollinators and pollinator-friendly planting. *PeerJ*, 2019(6). doi: https://doi.org/10.7717/peerj.7088

WILSON, E.O. (1984). *Biophilia*. Cambridge, MA: Harvard University Press.