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Discovering Trinity's Biodiversity

Report from the Biodiversity Audit Pilot Study[1]

August 2021

Report prepared by Dr Ursula King and Prof Jane Stout

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[1] The Pilot Biodiversity Audit project ran from May to August 2021, funded by the Provost's Sustainability Fund, the Botany Discipline, UNI-ECO Green Challenges and a philanthropic donation. The project was a collaboration between staff and students in the School of Natural Sciences, with members of the Estates and Facilities team, and the Trinity Sustainability Intern.

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Executive Summary

Earth is in the midst of a **biodiversity crisis**. Globally, species extinction rates are accelerating, and natural ecosystems are being damaged, degraded and lost. Current responses at international, national and local level are insufficient to reverse this loss[2].

It is our vision that we, the staff and students of Trinity College Dublin, be exemplary in our regard for nature, and take action to **ensure biodiversity is central to all operations** on our estate. This includes researching, and disseminating knowledge through teaching and engagement, the benefits of encouraging and allowing our co-existence with other species. This is not only for the sake of those species, but also for the services they directly or indirectly provide to us (including flood mitigation, pest control, pollination services, soil engineering, and healthier, more resilient habitats). We should endeavour to encourage an appreciation for the subtler aspects of biodiversity (the diversity of habitats, species and populations) amongst our college community and the wider public, and promote an increased awareness that a whole host of organisms contribute to **Healthy Trinity**, and the health of our city and our planet.

Trinity is home to more than just the iconic wildlife species that grab the headlines – the foxes, trees and swifts – and the familiar green sports pitches and manicured squares. There is a wealth of **hidden biodiversity** of plants, insects, fungi and other creatures, which mostly goes unnoticed. Discovering and documenting our biodiversity takes time, resources and expertise. A single night of moth-trapping on Trinity Campus during summer 2021 revealed 32 moth species, but this is only a fraction of the insect biodiversity likely to be living in the city, and there is great potential to discover new elements of biodiversity on Trinity's estate. Beyond this, there is so much to learn about what these species do, how they contribute to the complex urban ecosystem, and ultimately, to our own health and wellbeing.

Given that increased urbanization is recognized as being one of the drivers of habitat and biodiversity loss, our vision is to **capitalize on Trinity's position at the forefront of biodiversity research**, to utilize the full extent of the built and natural habitats across all Trinity's estate as a 'Living lab', and employ initiatives that are scientifically assessed and documented. We need to integrate biodiversity actions with other environmental sustainability goals (including climate, energy, water, resource consumption, waste), and acknowledge and eliminate practices that deplete biodiversity, both on Trinity's estate, and beyond. We are deeply aware that whilst engineering solutions may be appropriate to mitigating some of the effects of climate change, it will not be possible to engineer our way out of biodiversity loss, and that nature itself can provide many solutions to the impacts of the climate crisis.

Within our own staff and student body, we need to recognize and inform others that taking action for biodiversity is not just the responsibility of gardening or horticulture staff, but requires understanding and **action across the whole of our community** and operations. It is our hope that we can engage in active campus conversations to extend thinking, and inform how our individual daily actions translate to biodiversity loss or gain on a local and global scale. This will create informed advocates for biodiversity in our community and beyond. Whilst the practical actions we take on our small city-centre campus may be of limited direct benefit in the face of national biodiversity loss, our visible engagement in biodiversity issues on campus could **inspire and catalyse meaningful change** for staff, generations of students and the more than 2 million visitors Trinity receives each year.

We are also aware of the critical gap in **skills and funding** for natural history and taxonomic expertise, as well as the erosion of funding for natural history collections, and the risk of producing graduates that are not fully equipped to guide policy and provide accurate ecological advice. A vast body of experience and knowledge in species and habitat identification now resides in an aging population, and an entire generation has little

[2] IPBES 2019 Global Assessment https://ipbes.net/global-assessment

experience of engaging with the natural world, partly due to a diversion of funding from field studies of the natural world. In particular, we recognize an urgent need to commit funding to employing dedicated botanists, entomologists, and ecologists to teach and engage today's students and our future students in the understanding of natural history. The precariousness of this situation has been further highlighted during the current COVID-19 pandemic, where students were not able to engage in hands-on learning. This situation must be addressed as a matter of priority.

To this end, our main recommendations are:

1. Develop a **Trinity Biodiversity Strategy**, which encompasses the whole of Trinity's operations, including buildings, grounds, research, education, and public and policy engagement.
2. Develop a more **dynamic interaction** between staff and students, with clear communications, to facilitate a synergy across staff and students in tackling biodiversity loss on Trinity's estate.
3. Employ a full time **Biodiversity Officer** to oversee biodiversity data collection and use, and to engage with external bodies.
4. Construct a **central repository for information**, which will be the centralized source of information for biodiversity data.
5. Integrate the biodiversity data into **Natural Capital Accounts** for Trinity, to track changes in extent, condition, services and benefits from biodiversity.
6. Initiate a meaningful **biodiversity awareness campaign**, focussing on Trinity's estate and the resources within it.
7. Enhance the **taxonomic and field skills** of our natural science graduates to ensure future generations have the necessary expertise.
8. Increase the **knowledge and understanding** of biodiversity issues across staff and students in college, beyond the natural sciences.
9. Instigate a biodiversity **outreach programme**, whereby the expertise and experiences in Trinity can be shared with the wider community.
10. Take practical **actions to enhance biodiversity** across Trinity's Distributed Campus.

"*In the end we will conserve only what we love, we will love only what we understand, and we will understand only what we are taught*" (Baba Dioum 1968)

1. Overview of the Pilot Biodiversity Audit project

Interest in Trinity's biodiversity[3] has steadily increased amongst the whole College community (Figure 1) and it has become a key part of several of the university's strategies. From 2016 onwards, the Trinity annual Sustainability Report has included Biodiversity objectives and the Trinity Strategic Plan 2020-2025 embraces promotion of biodiversity as a key part of the goal to achieve a sustainable and healthy planet. The Trinity College Botanic Garden 10 year strategy (2020-2030) contains actions for conservation of Irish threatened plants and for public engagement on biodiversity and sustainability. During 2020, efforts to establish a Trinity Biodiversity Audit were underway (but hampered by the COVID-19 pandemic), and in 2021 the Pilot Biodiversity Audit was carried out from May to August. This followed a Provost electoral campaign in which climate and biodiversity issues were addressed by all candidates, and more action was called for by staff and students[4].

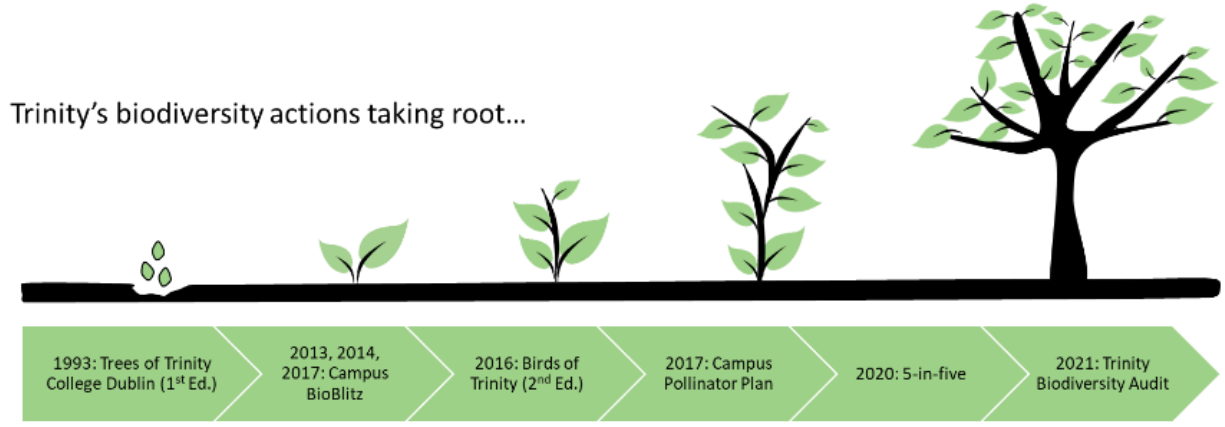

Figure 1: Trinity's biodiversity actions taking root: the first "Trees of Trinity College Dublin" book was published by the Botany Department in 1993 (a 4th edition was launched in 2019); campus BioBlitzes (intense, usually 12-24 hour, surveys, attempting to document as many species as possible on Trinity's Main Campus, performed by scientists, naturalists and volunteers) were undertaken in 2013, 2014 and 2017; an updated "Birds of Trinity" book was published by the Zoological Society in 2016; the Campus Pollinator Plan was launched in 2017; and the Botanical '5 in Five' series was established during 2020 as a vehicle for public engagement on biodiversity.

The Pilot Biodiversity Audit project was funded by the Provost's Sustainability Fund, the Botany Discipline, the UNI-ECO Green Challenges project and a philanthropic donation. Work was coordinated by Dr Ursula King, who was employed full-time in Botany for the duration of the project, and who supervised two student interns (Hazel Herbst and Kes Daly) and two student volunteers (Isabel Quinn and Scott Bastow). Tony Williams, currently registered as a PhD student in Botany, and another student intern (Danielle Varley) contributed to developing the mapping systems. Estates and Facilities (E&F) staff, including David Hackett, also contributed. The project was initiated and overseen by Dr Jane Stout, Professor in Botany, and the project establishment, including securing philanthropic funding, was assisted by Iseult Sheehy, Trinity's Sustainability Intern and member of The Green Campus Committee. This following section summarises the objectives, achievements, knowledge and resource gaps, and recommendations from the Pilot Biodiversity Audit project. Full details are given in subsequent sections of this report.

[3] Biodiversity is defined by the Convention on Biological Diversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems"

[4] Staff and students produced a video to highlight their concerns and call for action

1.1 Objectives

The objectives of the Pilot Biodiversity Audit were:

1. To gather a baseline inventory of habitats and species on Trinity's Main Campus with a particular focus on sampling certain taxonomic groups, to allow us to track change, and to provide a scientific approach to quantify the effects of any biodiversity initiatives implemented on campus.
2. To pilot a mapping system for Trinity's Main Campus and identify the resources needed to present and curate these data and extend it to the rest of Trinity's estate (Figure 2).
3. To gather, in a single repository, all existing biodiversity data for the rest of Trinity's Estate.
4. To explore time and personnel resources required to tailor appropriate sampling effort, whilst recognising spatial and temporal variation inherent in biodiversity across Trinity's properties and grounds.
5. To identify knowledge and resource gaps, and as part of this, to establish and document what in-house resources are available and establish links with external expertise.
6. To investigate the utility of developing the resources of Trinity's estate as a 'living lab', both for teaching and the quantitative assessment of biodiversity, and for research in mitigating the effects of biodiversity loss in urban areas.
7. To explore, with all contributors to the project, practical ways of increasing biodiversity on Trinity's estate.
8. To begin a journey of scientifically informed action on biodiversity within Trinity's properties, which can be taken into the public realm to raise the profile of the biodiversity emergency (declared by Dáil Éireann in May 2019).

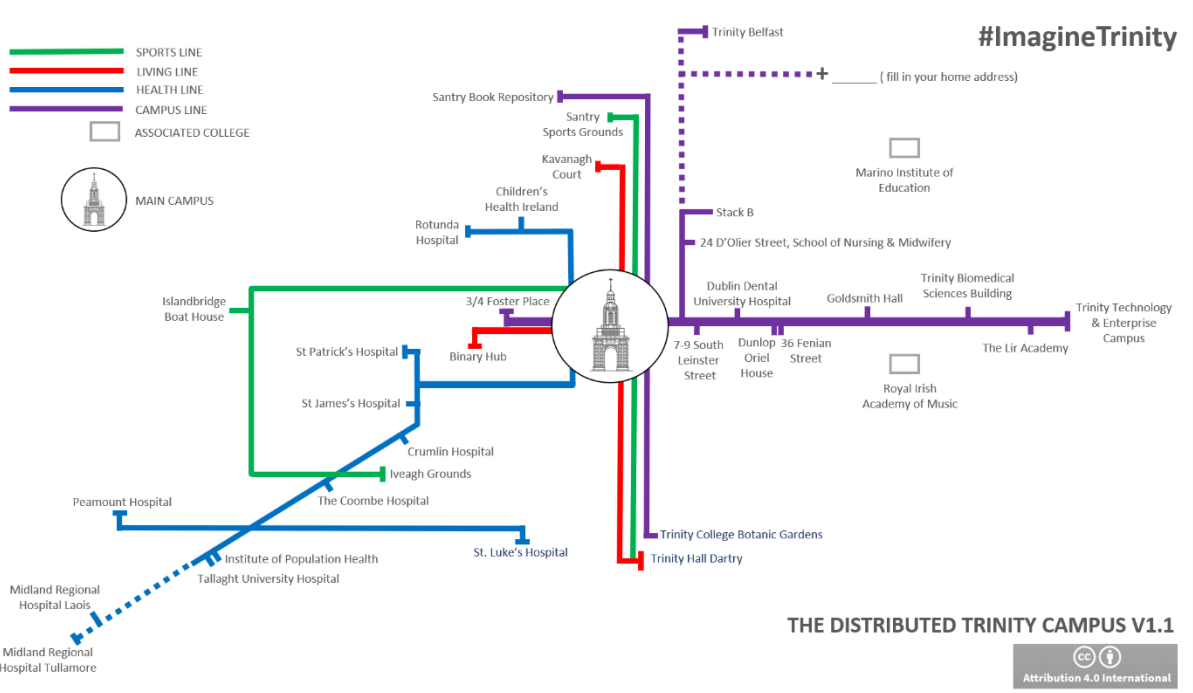

Figure 2. Trinity's "Distributed Campus", showing the location of Trinity's Estate (from Provost Linda Doyle's election manifesto *Imagine Trinity*)

1.2 Achievements

Over the four-month project, the following were accomplished:

- A pilot habitat mapping system for Trinity's Main Campus, designed with Estates and Facilities, which maps the built, ornamental, naturalized and water habitats on campus to facilitate:
    - Teaching and research
    - Future recording of campus biodiversity
    - Presentation and easy access to information on plant, animal and fungal species on campus
    - The promotion of awareness of Trinity's Main Campus biodiversity
    - Communication between grounds staff and researchers of biodiversity resources
- An inventory of horticultural species on Trinity's Main Campus, mapped by geographical location and habitat type
- A preliminary baseline inventory of a number of taxonomic groups (mostly invertebrates) on Trinity's Main Campus, mapped by geographical location and habitat type
- Geolocation of all trees on Trinity's Main Campus as a resource:
    - For research studies (e.g., mycology, invertebrate research)
    - To promote interest and awareness amongst staff, students and the public.
- A standardized database Excel template for recording species level data across the range of taxonomic groups (and including ornamental plantings)
- Protocols trialled and documented for the standardisation of invertebrate sampling, including the following methods: Moth trapping, Pitfall traps, Pan traps, Sweep netting, Dip netting, Tree beating, and Transect walks
- System for processing, recording and storing lab samples from the field as a future resource for:
    - Teaching
    - BioBlitzes
    - Undergraduate, Masters and PhD projects
- Collation of invertebrate identification resources.
- Protocols documented for obtaining relevant sampling licenses.
- Protocol trialled and documented for hedgehog surveying.
- Interdepartmental collaboration[5] in collection and identification of samples, creating an awareness of the resources and knowledge available, pooling expertise and facilitating a meaningful appreciation and discussion of biodiversity, along with practical campus and estate maintenance considerations.
- Relationship building with external taxonomic experts in a number of plant and animal groups[6], including a visit to the National Museum of Ireland - Natural History Collections at Santry (facilitated by Aidan O'Hanlon), agreement for the delivery of a moss identification day for students and help with moss identification on campus (Rory Hodd), and agreement for the delivery of a day on spider identification and collection techniques for spiders and other invertebrates (Myles Nolan)
- Hosted an Entomology Bootcamp for M.Sc. in Biodiversity and Conservation students
- Fieldwork, computer-based and lab experience for five students (both paid and volunteer). At the end of the project, one student commented:

  "It has been an eye opening experience and it has changed me as a person, for the better. … I urge everyone at least once in their life, to look at an insect down a microscope… it is truly life changing."

[5] See Acknowledgements for full list of collaborators

[6] See Acknowledgements for full list of experts

1.3 Knowledge and resource gaps

Key deficits were identified that would need to be addressed to enable a meaningful analysis and monitoring of biodiversity on Trinity's estates. These included:

1. The lack of awareness amongst staff of the extent of Trinity's estate and the biodiversity it supports.
2. The recognition that additional personnel resources will be needed to complete biodiversity mapping and a baseline biodiversity inventory for the rest of Trinity's estate.
3. The recognition that existing resources with respect to Computer Assisted Design (CAD) and Geographic Information System (GIS) mapping of Trinity's estate for various building works needs to be more accessible for Estates and Facilities maintenance staff and any Biodiversity Audit staff.
4. A lack of available in-house expertise in a number of taxonomic groups, particularly, the invertebrates and mosses.
5. A shortage of expertise nationally in the same taxonomic groups, which hampered identification of a number of species in our pilot study.
6. A need to open the conversation and overcome the pervading assumption that these skills are readily available at the national level to mitigate biodiversity loss, along with a general perception that these skills are easily gained. Recognition that a prior lack of value given to this expertise has left us in a vulnerable situation.
7. A need to provide students with basic field identification skills from their first year in college to allow a full appreciation of their course material, hone their observation skills and maximise their awareness of their natural environment.
8. A lack of wider appreciation for the importance of natural history collections and their scientific utility, which have underpinned multiple undergraduate and postgraduate research projects, but which could be integrated more into teaching across Trinity.
9. The need for investment in software for databasing the exiting natural history collections that can be cross referenced with data from biodiversity audits.
10. The need to bridge the gap between our scientists and Estates and Facilities staff, to open dialogue to clearer communications and understanding, and facilitate a more inclusive synergy in tackling biodiversity loss on Trinity's estate. A need to recognize that our grounds staff can provide a practical insight into the maintenance and management of urban habitats, which may not be part of the scientific staff or student perspective. A need to delve into and stretch our collective imagination on what might be attained for biodiversity on Trinity's estate.
11. A need to upskill Grounds Staff, along with general staff and student Biodiversity Induction Programmes.
12. The need to facilitate clear and accurate scientific reporting of biodiversity issues.

1.4 Recommendations / Opportunities

1. Develop a **Trinity Biodiversity Strategy**, which is integrated with other policies and strategies, and encompasses the whole of Trinity's operations, including buildings, grounds, research, education, and public and policy engagement.
2. Develop a more dynamic interaction between scientists, Green Campus and student groups, and Estates and Facilities staff, with **clear communications to facilitate a synergy across staff and students** in tackling biodiversity loss on Trinity's estate. This should lead to the shared understanding of issues and constraints, and the development of mutually agreed objectives and actions plans.
3. Resource additional personnel to complete biodiversity mapping and a baseline inventory for the rest of Trinity's estate, for curation of data, and for coordinating repeated monitoring in the future. Ideally, a full time **Biodiversity Officer** should be appointed who could also be involved in setting and reporting on

long term objectives and targets for biodiversity, engagement with external bodies (including Dublin City Council, the National Biodiversity Data Centre, the National Museum of Ireland - Natural History, other third level institutions, and others), and overseeing other personnel (e.g. those developing the GIS platform).

4. A Common Data Environment (CDE): a **central repository for information**, which will be the centralized source of information for biodiversity data, should be resourced and established. The accessibility of CAD (Computer Aided Design) and GIS (Geographic Information Systems) mapping, conducted as part of building works, should be improved for both Estates and Facilities and any Biodiversity Audit staff. This will reduce duplication of efforts and enable efficient use of data.
5. Integrate the biodiversity data into **Natural Capital Accounts** for Trinity, to track changes in extent, condition, services and benefits from the natural capital[7] on Trinity's estate. These natural capital accounts can be used to integrate various elements of Trinity's environmental activity and support more sustainable decision-making that recognises, respects and restores nature's value.
6. Initiate a meaningful **biodiversity awareness campaign**, focussing on Trinity's estate and the resources within it. This should include going beyond iconic species (foxes, trees, birds, bees…) and acknowledge the wide diversity of species and habitats, and the benefits that are derived from this biodiversity. This should be done in collaboration with the Communications and Public Relations staff, so that biodiversity issues are reported in a clear and scientifically accurate manner, and include an online interface for the biodiversity mapping system.
7. Increase the amount of taxonomy and field (species and habitat) identification in the **formal taught curriculum** for science students, from first year, and particularly for natural science students into their final year, and in Masters programmes. There are already some collaborations with external experts in particular taxonomic groups, but this could be increased, along with recruitment of academic staff with taxonomic skills and those who actively use the natural history collections (living and non-living) in their research and teaching.
8. Incorporate biodiversity issues and the opportunities associated with caring for biodiversity on Trinity's properties into the **learning and research environment across College**. As interest in these issues extends beyond natural science students, more collaboration in teaching and research on these issues is needed so that students and staff have the opportunity to upskill and nuance their knowledge and understanding of biodiversity issues.
9. Instigate a biodiversity outreach programme, whereby the expertise and experiences in Trinity can be shared with the wider community.
10. Resource additional, and upskill existing personnel to help take action to practically enhance biodiversity across Trinity's Distributed Campus, as outlined in section 8.

[7] Natural capital is an economic metaphor for nature; a concept that frames the world's resources like plants, animals, water, and minerals as assets or stocks that yield a flow of benefits to people (https://www.naturalcapitalireland.com/resources)

2. Results of Pilot Biodiversity Audit

2.1 Mapping system

The aim was to pilot a mapping system and identify the resources needed to present and curate these data. Ultimately, we envisage an online system whereby staff, students and the general public can click on a relevant sector on a map and access habitat and species level information. This would also allow for a finer scale resolution of our estate for the collection of data. We envisage that this would be a highly useful resource; for example, researchers might easily locate all trees of a particular species on our properties and study fungal, lichen or moss associations. As a teaching tool, we envisage that this system would allow our staff and students a way to easily explore our properties and interpret and engage with the various habitats and species in a more meaningful and informative way. On a practical level, it would allow scientific staff to communicate with Estates and Facilities (E&F) staff about future biodiversity initiatives and monitoring. Finally, it would provide a structure for the assembly of future biodiversity audit data and align with government targets for Open Data.

2.1.1 Progress:

In collaboration with E&F, Trinity's main campus was broken down into 16 sectors (Figure 3), which reflect management units on campus; and the built, ornamental, naturalized and water habitats on campus were listed.

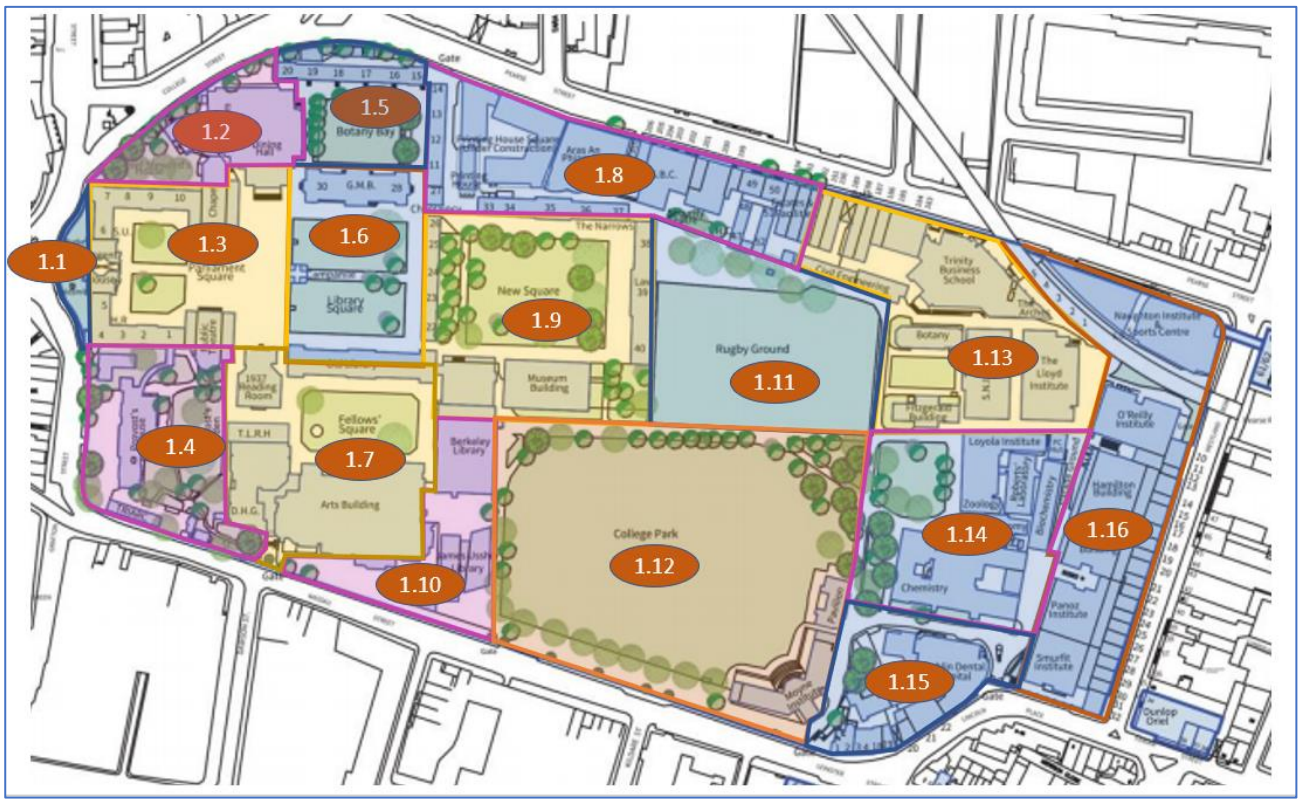

Figure 3. Sixteen campus sectors reflecting management units on campus. We envisage that our future online mapping system would allow staff, students and the general public to click on a relevant sector and access habitat and species level information.

A pilot GIS habitat mapping system for Trinity's Main Campus was designed which maps the various habitats according to Fossitt (2000)[8]. While we recognize that the habitat scale of Fossitt is not entirely pertinent to urban environments, it is useful as a first step to gain a more precise resolution of the various habitats on campus. This can be visualized and managed via a Computer Aided Design (CAD) platform (Figure 4).

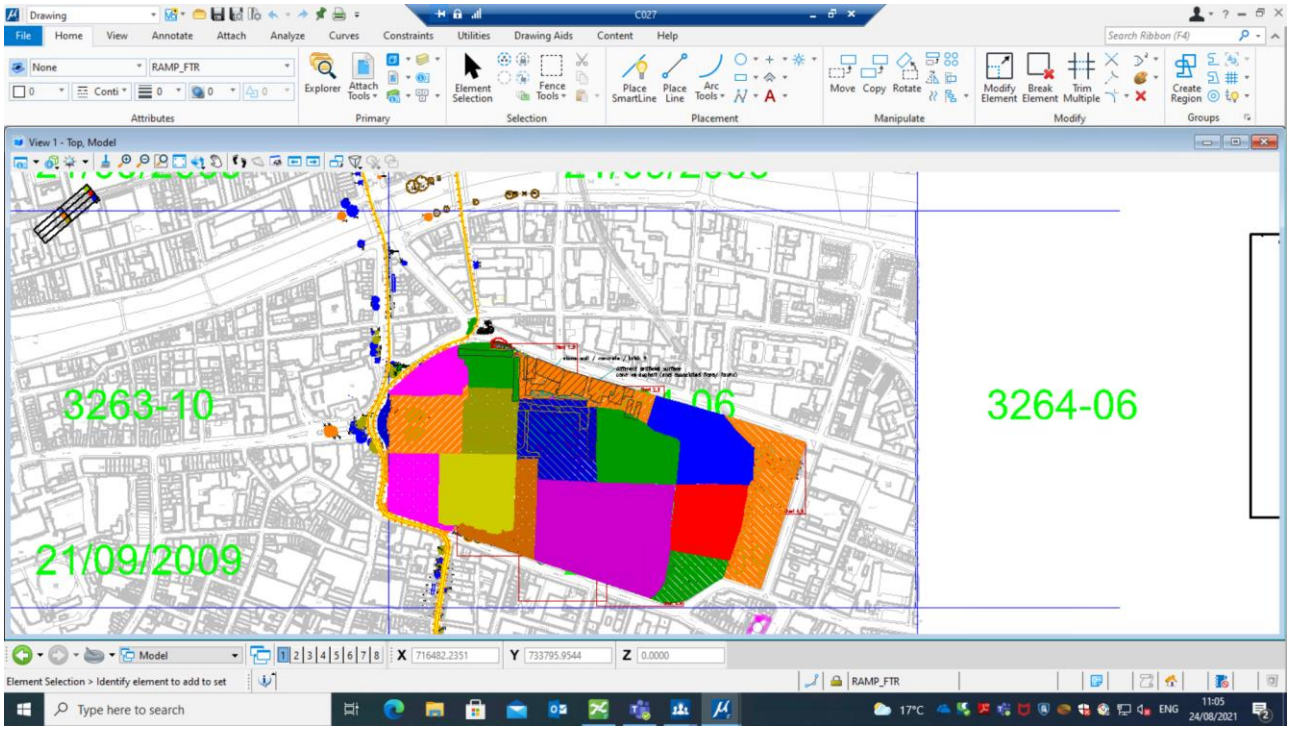

Figure 4. Pilot Geographic Information System (GIS) habitat mapping system for Trinity's Main Campus showing the 16 campus sectors. This is presented via a Campus Sectoral Map on Computer Aided Design (CAD) platform, requiring the assembly of a variety of CAD files.

1.2 Difficulties encountered:

A delay in receiving existing GIS maps due to COVID-19 restrictions, along with the variety and extent of various projects on campus, hindered the ability of the mapping portion of the project to proceed as quickly as we might have wished. Additionally, we are aware of a number of existing GIS maps of campus, associated with various building projects and we still await receipt of these maps from the Technical Services division of E&F.

However, we have been able to develop a pilot scale mapping to test the following:

- The designation of the college campus into sectors for use in the further development of management plans that integrate campus biodiversity, building works and maintenance
- The designation of portions of the campus as polygons, lines and points, in order to test the integration of the survey data in a GIS platform

[8] Fossitt, J.A. (2000) A Guide to Habitats in Ireland. The Heritage Council, Kilkenny https://www.npws.ie/sites/default/files/publications/pdf/A%20Guide%20to%20Habitats%20in%20Ireland%20-%20Fossitt.pdf

- The setting up of a test GIS pilot to log the data collected to date as part of a college mapping project (the landscape observatory), funded through Transport Infrastructure Ireland[9].

1.3 Resources required in the future:

To both spatially and temporally map our properties, a Common Data Environment (CDE) is essential. This will be a central repository where project information is housed, and which will be the central source of information for the project. This will be accessible for E&F staff, biodiversity scientists, and other relevant personnel, and could integrate existing and new CAD and GIS mapping for Trinity properties. To do this, additional personnel and expertise are required, potentially involving collaboration between staff in Civil Structural & Environmental Engineering, Geography, Grounds and Gardens Committee, and IT Services to set up the physical infrastructure. This offers the opportunity for the establishment of a real, live 'Living Lab' with regard to biodiversity.

2.2 Baseline inventory of habitats and species

Baseline data are needed for a scientific approach to quantifying existing biodiversity and the effects of any biodiversity initiatives implemented on campus, as well as for reporting on biodiversity targets.

2.2.1 Progress – species data management and curation:

We have collated data from existing sources and from pilot surveys conducted during 2021. As species level data came from a number of different sources, including E&F invoices and Excel sheets, formal surveys of trees or individual areas, student research projects and previous BioBlitz data[10], the database needed standardising, with the preservation of all relevant detail. Targeted sampling of certain taxonomic groups included plants (intentionally planted trees, shrubs and herbaceous plants, as well as 'wild' plants, i.e. those not intentionally planted/seeded) and invertebrates.

A standardised database Excel template for recording species level information across the range of taxonomic groups on campus (and including ornamental plantings) has been designed and all data collated and aligned. While we recognise that this is not the ideal platform for assembling these data, this standardised data form can easily be transferred to a formal database system as part of a next step in the development of the Biodiversity Audit. Currently, data collected and sampling protocols are archived in a 'BioAudit OneDrive' project folder.

Plant species data have been integrated into pilot maps (Figure 5), which are hosted on the Transport Infrastructure Ireland (TII) GIS system, as part of a collaborative PhD project between Trinity and TII. We envisage that in the future these data will be hosted on Trinity servers.

2.1.1 Difficulties encountered:

We had insufficient time to explore and develop a dedicated database system, given the available expertise on the project. In developing such a system of data collection, storage and analysis, the baseline data need to be assembled in a standard format and then formatted for use in mapping. The data exist in a number of forms including spatially, temporally, and at a variety of scales.

[9] Part of Tony Williams' ongoing collaboration with TII and part of his Ph.D. project is a small research grant to set this up.

[10] A BioBlitz is an intense, usually 12-24 hour, survey, attempting to document as many species as possible, performed by scientists, naturalists and volunteers Previous Campus 'BioBlitz' surveys were done in 2013, 2014 and 2017

It was possible to use the available time to explore the possible means by which the data may be entered for further analysis, using Excel as a starting point and refining the structure of data collection in tandem with the development of sampling protocols.

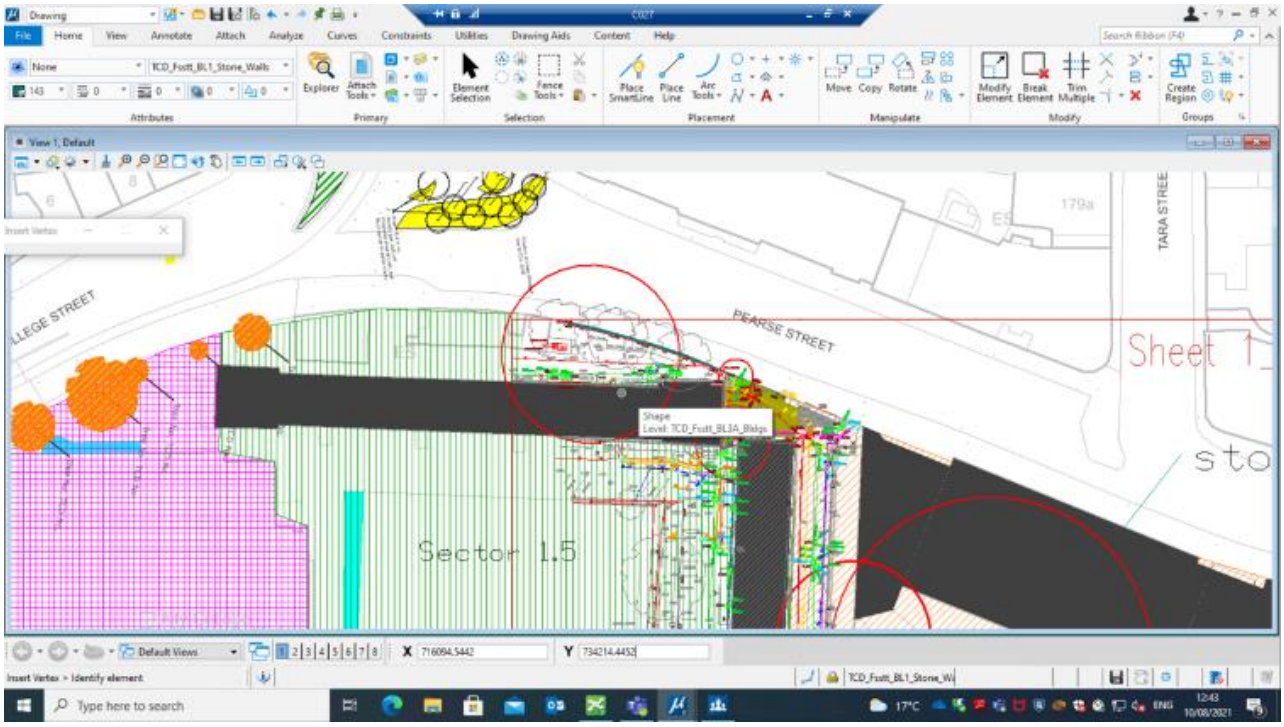

Figure 5. Pilot Geographic Information System (GIS) habitat mapping system for Trinity's Main Campus showing a close up of Sector 1.5 (New Square and Boundary Wall) on CAD (Computer Aided Design)[11].

2.1.2 Resources required in the future:

Initially, resources will be needed to move the existing data out of the Excel environment into a more formal database system. At a minimum this will require a graduate (from Computer Science or an allied discipline that deals with data management) and with the skill sets to manage data collection, transfer and storage. The migration of these data needs to be carried out as part of the assembly of both current and historic data and is at the kernel of the Biodiversity Audit to ensure the integrity of historic records. GIS mapping provides a spatial platform for the data and provides the database with more spatial functionality. As the GIS platform is developed, the existing and current data will require integration. A GIS mapping system will make it possible to generate spatially explicit biodiversity reports and update data (almost in real time). This should be done in discussion with E&F and integrated into existing Building Management Systems[12], which should be expanded to all Trinity's buildings.

Continued database curation will require appointing a dedicated member of staff. We would not envisage that this would be part of an overall Biodiversity Officer role, but would be an additional staff member

[11] Preparation of files for GIS requires preparation within CAD and then exporting to a GIS environment. This then requires integration with the data being collected in Excel.

[12] A BMS is used to manage mostly energy and utilities within a building, using remote sensors which provide real time data on what utilities are being used. There could be potential to have biodiversity data integrated into it, depending on which BMS Trinity is employing.

dedicated to the data management tasks. There would also be a requirement for support from Trinity IT Department, E&F and the Grounds and Gardens Committee.

Resources should also be committed to exploring the possibility of integrating with existing biodiversity database platforms such as inaturalist, where species can be loaded into a GIS platform, verified taxonomically and mapped in real time.

2.2.2 Progress – Plants

Working with E&F, we have now assigned all existing data on horticultural species, along with data collected during our targeted sampling, to polygons representing different habitat types, geographically located within each campus sector. All trees on Trinity's Main Campus have been geographically located as point data, with tree lines and wall climbers assigned as lines.

We have obtained agreement in principle from a moss identification specialist (Rory Hodd, Nimbosa Ecology) to conduct a targeted campus moss survey, along with a moss identification day for students and interested staff.

2.2.2.1 Difficulties encountered:

As lists for historic plantings on campus were not always retained, some cultivars are only listed to genus level. Due to time constraints associated with the need for student intern training and supervision in sampling, not all wild plants have been catalogued for each of the campus sectors.

There is a need to recognize and address the current trend for 'wildflower' plantings and the biodiversity issues they can raise[13]. Seed mixtures and roll-out turfs are marketed as beneficial for biodiversity. However, many can contain non-native species, non-native genotypes and/or combinations of species that do not occur in native Irish habitats. In addition, as intentionally planted mixtures, they do not recreate natural systems, but are a form of gardening, creating planted 'horticultural' or 'ornamental', rather than wildflower meadows. Just how beneficial these areas are for insects and pollinators remains to be scientifically determined. This is not to say that they are not beneficial for some species of insect during certain stages of their lives, and knock-on benefits for insectivorous animals, but they are not a biodiversity panacea.

Trinity has successfully established horticultural/ornamental meadows on the Main Campus near the Chemistry Building, the Pavilion Bar, and most prominently, at the Front Gate, on areas that were previously regularly-mown lawns. As such, the plant diversity has increased, and they have attracted considerable favourable attention from the college community, visitors and passers-by, and worldwide[14]. However, because of the potential for horticultural/ornamental meadows to interfere with and threaten, at the genetic level, native floral biodiversity if established in rural sites, and to contribute to pollution of the environment with the plastic matting and netting which forms the base of roll-out turfs, they have also attracted criticism[15]. Careful communication, and increased awareness amongst staff, students and the general public that these are horticultural/ornamental meadows, which cannot replace natural ecosystems, and may not support the complex lifecycle requirements of various insect groups is clearly required. This is especially important given Trinity's influential position and the increasing enthusiasm for action for biodiversity across public bodies, private corporations and community organisations.

[13] e.g. see https://pollinators.ie/wildflowers-to-plant-or-not-to-plant/, https://pollinators.ie/wildflower-seed/, and https://horticultureconnected.ie/horticulture-connected-print/2021/spring-2021/wildflower-or-wildfouler-how-the-industry-can-support-the-bees-and-biodiversity/

[14] https://www.thejournal.ie/trinity-college-dublin-front-gate-wildflower-meadow-5165117-Jul2020/

[15] https://www.irishtimes.com/news/environment/botanists-not-wild-about-trinity-college-s-wildflower-meadow-1.4649317

2.2.2.2 Resources required in the future:

Information for any new plantings on college properties, and the removal of existing trees and other horticultural plantings, need to be communicated on a regular basis to whomever is the Biodiversity Audit database administrator to ensure the database is kept up to date.

While expertise currently resides in the School of Natural Sciences for the identification of vascular plants (also known as 'higher plants', i.e. those with water and food conducting tissues within them), no meaningful assessment of plant biodiversity should exclude nonvascular seedless plants (including mosses). Without a permanent member of staff with this expertise, finances would be required to periodically employ relevant experts on a contractual basis, both to provide field training to students and for assistance in any biodiversity audits.

In future, if we are to rely on student volunteers and interns to help gather plant biodiversity data, they should already have obtained a minimum level of botanical skills, for example, in plant morphological terminology, identification of some common plant families and the ability to use a taxonomic key, along with other relevant field skills. We would recommend that Natural Science students be introduced to these skills at a formal level during the first year of their courses, and that this is built upon in subsequent years. Basic levels of botanical (and entomological – see next section) skills and knowledge are relevant to all students of the natural sciences, but have become seen as "old-fashioned", and are challenging to teach to large classes, and so have been lost from many third level programmes. Beyond the science student body, there is interest amongst staff, students and the public for botanical training and skills. Trinity is ideally placed to reinvigorate and lead on innovative education in taxonomy and field skills, and to enable graduates and staff to have a meaningful understanding of their natural surroundings. This could be achieved by recruiting staff with taxonomic and field work skills who would actively use Trinity's estate and the natural history collections (living and non-living) as teaching resources, or by contracting external experts to provide short courses in specific taxonomic groups and sampling methods to students, staff and others.

2.2.3 Progress - Invertebrates

Invertebrates comprise the largest component of Irish biodiversity in freshwater, terrestrial and marine environments and are fundamentally important to the functioning of all ecosystems[16]. Their populations fluctuate with the seasons, within and between years, and due to the enormous range of species and life histories, a range of sampling approaches are required to fully document their diversity.

During this part of the project, we trialled a number of sampling techniques, documented our protocols, and geographically located all sampling points to provide for the standardisation of future invertebrate sampling on campus. All protocols and sampling points are archived in the BioAudit OneDrive folder. Sampling strategies included Moth trapping (under licence), Pan traps (Figure 6), Pitfall traps, Pond Dip Netting, Sweep netting, and Tree Beating, along with observation and photographing. Due to time restrictions, we did not employ FIT (Flower-Insect Timed) counts[17] , Malaise Traps, Flight Intercept Traps (Barrier Traps), Slug Shelters or soil sifting techniques, but these should be considered in the future. Transect walks were employed by Biodiversity and Conservation (MSc) student, Emma King, as part of her MSc thesis research (Figure 6).

As many species required additional taxonomic expertise for identification, which often meant a time delay, any destructive samples were assigned a morphospecies code (this is a code given to individual specimens, which allows a non-specialist to separate species based on similarity, until later identification by an expert taxonomist, Figure 7). This allowed for the later assignment of a species name, if possible. For lab

[16] https://www.npws.ie/research-projects/animal-species/invertebrates
[17] https://pollinators.ie/record-pollinators/fit-count/

identification, we found that it was easier if one person in our group concentrated on a particular insect order (or a number of the smaller invertebrate groups) and attempted to gain some familiarity with the morphological characteristics of that group. Given the project timeframe, this was the most efficient way to process samples.

Figure 6. Pan traps (L) and Transect walks (R) for sampling flower-visiting insects.

Figure 7: Invertebrate reference collection. As new species were encountered, we initially identified them to Order (or other major grouping for other invertebrates). Depending on the size of the specimen and whether pinning would damage identification characteristics, the reference specimens were pinned on A4 sheets of recycled polystyrene or they were stored in 95% ethanol in Eppendorf tubes/vials on polystyrene boards. A new species was given a morphospecies name which indicated whether it was a pinned sample (P) or in a vial (V) and a three-letter code indicating the insect order. If an insect was later identified, we could attach the species name to the morphospecies code. This system allowed us to identify the number of species present to order, and process duplicate specimens, without having a recognized species name. Each reference board has an associated digital sheet with collection information, stored in the BioAudit OneDrive. Hymenoptera photo (P_HYM031) taken by student intern, Isabelle Quinn.

Our invertebrate reference collections remain as pinned specimens or specimens stored in ethanol, with accompanying microscope images for smaller specimens. As sampling progressed, we tested the utility of

this system in processing samples from the field. It is envisaged that our system for processing, recording and storing lab samples from the field will be used as a future resource for teaching and student research projects at all levels, and associated information is held within the BioAudit OneDrive.

We have achieved a preliminary temporal baseline inventory of a number of invertebrate groups, which hugely increases our knowledge of the presence of these groups on campus. In a 2014 campus BioBlitz, 47 invertebrate species were recorded from a total species count of 347[18]. Sixteen of the invertebrate species were insects, representing five insect orders: Hymenoptera (bees, wasps, ants: 5 species), Diptera (true flies: 4 species), Coleoptera (beetles and weevils: 2 species), Hemiptera (true bugs: 2 species), Lepidoptera (butterflies and moths: 2 species), Psocoptera (booklice and barklice: 1 species). In a 2017 BioBlitz, of a total of 157[19] species recorded (15 invertebrate species), only 10 insect species from four insect orders were recorded, including: Hymenoptera (5 species), Diptera (1 species), Lepidoptera (3 species), Coleoptera (1 species).

In our sampling from June-August 2021, from 632 invertebrate records (i.e. individuals), sampled from 11 locations across campus, we have recorded 327 invertebrate species, including 289 insect species/morphospecies (Table 1).

Table 1. Numbers of invertebrate species (identified to species, genus or morphospecies level) recorded on Trinity Campus between 15th June - 25th August 2021.

Invertebrate group	Common name	No. of species
Annelida	Worms	2
Mollusca	Slugs and snails	4
Arachnida	Spiders	25
Crustacea	Crustaceans	5
Collembola	Springtails	6
Insect order		
Coleoptera	Beetles	11
Dermaptera	Earwigs	1
Diptera	True flies	117
Hemiptera	True bugs	43
Hymenoptera	Ants, bees, wasps, sawflies	46
Lepidoptera	Butterflies and moths	60
Neuroptera	Lacewings	2
Thysanoptera	Thrips	2
Trichoptera	Caddisflies	7

The differences encountered between years likely reflects a difference in sampling techniques between the previous BioBlitzes and our pilot study here, (sampling intensity [several repeated samples versus single days], and year to year variation in insects due to weather conditions) and cannot be interpreted as any increase in biodiversity. Had we employed additional invertebrate sampling techniques in this study, and repeated the sampling more often, and for a longer portion of the year, we probably would have uncovered more species.

Apart from single observations of a Holly Blue (*Celastrina argiolus*) at the Zoology border, a Small Tortoiseshell (*Aglais urticae*) and Red Admiral (*Vanessa atalanta*) at House 40 Garden and a handful of sightings of Green-veined White butterflies (*Pieris napi*), no other butterfly species were recorded during the

[18] 2014 BioBlitz total no. species =347; 270 plants, 21 vertebrates, 47 invertebrates, 4 fungi, 4 lichens, 1 protozoa
[19] 2017 BioBlitz total no. species = 157; 135 plants, 7 vertebrates, 15 invertebrates.

period of this pilot study. Our observations correlate with the observations of experienced E&F Grounds staff. Even if nectar-rich, butterfly-friendly, floral resources are provided, different species of butterfly have different larval host plant requirements, and host plant specificity must also be taken into account to maintain populations. This could be particularly important in urban environments with fragmented habitat patches within a matrix of artificial surfaces and buildings.

The aquatic invertebrates (Water louse (*Asellus aquaticus*), Water flea (*Daphnia pulex*), Mosquito larvae (*Daphnia pulex*) and rat-tailed maggots [hoverfly larvae] (*Eristalis tenax*)) sampled from the Chief Steward's Pond on 27 July 2021 indicate very poor/stagnant water quality. This is likely to be caused by accumulation of leaves and other organic matter at the base of the pond, total cover of the surface of the pond with vegetation blocking out sunlight, and a lack of submersed aquatic oxygenating plants. Suggestions to improve water quality in the pond are included in Section 8.

We have had a number of notable insect records (summarised in Appendix 1), including the first official Irish record of the non-native Rosemary Beetle (*Chrysolina americana*)[20], and a second official record for a species of weevil (*Malvapion malvae*).

We have obtained agreement in principle from arachnid identification specialist (Myles Nolan, Spiders of Ireland, NBDC verifier) to conduct a spider identification workshop, along with targeted surveys for other invertebrate groups, as part of a sampling techniques instruction day with students. Myles will also provide instruction on spider and insect microscopy.

Throughout the project, we interacted with a number of taxonomic experts and collated a range of useful identification resources. All of these resources are documented, and reside in the BioAudit OneDrive folder, along with requirements and contact details for obtaining relevant sampling licences.

2.2.3.1 Difficulties encountered

While identification of larger or more charismatic insects and invertebrates was relatively easy through contacting specialists on online forums, such as Moths Ireland and Invertebrates Ireland Online, identification of other groups proved more difficult, and the majority of Diptera (true flies) and Hymenoptera (ants, bees, wasps and sawflies), two of the largest insect orders, were not identified to species level (Figure 8).

By far, the most diverse groups in our invertebrate sampling were the Diptera (two-winged or "true" flies) and Hymenoptera (ants, bees, wasps and sawflies). This may be due to the sampling techniques employed. However, a summary of the most recent checklists[21] showed that, out of a total of 11,656 species of insects recorded in Ireland, the Diptera (3,313 species) and Hymenoptera (3,194 species) orders represent the two most species-rich insect orders. The next most species-rich insect groups in Ireland are the Coleoptera (beetles), with 2,154 species, and Lepidoptera (moths and butterflies) with 1,454 species. The number of non-insect invertebrate species (marine and terrestrial) in Ireland is estimated to be approximately 8,000 species[22].

The Diptera is also one of the most ecologically diverse order of insects, fulfilling many different ecosystem functions; such as, pollination services, pest predation, prey items for other organisms, and decomposition and recycling of nutrients. However, the identification of many dipteran groups is notoriously difficult with

[20] This species originates from southern Europe, and has been widespread in Britain since the mid-1990s https://www.cabi.org/isc/datasheet/113295

[21] Regan, E., B. Nelson, S. McCormack, R. Nash, and J. P. O'Connor. 2010. Countdown to 2010: Can we assess Ireland's insect species diversity and loss? Biology and Environment: Proceedings of the Royal Irish Academy **110B**:109–117

[22] FitzPatrick, Ú., E. Regan, and L. Lysaght. 2010. Ireland's Biodiversity in 2010: State of Knowledge. National Biodiversity Data Centre, Waterford.

few taxonomic experts available in Ireland, and 77 percent of our morphospecies will require identification in the future, when we have located relevant experts who will agree to identify our samples.

Figure 8. Proportion of insects (289 species) sampled in Biodiversity Audit Pilot Study categorised to genus, species or morphospecies. All insects collected were assigned a morphospecies code, until we could confidently identify to species level. Insects sampled included the Diptera (true flies), Hymenoptera (bees, wasps, ants, sawflies), Lepidoptera (butterflies and moths), Hemiptera (true bugs), Dermaptera (earwigs), Coleoptera (beetles), Neuroptera (lacewings and other net-winged insects), Trichoptera (caddisflies) and Thysanoptera (thrips).

With respect to the Hymenoptera, while we have good knowledge of the number of bee species in Ireland, our knowledge of diversity in other hymenopteran groups is limited, especially the parasitoid wasps. Increased sampling of this group in Ireland is likely to yield many more species. Currently, our unidentified Hymenoptera specimens are with Dr. Aidan O'Hanlon at the National Museum of Ireland - Natural History, who has kindly agreed to attempt identification.

Other insect groups that were difficult to identify were the adult caddisflies (Trichoptera), the lacewings (Neuroptera) and nymphal stages of the Hemiptera (true bugs).

We did not achieve identification of a number of the slugs (Mollusca) from our pitfall traps as many were small individuals, and we were later informed that it was easier to identify this group while alive.

Honey bees (*Apis mellifera*) were often encountered in our sampling sites in floral areas, presumably from the managed colonies established in hives on the roof of the Parson's Building. It is important to note here that these colonies were established for research purposes and **not as part of any biodiversity actions**. Honeybees are managed pollinators and not in decline in Ireland, and too many honeybees in the landscape often have the potential to interfere with struggling native bees through competing for floral resources[23].

[23] https://pollinators.ie/beekeeping-is-important-but-getting-honey-bee-hives-is-not-an-action-that-is-helping-the-all-ireland-pollinator-plan/

2.2.3.2 Resources required in the future

Additional sampling will be necessary to assess temporal species variation on campus. This will involve repeating some of the methods already trialled, as well as exploration of additional sampling techniques. For example, Flight Intercept Traps may be more effective in trapping slow-flying insects such as beetles; and the deployment of slug shelters (45cm x 45 cm mats or sheets of plywood) may be more useful to obtain live slugs for identification. Additionally, targeted ground searches of different areas (for example, areas with high levels of leaf litter or piles of logs) should uncover more carabids (ground beetles), myriapods (millipedes and centipedes) or terrestrial crustaceans (woodlice). Targeted sampling of different vegetation types may uncover additional snails (Mollusca) and other invertebrate species.

This sampling will necessitate access to sufficient lab space with access to microscopes for identification of smaller samples. A small amount of storage space will be required to house the reference collection. The pinned samples should be housed in sealed entomological boxes and the samples in ethanol would require a suitable fireproof storage cabinet. A small library of insect taxonomic keys and guide books would also be necessary.

Since the number of taxonomic groups and diversity of organisms is massive, it would not be practical to attempt to sample all groups repeatedly, but to select indicator taxa and design an appropriate sampling regime that is both logistically achievable, and scientifically sound. However, this is not a straight-forward exercise and requires careful consideration, and analysis of baseline data. Some Trinity staff have experience and expertise in biodiversity indicators and are currently working with outside partners in various contexts[24], but additional resources would be needed to develop a rigorous invertebrate sampling regime for Trinity.

This future sampling could be incorporated into teaching or research programmes, under the guidance of an overall coordinator (staff member). Since most insect activity occurs outside of formal teaching term (April to September), it is difficult to incorporate systematic temporal sampling into the taught programme, but the value of such an action would go beyond documenting Trinity's biodiversity, and would provide students with valuable career expertise. As invertebrate sampling events will mostly need to be conducted outside of teaching term, this offers the opportunity for summer internships and work experience.

We urgently recognize the need to provide students with entomological skills for their future careers. Due to a diversion of funding and lack of appreciation of basic taxonomic identification and field work skills, nationally, this knowledge now resides in an aging population. Undeniably, this leaves Ireland ill-equipped and highly vulnerable to understand or mitigate against biodiversity loss.

Entomological expertise will be necessary for the identity of a number of our existing insect samples (e.g., Diptera, Hymenoptera, Trichoptera), and for future sampling events. This will require continued relationship building with a range of taxonomic experts.

Flowering plants represented the vast majority of species in the 2014 and 2017 BioBlitzes (244 and 125 species respectively), likely reflecting available in-house expertise in this group. While we recognise the utility of BioBlitzes in highlighting biodiversity in our natural surroundings, cross-disciplinary cooperation and engaging the campus community; we also recognise that with over 11,000 insect species in Ireland, underpinning all ecosystem functions, no meaningful biodiversity assessments can overlook insects. We recognize this as a major gap in our quantification of biodiversity on our properties using the BioBlitz method.

[24] e.g. see recent research Ruas et al. 2021 (https://www.sciencedirect.com/science/article/pii/S1470160X21003447), Delaney and Stout 2018 (https://www.sciencedirect.com/science/article/abs/pii/S1470160X18303297), White et al. 2020 (https://doi.org/10.1038/s41559-020-01315-w) and ongoing work on farmland "Scorecards" with DAFM and Teagasc, on windfarms via Nature+, and with Natural Capital Ireland as part of the Irish Business and Biodiversity Platform.

Our audits on Trinity properties primarily deal with urban locations, with the majority of species encountered likely to be common species that can cope with highly human-modified habitats. To recognize rare species, one first of all has to be able to identify more common species, and place new encounters in context with an overall knowledge. This requires a large amount of knowledge of both the flora and fauna of our Island. This knowledge and experience can take many years to acquire. We acknowledge that this gives an urgency to begin this process immediately.

To provide students with skills and training in fieldwork sampling, invertebrate taxonomic identification skills and microscopy skills, additional expertise will be required. This could be on a contractual basis but given the enormous contribution that invertebrates (particularly the insects), contribute to ecosystem functions, we would strongly advocate for the employment of additional permanent staff to guide student learning and research. Incorporation of Trinity's natural resources (both living and non-living) into the learning environment would make any skills gained highly marketable in the current biodiversity crisis.

2.2.4 Progress – Vertebrates

Mammals – Mammal surveys are time and labour intensive and can be seasonally-sensitive. It was therefore considered beyond the remit of the pilot study to carry out formal mammal surveys. However, potential survey areas were scoped out for future survey seasons. These included Trinity's Main Campus focusing on the Provost's Garden and the Chief Steward's Garden, as well as off campus at Trinity Hall and Trinity's Botanic Gardens, Dartry; Santry Sports Grounds including woodland; and the Islandbridge Boat House (see Section 3). All opportunistic mammal observations during these visits have been recorded.

Additionally, as we had access to Hedgehog (*Erinaceus europaeus*) Footprint Tunnels, six of these were deployed for one week in various locations around the Main Campus to determine absence/presence, and also to augment student learning in the practical aspect and documentation of protocols. Dried cat food was employed as bait in these tunnels, and while we found no evidence of any hedgehog footprints; one tunnel had mammal footprints, made by cats (*Felis catus*), and on six occasions tunnels had been disturbed and dragged by a larger mammal, indicating that foxes (*Vulpes vulpes)* had possibly attempted to gain access to food. Aside from this, the only observed activity was from molluscs.

Foxes are known to breed on the Main Campus. During the last week of July, we were able to facilitate E&F staff, by obtaining camera trap footage showing a male fox and cubs entering ground vents to the basement of the Church.

Common pipistrelle (*Pipistrellus pipistrellus*) bats have been detected foraging over the planted meadows close to The Pavilion by Collie Ennis, using a Magenta Bat5 handheld detector (11 June 2020); and a few years ago, a single bat was observed flying during the daytime over the Zoology and Anatomy buildings by Aoibheann Gaughran. This daytime flight would suggest that it had been disturbed from a local roost.

Grey squirrels (*Sciurus carolinensis*) are regularly observed on Trinity's Main Campus, with a squirrel's drey located in the Chief Steward's Garden.

Birds – While we did not carry out any formal bird surveys during this pilot study, Trinity's campus has been extensively surveyed in recent years, summarised in the booklet "*Birds of Trinity*", updated 2016. However, observations were noted as we conducted invertebrate sampling and lunchtime walks during our summer pilot audit. Data were also contributed by Jamie Rohu (PhD in Geography and Birdwatch Ireland).

Gulls (various species), magpies (*Pica pica*), feral (*Columba livia* f. *domestica*) and wood pigeons (*Columba palumbus*) are abundant on the city centre campus. Sparrow hawks (*Accipiter nisus*) have been observed using campus for hunting and we also observed hooded crows (*Corvus cornix*).

Swifts (*Apus apus*) were observed entering six of the air vents to the west side of the Museum Building during a survey by Birdwatch Ireland on the morning of July 13th 2021. Although a more thorough survey would be necessary to confirm whether breeding is taking place, it is likely these vents are being occupied as nests. This would represent an increase of three nesting sites since 2020. Separately, swifts were observed entering behind the gutter flashing on the north side of the Museum building. This colony had previously existed for many years but nests had fallen into disuse after building works. Swift attraction call boxes were installed in 2019, and attraction calls played in 2019 and 2020, and subsequently swifts were observed nesting in both years.

We were also provided with information that blue tits (*Cyanistes caeruleus*) had been observed nesting in the vents on the east side of the Museum building earlier in the year, but we did not observe any blue tit activity during our invertebrate surveys in that location. Aside from a robin in the Chief Steward's Garden, two observations of a blackbird (*Turdus merula*), one each of a wren (*Troglodytes troglodytes*) and a goldfinch (*Carduelis carduelis*), in front of Chemistry and Zoology and a handful of mistle thrushes on College Park and the Rugby Pitch, we recorded no other bird activity (Note: these observations do not include the Provost's Garden). It would be useful to conduct a formal survey throughout the year to compare with the 2016 surveys to detect whether there has been any change in bird populations.

A number of activities may contribute to lower numbers of small birds on campus, than the ideal populations. These may include:

- An increase in building works both on campus, and in the city centre in general, causing disturbance and loss of feeding and nesting habitats, as shrubs and trees near building sites have been cleared.
- Changes in building designs and materials resulting in a loss of nesting cavities.
- The requirement to prune trees along pathways for vehicular (3.5m) and pedestrian (2.5m) access, along with providing lighting to buildings, means that smaller birds do not have many suitable cover and perching sites for feeding on campus.
- Ivy and other climbers can be important in providing nesting sites and invertebrate food for small birds (and bats) and winter berries for frugivores. However, the aesthetic in more formal locations, the legal requirements surrounding health and safety and building access, along with the requirement to remove ivy at ground level, and to a height of 2m above ground, during each five-year tree health survey, means that ivy is removed or periodically set back on all estate property trees and periodically trimmed on buildings.

Amphibians - A survey of the Chief Steward's Garden Pond was carried out on 27th August 2021. The discovery of a juvenile common frog (*Rana temporaria*) suggests that there may have been an accidental or deliberate introduction of spawn or tadpoles to the pond at some prior stage, as there is no opportunity for natural recruitment to this pond given its location. The estimated age of this individual was approximately two years and additional observations will be necessary to determine whether there is a viable breeding population present. This shape of pond (approx. 1.2m deep and shallow at edges) is ideal for all forms of aquatic/semiaquatic pond life. There is good cover surrounding the pond, in the vegetation and in the log piles and other refuges, and the garden could support a sizeable population of two of our native species of amphibian, the common frog (already present in unknown numbers) and the smooth newt (*Lissotriton vulgaris*). However, the pond requires some maintenance to maximise its potential for biodiversity (see Section 8).

2.2.4.1 Difficulties encountered

It was not possible to carry out any bat detection surveys as static bat detectors (AudioMoth), ordered prior to the sampling season, did not arrive in time for the pilot survey, and we lacked compatible tablets for a handheld Echo Meter bat detector that was on loan to us.

Due to a period of hot weather in July, we took the decision not to deploy small mammal traps as the risk of animal stress or injury was too high.

2.2.4.2 Resources required in the future

Timely training of students in bird surveying (point counts and transects) methods, small mammal trapping, the use of handheld and static bat detectors, along with camera traps and footprint tunnels will be necessary to complete an inventory of vertebrate activity on Trinity's estate and monitor the effects of any biodiversity initiatives. This will provide excellent hands-on, practical experience for Zoology students in these sampling methods.

Mammals - For a targeted baseline inventory of mammals, we suggest:

- Conducting small mammal surveys using Longworth traps in the Provost's Garden and Chief Steward's Garden. Summer is not the ideal time to survey small mammals, and we recommend that surveys be carried out in late spring and/or early autumn.
- Setting camera traps in the Provost's Garden. This would require purchasing trail cameras and using in secure locations only.
- Using Static Bat Detectors, situated on Flat Iron area, Provost's Garden, Chief Steward's Garden and New Square. Bat surveys should take place between April and September, with a focus on May-August.
- That Bat Transect Walks should be carried out using Handheld Bat Detectors on Trinity's Main Campus (Zoology Building to College Green via College Park, New Square, Library Square and Front Square). Bat surveys should take place between April and September and especially during the May-August period.
- A National Parks and Wildlife Service (NPWS) licence will be required to check any bat and bird box installations.

Birds - For a targeted bird inventory, Trinity's Main Campus could be covered effectively with two transects along the North and South sides, designed to cover the ornamental areas. Once established, a bird survey along the transect and two point counts should be carried out at least twice in the daytime and once at night in each season (spring, summer, autumn, winter) to give a standard assessment of the birds present which can be compared from year to year.

- Bird box monitoring at each site in which boxes have been installed should be carried out in spring and the nestlings ringed (under licence).
- Visitors, students and employees should be facilitated to report sightings of birds, perhaps through a link accessed through a QR code to an online site where such sightings could be entered.

Amphibians – As there may be a viable population of breeding frogs in the Chief Steward's Pond, visual night surveys for breeding adult frogs should be undertaken from January to March. If a breeding site has established, follow up spawn clump counts will give a good estimate of the adult frog breeding population.

2.2.5 Progress – Fungi

Any fungal 'fruiting' bodies encountered during invertebrate and plant sampling events and site visits were photographed, and these were later identified by Prof. Paul Dowding, Professor Emeritus, Botany. Relevant tree associations were also recorded. In total we recorded 10 species of fungi this summer.

Dr. Daniel Kelly, Fellow Emeritus, Botany provided us with details of a lichen survey conducted on a number of campus trees in 2019. These data have been incorporated into our database.

2.2.5.1 Difficulties encountered

In Ireland, autumn is recognised as the best time for sampling fungal diversity, and so additional sampling needs to occur during this time to maximise information on species diversity. Therefore, during this study, we were only able to sample a very small portion of the fungal diversity likely to exist on campus (and other Trinity properties).

We lacked available expertise to carry out any lichen surveys on campus during our study. The identification of lichen species requires expertise and often entails microscopy.

2.2.5.2 Resources required in the future

As we have a newly appointed mycologist in the Botany Department (Dr. Carla Harper), we do not envisage any additional personnel resources for fungal identification, and in the future, fungal surveys will be incorporated into the formal teaching program. However, additional taxonomic expertise would be required to conduct detailed lichen surveys on campus and other Trinity properties, and to provide student training.

3. Biodiversity across Trinity's estate

We aimed to gather, in a single repository, all available biodiversity data for the rest of Trinity's estate. The Trinity estate totals 17 properties (Figure 2). Provisional habitat lists were supplied by E&F staff and site visits were arranged for a number of Trinity's properties, which have potential for biodiversity initiatives and research. These sites included Trinity Sports Grounds, Santry (~13 ha); Iveagh Grounds, Crumlin (~9 ha); Trinity Hall and Trinity College Botanic Gardens, Dartry (~5 ha); St. James's Hospital (~1.5 ha) and Trinity Boat House, Islandbridge (~0.5 ha). These visits allowed observation of the existing habitats and current management practices, and informed on the logistical requirements needed for transport and access. Compiled maps and habitat information reside in the BioAudit OneDrive folder.

In collaboration with E&F, all available tree survey data have been standardised in our database. Pitfalls and Pan traps were installed in the Trinity College Botanic Gardens on one sampling event; however, within the time frame of the project it was not possible to carry out any further surveying. Additionally, plant species lists for the Longhouse Lawn area of the Trinity College Botanic Gardens were drawn up and geographical mapping of a number of trees on the Trinity College Botanic Gardens site was achieved as a starting point. Grey squirrels (*Sciurus carolinensis*) are found in Dartry. A rat (*Rattus norvegicus)* was observed at the Islandbridge Boat Club. Two potential badger (*Meles meles*) setts were observed in the woods in Santry, however it is possible that these are not active badger setts but are being used by foxes.

Formalised plant, fungi, lichen, vertebrate and invertebrate sampling should be extended across other properties; particularly, Trinity Sports Grounds, Santry; Iveagh Grounds, Crumlin; Trinity Hall and Trinity College Botanic Gardens, Dartry; St. James's Hospital, Dublin 8; and Trinity Boat House, Islandbridge.

Plants - As all trees on these properties are regularly surveyed (every five years) by E&F staff, there is good information for this element of the flora. Any additional sampling would need to incorporate seasonal

variation due to different life cycles and to observe/obtain reproductive structures if necessary for identification. To obtain a baseline inventory of other plant groups, we suggest:

- Employing transects to assess species diversity in grassland areas
- Compiling lists of horticultural species on relevant sites
- A survey of the flora of the old stone walls and ruins at St James's Hospital
- Random quadrat sampling of the ground floor vegetation, along with observational walks in the Santry woodland and Dartry Arboretum.
- Compiling an inventory of the Trinity College Botanic Gardens (in progress)
- Targeted sampling of mosses to include a range of different habitats e.g. trees and fallen logs in Trinity College Botanic Garden and Santry wooded areas, or manmade structures such as the water-based hockey pitch in Iveagh Grounds.

Mammals - For a targeted baseline inventory of mammals off campus, we suggest:

- Conducting small mammal surveys in late spring and/or early autumn using Longworth traps at Santry Sports Grounds (woodland), Islandbridge Boat Club (hedgerows) and Trinity College Botanic Garden grounds.
- Setting camera traps (secure locations only) in woodlands (potential badger setts) and Trinity College Botanic Garden grounds.
- Deploying Hedgehog Footprint Tunnels in Santry Sports Grounds and Trinity College Botanic Garden grounds.
- Using Static Bat Detectors between April and September, situated along woodland edges in Santry, Islandbridge Boat Club and Trinity College Botanic Garden grounds.
- That Bat Transect Walks between April and September should be carried out using Handheld Bat Detectors in Santry Sports Grounds (woodland edges and treelines) and Trinity College Botanic Garden. It is particularly important that any surveying carried out at Islandbridge Boat Club should have a focus on detecting Daubenton's bat, which is associated with water bodies.
- A National Parks and Wildlife Service (NPWS) licence will be required to check any bat and bird box installations.
- For bird surveys, a single transect could be established at Santry, Trinity College Botanic Garden and Islandbridge boat house grounds, designed to cover the range of habitats present in each. Once established, bird surveys should be carried out along transects in a similar manner to Campus surveys. Similarly, where bird boxes are installed, monitoring should occur, and any bird sightings recorded through an online system.

Amphibians - Frog populations already exist in the southern arboretum in Trinity College Botanic Garden and the Iveagh Grounds (neighbouring ponds). Visual surveys should be conducted in the woodland at Santry and Islandbridge to determine whether there are any populations there.

Visual night surveys for breeding adult frogs should be undertaken from January to March. Once a breeding site is established, follow up spawn clump counts will give a good estimate of the adult frog breeding population.

Visual night surveys and trapping (under licence) during the same months will establish the presence of smooth newts. Mesh net baited traps with air pockets should be left in place for no more than 12 hours. Adult newts captured can be photographed and identified by individual markings. A combination of these methods will give an estimate of population size.

Fungi - It is planned that targeted fungal sampling of properties will occur as part of the taught curriculum in Mycology for Botany students this Autumn. A range of undisturbed habitats on all properties should be

surveyed for lichens, including trees, logs, bare soils and built structures. While many can be identified from photographs which include the underside, samples may also be dried down for later identification.

Invertebrates - To build a baseline inventory of invertebrates on these sites will require a substantial amount of sampling, using a range of techniques, as outlined in Section 2.2.3.2 above. Without substantial additional personnel resources, it is unlikely that any meaningful baseline inventory for all properties could be achieved in any one year. In this respect, it may be helpful to identify individual habitat types and/or indicator taxa for specific targeted surveys across all properties (where appropriate), with repeated temporal sampling during any one year. Alternatively, the focus could be on a single property in a given year, employing the widest range of sampling techniques across all habitats. Future decisions about sampling strategy will therefore depend on the amount of available taxonomic expertise and sampling personnel (see below).

4. Future sampling effort required

In recognising the different scales of biodiversity existing on Trinity's properties and the additional need for temporal sampling, time and personnel resources required to tailor sampling effort need consideration. Highly aware of the need for temporal sampling across various habitat types, the invertebrate sampling portion of this pilot project has given us an indication of the time and personnel resources needed to conduct sampling for this group in any meaningful way.

Terrestrial invertebrate sampling (17 sampling events, employing different trapping methods) was conducted between 15th June 2021 and 25th August 2021 with one full time coordinator and four student interns (both paid and unpaid), providing varying levels of input due to external work commitments. We had the additional help of Sam Preston (PhD student in Zoology) for moth sampling. Undoubtedly, the greatest portion of time was spent in the lab, identifying samples and developing a rigorous system of processing and recording.

For example, one moth trap deployed in the Chief's Steward's Garden on 16 July 2021, yielded 125 individual specimens: (64 Lepidoptera, 25 Diptera, 17 Hymenoptera, 8 Hemiptera, 6 Trichoptera,1 Neuroptera, 1 Thysanoptera, and 3 Arachnida) (Figure 9).

Our objective was to non-destructively sample the moths. This entailed refrigeration and photographing of samples that we could not immediately identify in the field, and later releasing these individuals back to their habitat. This translated to one full week of lab processing (two days to take quality images, three days to identify the moths, and to process the other samples). For some of the smaller specimens we needed to engage with additional taxonomic expertise. To date, a small number of the micromoth species, along with some Diptera and Trichoptera await identification, and some of the Hymenoptera are currently with Dr. Aidan O'Hanlon at the National Museum of Ireland - National Museum of Ireland - Natural History for formal identification.

As different taxonomic groups require sampling during different time frames, we envisage that biodiversity auditing would need to be conducted throughout the year on Trinity's properties (Appendix 2). Ideally, it would be incorporated into student curricula as a means of teaching identification and fieldwork skills during term time. This would require identifying lead people responsible for the different taxon groups, under the overall coordination of a Biodiversity Officer. Ultimately, efficient and meaningful assessment of invertebrate biodiversity will require employing expertise.

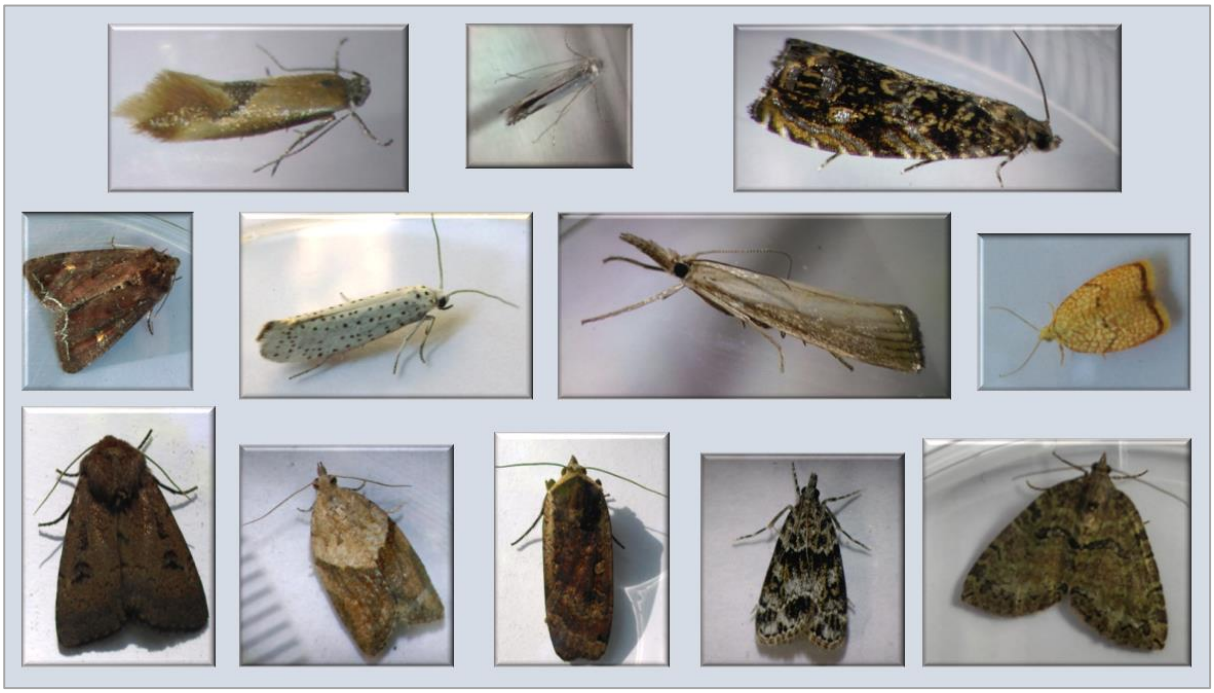

Figure 9. Sample of moth species obtained from Robinson Moth Trap placed in Chief Steward's Garden on 16th July 2021. From left to right: Lesser Tawny Tubic (*Batia lunaris*), Apple Leaf Miner (*Lyonetia clerkella*), Cherry Bark Tortrix (*Enarmonia formosana*), Bright-line Brown-eye (*Lacanobia oleracea*), Bird-cherry Ermine (*Yponomeuta evonymella*), Straw Grass-veneer (*Agriphila straminella*), Maple Button (*Acleris forsskaleana*), Double Dart (*Graphiphora augur*), Light Brown Apple Moth (*Epiphyas* postvittana), Large Yellow Underwing (Noctua pronuba), Small Grey (*Eudonia mercurella*), July Highflyer (*Hydriomena furcata*). *Images not to same scale.*

To provide students with additional opportunities to augment their practical skills during the summer period, whilst also providing biodiversity data for Trinity's estate, one possibility that should be explored is a number of summer student internships by competition, to carry out summer audits. We would recommend that engagement with alumni (or outside industry) as benefactors to such a permanent summer student internship scheme should be investigated. This would require oversight and coordination by a Biodiversity Officer.

5. Overall knowledge and resource gaps

At the outset of the pilot project, we contacted various members of staff in the Botany and Zoology Departments to explore levels of interest for a long-term project and request their assistance with the pilot audit. All members of staff were happy to participate at varying levels of commitment and provide assistance and guidance. Similarly, we contacted a number of graduate students to determine interest, expertise and time availability.

From the outset we were aware of a deficit of available internal expertise in a number of groups, particularly the insects, mosses and lichens. With that in mind, we sought the assistance of a number of external taxonomic experts, including Dr Aidan O'Hanlon (National Museum of Ireland - Natural History) and Gill Weymen (University College Cork), Dr. Max Barclay and Prof. Jim Hardie (Royal Entomological Society); and through online forums, Owen Beckett and Michael O'Donnell (Moths Ireland), Stuart Dunlop and Dr. Brian Nelson (Invertebrates Ireland), Stephen Falk (Dipterists Forum) and Andrew J. Greene (The Sawflies (Symphyta) of Britain and Ireland).

Additionally, we discussed the potential with other taxonomic experts of providing one-day training events with our student interns, whilst also conducting surveys within their field of expertise, for a monetary fee. However, due to COVID-19 restrictions and available finances, we were not able to advance this any further during the pilot study.

Implicit in continuing with formal biodiversity auditing of our properties, we identified the need to appoint at least one member of staff (Biodiversity Officer) to coordinate and manage data and sample processing, organize events, liaise with campus and external expertise, and communicate findings. Additionally, personnel resources will be needed to develop and manage the GIS mapping system and databasing.

As we lack in-house expertise in a number of groups, some external taxonomic experts could be engaged on short contracts to provide courses in their areas of expertise. Ideally, we would hope to have more in-house taxonomic experts, particularly for the biggest groups, who would actively incorporate Trinity's biodiversity resources into the teaching and research environment. Also, building stronger connections with organisations such as the Dublin Naturalists' Field Club has the potential to connect students with a wealth of experience and expertise in the flora and fauna of Dublin and nationally and is something which should be encouraged.

> '*.. nothing will substitute for the activities of the field naturalist. No matter how much we speak about instant identification through DNA analysis, hand-held keys or other modern approaches, unless there are very many people who can recognize organisms, find them, go into the field and find them again, whether they be in the tropical moist forests of Congo or the chalk grasslands on the South Downs of England, nothing will work*' From: Raven, P.H. (2004). Taxonomy: where are we now? *Philosophical Transactions of the Royal Society of London,* B **359**: 720-730.

6. Trinity as a 'living lab'

Trinity's estate could be used as a 'living lab', both for teaching and the quantitative assessment of biodiversity, but this requires additional resourcing.

One of a number of fruitful collaborations during this project, which demonstrated the utility of formalising a system of gathering biodiversity data on campus properties, was engaging with formal project work undertaken by students. Emma King, Biodiversity and Conservation (M.Sc.) student benefitted from the Bioidiversity Audit project in terms of getting access to site information and identification resources, and Emma has contributed the data she collected as part of her research project to the Biodiversity Audit database. The objective of Emma's study was to assess bee, butterfly and hoverfly diversity in herbaceous borders, planted meadows and naturalised vegetation in urban settings within 10 kilometres of Trinity. For her study, she chose two sites on campus, the Front Lawns (Sector 1.1) and the Flat Iron (Sector 1.12). Our combined dataset provides a temporal baseline of diversity within these groups for these sites on campus, and we eagerly await the results of Emma's study for comparisons with other urban settings.

Another collaboration was with the Biodiversity and Conservation (M.Sc.) class as a whole. These students would normally have received an introduction to invertebrate sampling techniques during their overseas field course trip, which was cancelled due to COVID-19. When approached, we were happy to fill the gap for instruction. The benefits of this were that we were able to provide instruction on a range of sampling techniques, insect pinning, general lab processing and identification resources; and the resulting sampling data were centrally recorded on the Biodiversity Audit database. Additionally, our project student interns had the benefit of sharing their skills and knowledge (Figure 10), and acquired valuable teaching skills.

Figure 10: One of our student interns, Scott Bastow (SF Science), sampling Pan Traps in Front Lawns (L) and another of our interns, Isabel Quinn (SF Science), processing insect samples in the lab (R).

It became increasingly evident in surveying the various College properties that Trinity's estate presents a wonderful opportunity for Natural Science students to gain practical field-based sampling and identification skills, along with an introduction to the rigour of scientific recording.

Feedback from our student interns showed how important it is to involve the students in this process, and how much they benefitted from the experience. They gained practical skills and broadened their knowledge beyond the classroom activities they had experienced so far; appreciated the challenges associated with creating repeatable protocols, and the difficulties inherent in taxonomic identification; and enjoyed the opportunity to work across campus (physically and in terms of the range of people they were working with). Some of the feedback included:

"Before this experience I was aware of the biodiversity crisis, however I was completely unaware of the extent to which it has snowballed."

"My knowledge of invertebrates has increased immensely during this project, which will be of serious benefit in my future college modules and career thereafter."

"This experience has made me realise how lucky we are at Trinity to be studying in a 'living lab'."

"I don't think I truly understood how much easier it is for me to learn and pick up skills through repetition and physically carrying them out…"

Our national commitments under the European Green Deal and the EU Biodiversity Strategy to 2030 give an urgency to the requirement that our Natural Science graduates have a practical understanding and knowledge of our flora and fauna, along with habitat identification and field surveying techniques. However, there is an acute shortage of trained botanists and entomologists to guide and inform policy, to conduct baseline monitoring and monitor change. Increasing the amount of taxonomy and field (species and habitat) identification in the formal taught curriculum will mean that Natural Science graduates will be better able to hit the ground running, and equipped for their careers.

Unquestionably, there is an opportunity to integrate biodiversity recording into student curricula. We would recommend that an active discussion should ensue between all resident expertise in the Natural Sciences, as to how this might be achieved. This may require a buy-in from some of our academic staff. However, it is believed that if biodiversity audits were a formal process, whereby data were systematically collected, rigorously validated and stored in a standardised fashion, this would have a utility for future research and monitoring, and the necessary buy-in could be achieved.

We found that a number of academic staff in the Natural Sciences were not aware of potential research/teaching resources on the various Trinity properties. To fully integrate and make these resources available for research, we recognize the need for a mapping system detailing the various habitats, and a central repository for biodiversity data on each of the sites. This information should be openly available to all researchers, academic staff and the E&F campus maintenance team, to utilize to full value.

7. Future research in mitigating biodiversity loss in urban areas

Given the geographical location of our estate, along with the diversity that exists across all of our properties, Trinity is ideally located to trial and document various urban biodiversity initiatives. Trinity is leading several urban ecology related projects funded by the European Commission, including 'Connecting Nature'[25], GoGreenRoutes[26], ReNature[27], and NovelEco[28]. Trinity also co-founded the All-Ireland Pollinator Plan[29], and so has a nationwide track record in ecological research in both rural and urban settings. Building on the resources compiled, baseline inventories conducted, and collaboration between E&F and scientific staff achieved during this pilot study, at a minimum, we would recommend that all biodiversity initiatives applied on campus in the future be scientifically monitored and documented.

Additionally, we recommend that formalised sampling be extended across other properties; particularly, Trinity Sports Grounds, Santry; Iveagh Grounds, Crumlin; Trinity Hall and Trinity College Botanic Gardens, Dartry; St. James's Hospital, Dublin 8; and Trinity Boat House, Islandbridge. Aside from providing material for practical student learning, baseline surveying is needed so that science-based planning can occur.

Trinity has a number of highly valuable biodiversity resources residing in its property portfolio some of which are currently under-utilized as resources for the study of biodiversity; from the city centre campus (including

[25] A €11.4m five year project with 30 project partners from industry, local authorities, local communities, NGO's and research in 16 countries, and hubs in Brazil, China, Korea & The Caucasus (Georgia and Armenia). The aim was to position Europe as a global leader in the innovation and implementation of nature–based solutions (https://connectingnature.eu/).

[26] A €10.5m, five-year project seeking to broaden the understanding and concept of Nature-based Solutions and to develop new approaches for city (re)design which actively promote the health of urban dwellers in particular (https://gogreenroutes.eu/).

[27] A 1.2m, three-year project aiming to establish and implement a nature-based solutions research strategy with a vision to promote research and innovation and develop solutions in a pursuit of economic growth, whilst at the same time improving human well-being and tackling environmental challenges (https://renature-project.eu/).

[28] A €2m, five-year citizen science project measuring societal attitudes to urban novel ecosystems

[29] https://www.tcd.ie/news_events/articles/the-all-ireland-pollinator-plan-2021-2025-an-ambitious-new-plan-to-save-our-bees/

the Trinity Herbarium and Zoology Museum), to the woodland in Santry Demesne, to the Trinity College Botanic Garden. The recent addition of a substantial site at Iveagh Grounds, Crumlin (~9 ha), provides further opportunities for biodiversity initiatives and research. The St James's hospital site has an interesting urban flora associated with the old stone walls and ruins on site, as well as ample opportunity to improve existing planting and maintenance regimes for biodiversity. The Islandbridge boathouse, located within the War Memorial Park on the south side of the Liffey, presents opportunities for putting into place practical initiatives associated with the buildings there, especially concerning birds and bats. Monitoring of such initiatives will provide wonderful opportunities for students to gain practical skills.

All of these sites are within close proximity of the city centre, and so, are ideally located to allow easy access from campus for students. The availability of a number of different urban sites, with similar and differing habitat types provides a wonderful opportunity for a range of scientific studies, including valuable material for Natural Science student projects, with a wealth of resources for augmented student learning in practical techniques.

8. Increasing biodiversity on Trinity's estate

It is important to recognize that much has been achieved for biodiversity on Trinity's estate to date, including instigating a Campus Pollinator Plan[30], reducing the number of areas with regularly mown lawns, reducing pesticide use, providing for sensitive scaffold construction to protect swift nesting habitat, and installing green walls and roofs. All of these initiatives contribute to the mitigation of biodiversity loss - but much more can be achieved and we must continue building on this.

Within the wider landscape, it is important to recognize that increasing habitat heterogeneity will provide for a more diverse group of organisms. Thus, an overall objective should be to increase the diversity of habitats supported by Trinity's estate, as well as the diversity of species that use those habitats.

Some suggestions for **enhancing biodiversity** on Trinity's estate include those listed below:

Action	Details	Management required
Improve the state of the Chief Steward's Garden pond	To remedy likely factors causing poor water quality referred to in Section 2	1. Remove leaves and organic matter from the pond base annually, depositing them beside the pond to allow aquatic creatures to return to water. 2. Remove 50-60% of the vegetation covering the surface of the pond. 3. Add native oxygenating plants to the bottom of the pond 4. Introduce pond snails, such as the great Ramshorn (*Planorbarius corneus*) or similar species, to help break down organic matter and control excessive plant growth.
Installation of new micro ponds and mini wetland habitats on campus (e.g. the Flat Iron and the Provost's Garden)	The water levels in these habitats do not need to be deep (maximum 0.5m) and will not pose a safety risk. With the increasing loss of wetlands as a result of agricultural drainage and urbanization, anthropogenic habitats play increasingly vital roles as refugia for frogs, newts and other aquatic	Occasional minimum maintenance (see recommendations for Chief Steward's Garden Pond above) will ensure that these ponds become healthy, vibrant habitats that attract many more species to campus. They may need fencing if in a public area.

[30] https://naturalscience.tcd.ie/pollinator/

and elsewhere on the estate	species. A 2013 Wildlife Trust survey[31] found that 44% of all waterbody types supporting smooth newt populations were garden ponds.	
Increase the amount of dead wood (e.g. the Flat Iron, in front of Chemistry and the Zoology border) on Campus, and off-campus sites	This will increase the number of saproxylic invertebrates, which in turn will provide food for small birds. It should also help to increase moss and fungal diversity. Woodpiles and brushwood will also provide suitable nesting sites for scrub-dwelling birds such as wrens and dunnocks	Little or no management needed
Increased use of organic mulches	Mulching has a range of benefits, including reduced weed growth, improved water penetration and conservation of soil moisture, regulation of soil temperatures, improved soil microbial/microfauna activity (including, ants, spiders, centipedes and earthworms) and control of pests and diseases. Areas that are not under constant cultivation e.g. the base of trees and shrubs, established herbaceous/shrub borders and difficult to maintain areas (e.g. under fencing in Iveagh Grounds), that are not currently mulched should have an initial application of a 10 cm layer of the appropriate grade mulch (bark/recycled compost).	Topping up of mulch every 3-4 years.
Provide resources for birds	Wherever possible, scrub, bushes and perennial planting should be provided, as cover, nesting sites and food sources. Native species are particularly good, but any greenery is better than nothing. Choose species that produce flowers at different times of year to keep insect populations alive through the year, providing year-round food for birds. The old set of nestboxes have decayed or been removed over the past 10 years, reducing nesting opportunities for many passerine species.	Longer grass and more diverse weedy areas should be encouraged wherever this does not impinge on the desired appearance of the grounds e.g. out of sight areas. Add a variety of nestboxes on the existing trees, including replacement of old boxes with 50 new ones on the Main Campus, 50 in the woodland in Santry and 30 around the Trinity College Botanic Garden and student accommodation. There should be three designs of box offered, tailored for tits, robins, and sparrows. Boxes for larger birds such as owls and raptors could be tried at Santry.
Provide additional food sources for birds	Many birds are insectivorous, and increasing insects can have knock-on benefits for birds. In addition, natural food sources such as berry-bearing shrubs and trees and floral seed heads, along with bird feeders can offer a variety of food types appropriate for requirements during the year. In terms of our overall sustainability goals, bird seed should be sourced from Irish growers, where possible, and sustainable packaging should be requested.	Establish a rota for the proper maintenance and cleaning of any bird feeders on a regular basis. Bird feeders can be important routes of parasites and disease unless properly cleaned and maintained; for example, the *Trichomonas* parasite, which has been undermining finch populations in recent years. Additionally, bird feeders should be monitored to establish the range of species using them, and alter positioning and content if this would be of biodiversity benefit.

[31] https://iwt.ie/wp-content/uploads/2017/09/Newt-Survey-2013.pdf

Floral resources for pollinators	We strongly recommend careful consideration and communication with regards to planting 'wildflowers' on Trinity's properties. We need to create an awareness amongst staff, students and the general public that these are horticultural constructs. We must recognize that our actions in Trinity give validity to other well-intentioned, but poorly informed groups around the country. Planting for pollinators should continue in ornamental areas, not only with herbaceous flowers but also flowering shrubs and small trees. The objective should be to extend the floral season for the adult stages of pollinators, but also to provide additional feeding (berries, seed heads, insects), perching and nesting resources for small birds.	Remove signage/media that describes these ornamental meadows as 'wildflowers' and in future, refer to existing plantings as 'Horticultural Meadows' or 'Ornamental Meadows'. Also, explore the potential of leaving unmown grass in high profile areas of nutrient poor soil, for example, the existing narrow border to the east of the Museum Building on campus and to the front of the William Stokes building at St James's Hospital. This could be done in a creative and pleasing way and can be enhanced through the use of creative wooden signage, utilizing our own timber stored in Santry.
Provide additional nesting resources for ground-nesting bees and resources for other invertebrates	Most of Ireland's solitary bees are ground-nesting species that do not use insect hotels. Nesting habitats for solitary bees could be provided through introducing suitable bare soil areas in open sunny locations with floral resources close by. We recommend that actions on Trinity's estate continue to be guided by the **All-Ireland Pollinator Plan guidelines**[32], in seeking to set aside wild habitats for pollinators and other insects and invertebrates where possible. Aside from providing resources for invertebrates and reducing fossil fuels associated with mown areas, this will play an important part in gradually educating staff, students and the general public that insects have complex lifecycles, with larval stages often requiring entirely different resources to the adult stages.	An active discussion should ensue between E&F staff and scientific staff to explore the potential of setting aside some of wilder areas on campus and other Trinity sites. This will require an initial assessment of the existing flora and soil nutrient levels on chosen sites. Management plans should be documented and sites annually monitored and documented. This could be a highly valuable teaching resource.
Encourage hoverflies	Along with important pollination services, hoverflies provide other beneficial ecosystem services, such as controlling aphid numbers. The larvae of different hoverfly species occupy very different ecological niches to the adults, with some species being aphidophagus (eating aphids), some saprophagous (eating decaying organic matter), whilst the larvae of other species are leaf miners. Yet other species require water to complete their lifecycles. Providing only floral resources will not guarantee that the necessary conditions have been fulfilled to complete a species lifecycle.	The expectation is that practical initiatives mentioned above, such as adding aquatic habitats, distributing logs and increasing organic matter through mulching, should increase hoverfly species diversity. However, this needs to be scientifically monitored to determine success.

[32] https://pollinators.ie/wordpress/wp-content/uploads/2018/04/How-to-guide-Nesting-2018-WEB.pdf

Provide host plants for butterflies	Provide host plants for some of the more common Irish species e.g. common nettle (*Urtica dioica*) for the Peacock (*Pavo cristatus*), Red Admiral (*Vanessa* atalanta) and Small Tortoiseshell (*Aglais urticae*); a range of brassicas for the Green-veined White (*Pieris napi*), Large White (*Pieris brassicae*), Orange Tip (*Anthocharis cardamines*) and Small White (*Pieris rapae*); Creeping and Spear Thistle's (*Cirsium arvense*, *Cirsium vulgare*) for the Painted Lady (*Vanessa cardui*); Bird's-foot-trefoil (*Lotus corniculatus*), Lesser Trefoil (*Trifolium dubium*) and possibly Black Medic (*Medicago lupulina*) and Greater Bird's-foot-trefoil (*Lotus pedunculatus*) for the Common Blue (*Polyommatus icarus*); and hollies (*Ilex*) and ivies (*Hedera*) for the Holly Blue (*Celastrina argiolus*). Other species have a preference for a range of grasses such as the Meadow Brown (*Maniola jurtina*) (Meadow-grass (*Poa*), Common Couch (*Elymus repens*) and *Fescue* species), and the Speckled Wood (*Pararge aegeria*) (broad blade grasses such as Cock's-foot (*Dactylis glomerata*), Yorkshire-fog (*Holcus lanatus*), Common Couch (*Elymus repens*) and False Brome (*Brachypodium sylvaticum*)[33]	Some consideration should be given to provide areas for these host plants to populate on our properties to support various butterfly species.
Plant native trees of native seed provenance	This is particularly important given the recent change in legislation (December 2019), whereby the country of origin on a plant passport can change to 'Irish' for plants sourced from other EU or non-EU countries, after being retained on an Irish nursery for a period of one month (potted plants, cuttings, herbaceous perennials) or one year in the case of woody stock[34]. This has obvious implications for the genetic integrity of our own native species. Even though Main Campus is in the city centre, surrounded by non-native species, advocating for native trees and native provenance sends a strong message and demonstrates leadership in best practice.	Active engagement with current and future suppliers when purchasing to ensure that native plants are of native seed provenance. This may involve ordering early in the season before stocks run out. Actively create awareness about provenance and the benefits of native stock in terms of pest and disease management.
Further reduce pesticide use and ensure sustainable use	Very little pesticide is used on the grounds of Trinity's Main Campus: rodenticides are used in the vicinity of the kitchens, insecticides and fungicides are not used, and herbicides are employed rarely (except for invasive species control). The sports grounds will always have a requirement for	Estates and Facilities should continue to take an "Integrated Pest Management (IPM)" approach[35], to document IPM strategies, monitor, and ensure that where pesticides are deemed the only option, all operators are fully licensed and adequately trained in pesticide usage, sprayer

[33] Nash, D., Boyd, T. and D. Hardiman (2012). Ireland's Butterflies. A Review. The Dublin Naturalists' Field Club.
[34] https://www.gov.ie/pdf/?file=https://assets.gov.ie/77308/d1a2a37a-f302-45ca-8cb1-1a1e40ceb8ca.pdf#page=null
[35] https://www.pcs.agriculture.gov.ie/media/pesticides/content/sud/integratedpestmanagement/GuidanceforLocalAuthorities260421.pdf

	selective pesticide control, because some plants, e.g. plantain, are a slip risk to players and need to be removed for players' health and safety.	calibrations and the disposal of washings, and that pesticide application records are kept up to date.
Responsible horticultural procurement and contracting	In the procurement of horticultural products and services, we should be proactive and require our suppliers to meet genuine minimum standards. In addition, to demonstrate leadership in best practice, IPM plans and spray records should be available, and horticultural use of peat and plastics should cease.	Actively seek sustainable alternatives to peat and plastics. Monitor and ensure that maintenance shortcuts are not being taken and that contractual obligations are met. Actively ensure best practice, for example, raking/hand weeding for maintenance of the gravel area surrounding Trinity Boat House, rather than spraying.
Include biodiversity mitigation into built structures	We recommend that the design and construction of all future building works on the Trinity estate should have biodiversity (and climate change) mitigation as a central theme. Swift Attraction Calling boxes, recently installed during the Museum Building renovation, is thought to have been successful. House martins and swallows could also be encouraged via the provision of artificial nest boxes at appropriate sites. Artificial light at night is often a problem for birds, bats and moths, disrupting their diurnal rhythms and behaviour. We recommend the installation of bat boxes. During this project, we have already been able to facilitate a collaboration between E&F staff and members of the Zoology department who had secured funding for biodiversity projects, and together they are actively pursuing the feasibility of installing bat boxes on campus.	Increased collaboration between E&F project teams and the E&F maintenance team at all project stages, from design to completion of new builds on the Trinity estate, to integrate existing biodiversity initiatives and plans, along with practical maintenance considerations of new building works (and associated landscaping). The library reconstruction project should consider the swifts nesting on the north side of the building, and the E3 Teaching Foundry should be built to accommodate attraction and nesting of various species. The problem of faeces below the nests can be alleviated by placement of a board below the nest above human head height. Artificial lighting at night should be assessed and minimisation/screening of lights should occur, light wavelengths should be addressed, and motion-sensors employed[36]. Crevice-style bat boxes could be erected on external walls of buildings in areas that are not well lit. These should be monitored annually for use by bats (avoid lactation season mid-June to mid-August), and any that remain unused 2 years after the date of erection should be relocated. In winter, boxes should be inspected by an experienced person, under license from the NPWS for general wear and tear and to remove droppings.

9. Addressing the global biodiversity crisis

This project aimed to begin a journey of scientifically informed action on biodiversity within Trinity's properties, which can be taken into the public realm to raise the profile of the biodiversity crisis. There are several actions that can be taken to make this aim a reality.

[36] Advice should be sought from Prof Brian Espey in Astrophysics, who has been involved in light pollution studies and has made recommendations to protect dark skies.

9.1 Increased collaboration on biodiversity issues

The Grounds and Gardens Committee, Provost's Advisory Committee on Sustainability and Low Carbon Living, and the Green Campus Committee have had major roles to play in bringing different parts of the campus community together to explore ways of making our campus more sustainable. However, many staff from several areas in College, recognize that a lot more can be achieved through open dialogue and clearer communications with respect to biodiversity issues. This is true not only at the College level, but because of Trinity's influential role, this has implications outside of the College community as well.

Where actions occur on Trinity properties that could potentially be harmful to biodiversity, during the course of building works, and/or maintenance to protect health and safety of staff, students and visitors, opposing opinions can be inflamed by poor communication, both within College and in the public media. Our goal should be to bring everyone on board to a full understanding of the importance of biodiversity and a more complete understanding of the natural world around them. Given that alternative measures to any potentially harmful actions will have been fully explored, great thought and care should be given to provide clear communications on the necessity of these actions, for both staff and students, and the wider public. Additionally, regret for the necessity of these actions should be expressed, and the beneficial effects of leaving organisms/habitats intact where possible emphasised.

This project has highlighted the wonderful collaboration that can exist between E&F and our scientific staff and students. Without doubt, all concerned wish to play their part in increasing biodiversity on campus properties, and were open to listening to advice and experience on both sides. It was recognized and acknowledged that assumptions can often be made about perspectives or level of knowledge on both sides.

Both parties recognize the need for the distillation of scientific knowledge and expertise, and its clear conveyance to non-scientific staff. One possibility that should be explored is the request for more formal biodiversity training for E&F staff, many of whom would welcome the opportunity for upskilling. This would allow them to meaningfully engage with biodiversity initiatives and manage changes in operations. Conversely, it is also recognized that many scientific staff and students do not understand the practical realities of maintaining our properties, or implementing new initiatives. We would recommend that some consideration be given to bridging this gap. This could be in the form of a seminar during each of the term times, and/or property walkabouts, with input from both E&F and the scientific staff. It would be most helpful if this were done in a formal way.

Increased internal collaboration and communication will benefit both our College community and campus biodiversity, and enhance our credibility as an institution in terms of addressing the global biodiversity crisis in a meaningful and genuine manner.

9.2 Biodiversity Induction Programmes

We recommend engaging staff, students, visitors, communities and businesses in a dynamic and meaningful way with biodiversity (and its rapid decline) through our biodiversity resources and practices on campus. Through engaging with these urban resources in a more meaningful way, we hope to inspire thought and create awareness of habitat loss in the wider landscape. This means nuancing the conversation about biodiversity, and upskilling all concerned to think beyond "green" to thinking about "diversity" of species and habitats, and the multiple values we derive from them.

- One possibility would be to provide staff and student Biodiversity Induction Programmes, introducing new staff and students to biodiversity research, initiatives and resources on campus.
- Alternatively, Natural Science graduate students (or capable undergraduates) could augment their teaching skills by running Outreach Programs to engage local communities. This has happened

successfully in the past, with Natural Sciences staff and students collaborating with Trinity Access Programme and Science Gallery initiatives, Science week and BT Young Scientist Exhibition, along with numerous other outreach events, podcasts and programmes.

- Another possibility would be to extend an invitation to staff and students in the wider campus community to actively engage with biodiversity monitoring schemes on the Trinity estate.
- Trinity is well placed to engage in outreach with other city-centre businesses and organisations whose corporate commitments to biodiversity will increase substantially in the coming years, requiring them to undertake similar biodiversity audits, employ best practice and site-specific interventions. The recently established Taskforce on Nature-related Financial Disclosures (TNFD) is a global initiative committed to deliver, by 2023, a framework for financial organisations and companies to report and act on nature-related risks and opportunities and builds on the success of the Taskforce on Climate-related Financial Disclosures. An opportunity therefore exists for Trinity's Business School and students to collaborate with the Natural Sciences in this respect to provide engagement with businesses in the local community. This kind of transdisciplinary collaboration is key to building a shared language across scientific and business communities for environmental restoration and Trinity has the potential to pioneer this approach. In a similar way, Trinity can engage with the Irish Business and Biodiversity Platform[37] when it is established.
- There may also exist the opportunity to engage with alumni (or external industry) to provide financial help for biodiversity audits. Perhaps the audit could have a patron (or a different patron each year) to provide for student summer internships.

All of the above could be achieved by a Biodiversity Engagement and Outreach officer, under the direction of a dedicated Biodiversity Officer.

9.3 Scientific approach to biodiversity issues.

Scientists define biodiversity as the variety of life, at genetic, species and habitat level. Thus, biodiversity issues are not just about iconic species, but about the variety of all life. And addressing biodiversity loss is complex and challenging, and context dependent: there is no one-size fits all solution.

We recommend that a more scientific interpretation of biodiversity is used in Trinity's sustainability goals, campus publications and media. For example, the Trinity Sustainability Report lists "Biodiversity and Trees" as one of its sustainability themes. Since trees (woody perennial plants) are one element of biodiversity, albeit an element with popular appeal, this could easily be reframed under a banner of biodiversity and ecosystem services (the cultural significance of trees being one such service). Furthermore, we should recognize that foxes are not a new phenomenon in Trinity, and have long been established on campus. Thus, we should not be trading on the idea that we are now providing them with a habitat through any particular biodiversity initiatives. The stark reality is that foxes have been driven out of their natural habitats in Ireland and elsewhere, and Dublin is likely to have the same concentration of foxes as other major European urban centres. Finally, although pollinators, and bees in particular, have popular public appeal, keeping hives of managed honeybees (*Apis mellifera*) is not a biodiversity action, and Trinity's hives on the Parson's building are for research purposes.

[37] The UN Convention on Biological Diversity's Global Business Partnership is driving the creation of national Business and Biodiversity Platforms to facilitate the development of measurable, certifiable actions on biodiversity. In response, Ireland's National Biodiversity Action Plan 2017 – 2021, and one of the Seeds for Nature from the National Biodiversity Conference in 2019, commits Ireland to establishing a Business and Biodiversity Platform as a key element of biodiversity protection and restoration.

Thus, a more scientific approach to biodiversity issues is needed throughout Trinity's operations. To this end, a senior role in college to address these issues, as part of the new Provost's regime, is warmly welcomed.

Trinity Communications and Public Relations do an excellent job on reporting on and promoting biodiversity research, usually in close collaboration with the researchers themselves. In a similar way, it might be useful to set up a mechanism for enabling scientific input to public announcements about biodiversity on campus. This could be facilitated through appointing a contact person on the scientific staff.

9.4 Making biodiversity a priority

In May 2019 the Irish Government declared a climate change and biodiversity crisis. By implication, this required urgent and immediate action to reverse and mitigate the effects of biodiversity loss. Since then, political inertia has apparently set in, which has more recently been overshadowed by the COVID-19 crisis. However, neither the threats of climate change or biodiversity loss have disappeared, as we see with the recent stark warning from the Intergovernmental Panel on Climate Change report[38] , and the most recent report on biodiversity loss in Ireland[39]. "*Global warming may dominate headlines today. Ecosystem degradation will do so tomorrow*."[40]

In the public realm, there is often the misconception that climate change is a bigger threat than biodiversity loss, or that the latter is a consequence of the former, rather than a phenomenon acting out on its own stage to be further compounded by the effects of climate change. Additionally, as people become more detached from the natural environment, an assumption pervades that the natural world will continue to provide for our needs, or that expert knowledge will be sufficient to engineer solutions to satisfy the needs of a growing population. In other words, there is no sense of urgency to begin addressing biodiversity loss today. But as the human population grows and needs food and other resources, and as climate change becomes an everyday reality, the need to reverse biodiversity loss becomes ever more important.

We, in Trinity, must become leaders in elevating biodiversity loss out of the political doldrums that have ensued since May 2019. Although we have staff who have successfully engaged on biodiversity issues at the highest political levels, with industry, local communities and schools, and who teach the issues to our students, we have not yet done enough. We owe it to our current students and our future students to be leaders in this field. We need to engage everyone in our university as active and knowledgeable advocates for biodiversity.

There is an urgent need to recognize that undoubtedly, there looms on the horizon far greater challenges than those we have experienced during the past year and a half with COVID-19 should we continue on our current trajectory.

With the recommendations made in this report, we believe that Trinity can take steps towards making biodiversity a priority, for everyone's benefit.

[38] IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change)

[39] Interim Review of the Implementation of the National Biodiversity Action Plan, 2017-2021

[40] Hanson, C., J. Ranganathan, C. Iceland, and J. Finisdore. 2012. The Corporate Ecosystem Services Review: Guidelines for Identifying Business Risks and Opportunities Arising from Ecosystem Change. Version 2.0. Washington, DC: World Resources Institute.

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Appendix 1. New arrivals and Invasive species

During the course of this summer audit a number of new arrivals and introduced species were recorded on Trinity's properties, including the Harlequin Beetle (*Harmonia axyridis*), the Noble false widow spider (*Steatoda nobilis*), the Rosemary beetle (*Chrysolina americana*), a weevil species (*Malvapion malvae*), the grey squirrel (*Sciurus carolinensis*), and Giant Knotweed (*Reynoutria sachalinesis*) on campus and at the boathouse in Islandbridge. Whilst active programs are in place to remove Giant Knotweed, as it is a highly invasive alien species, the introduced insects are likely here to stay due to difficulties in eradicating.

Harlequin Ladybird - In 2007, the Harlequin Ladybird was listed as *a most unwanted potential invader* in the Invasive Species Ireland Risk Assessment[41]. Shortly after, in 2010, two specimens were officially identified in the Republic of Ireland and this beetle is now believed to be well established across the Island. Harlequin Ladybirds have the potential to cause the decline or extinction of Ireland's native ladybird species, through direct competition for resources and predation on other ladybird species. On the 4 August 2021, an adult Harlequin beetle was removed from a plant in the Broadwalk Border on campus. Identification was later verified by Gill Weyman in University College Cork. As far as we are aware, this is the first record for this troublesome pest on our properties.

Noble False Widow Spider - Twenty-three years after it was first spotted in Ireland, the Noble false widow spider is now well established throughout the country. In fact, they are one of the most common urban spiders along eastern coastal counties. Research at NUI Galway recently showed that the Noble false widow shares two-thirds of its venom toxins with the true Black widow spider. These toxins are highly powerful neurotoxins that affect the nervous system of mammals.[42] Ireland has low spider diversity (390 species) compared with Britain (675 species)[43] and France (1711 species)[44]. A combination of life traits makes the Noble false widow highly competitive against Irish spiders, and all evidence to date suggests that the Noble false widow displaces native species (which in the long run could have a devastating impact on Irish ecosystems). On the same day that we observed the Harlequin Ladybird, a Noble False widow was collected from a light structure alongside the Flat Iron. Collie Ennis (Research Associate in Zoology) confirmed identification and informed us that they may be found throughout campus.

Rosemary Beetle - Since first observed in London in the late 1990's, it was suspected that the Rosemary beetle had established in Ireland. Originating in the Mediterranean and North Africa, this beetle eats the flowers and foliage of a number of related aromatic herbs, such as lavender, sage and thyme. Over the space of a couple of minutes surveying on 15th June 2021, five adult beetles were removed from the Lavender bed in Library Square. The beetles from Trinity represent the first official record for Ireland, and a specimen has been lodged with the National Museum of Ireland - Natural History.

European Wool-carder Bee - The first confirmed Irish sighting of the European Wool-carder bee (*Anthidium manicatum*) occurred in Wexford in July 2015. Since then, the species has been progressing northward. The most northerly record to date being a casual sighting in Arbour Hill, Dublin (26th June 2020). This species gets its common name from its behavior of scraping hair off plant leaves, rolling them into a ball for transportation back to their nests, where they use the plant hairs to line their nests. This behaviour induces changes in the plant to emit chemical attractants to other carder bees. They are a generalist species, who visit a range of

[41] https://invasivespeciesireland.com/wp-content/uploads/2013/03/Risk-analysis-and-prioritization-29032012-FINAL.pdf

[42] JP Dunbar, J.P., Afoullouss, S., Sulpice, R. & M.M. Dugon. Envenomation by the noble false widow spider Steatoda nobilis (Thorell, 1875)–five new cases of steatodism from Ireland and Great Britain. Clinical Toxicology, 2018

[43] Ferriss, S. E., Smith K. G., & Inskipp T. P. (eds.) Irish Biodiversity: a taxonomic inventory of fauna. Irish Wildlife Manuals, No. 38. National Parks and Wildlife Service, Department of Environment, Heritage and Local Government, Dublin, Ireland. https://www.npws.ie/sites/default/files/publications/pdf/IWM38.pdf

[44] https://araneae.nmbe.ch/biodiversity/countrylist

floral species, potentially competing with native bees. Males aggressively defend floral patches, having evolved long spines on the last two abdominal segments to attack intruders who are not a potential mate, and through aerial exchanges directly fracturing the wings of other pollinators[45]. Along with inflicting injury, these tactics often result in death of the attacked individual. Habitat preferences in Ireland for this species are not yet known. On 7th July 2021, an individual male of this large solitary bee was observed and photographed outside the Botany Building beside an ornamental mullein (*Verbascum* sp.), a grey leaved plant noted for its dense hairs.

Since being introduced to North America sometime in the mid-20th century, this species has become an invasive pest threatening native bee species there. Undoubtedly, we need to assess the impact of this new arrival in Ireland and initiate a study into its impact on our already threatened bee populations.

Mallow Weevil - On the 15th June 2021, we obtained the second Irish record for a weevil species, *Malvapion malvae*. This specimen was collected from the Ecology Border on campus, and identified by Dr. Aidan O'Hanlon. The only other Irish record for this species is from Portrane, Co. Dublin in August 2007. It is believed that this weevil is also a new arrival to Irish shores, rather than a previously overlooked species.

All relevant records from this study (horticultural species excluded) will be contributed to the National Biodiversity Data Centre.

[45] Wirtz P, Szabados M, Pethig H, Plant J (1988) An extreme case of interspecific territoriality: Male *Anthidium manicatum* (Hymenoptera, Megachilidae) wound and kill intruders. Ethology 78:159–167

Appendix 2 Detailed breakdown of sampling effort

An approximate calculation has been made of the sampling effort to conduct a full biodiversity inventory. The number of days per site in each season (Table A1) adds up to 317 person days per year per site, plus in many cases two people will be needed at the same time to set up traps (Table A2), and specific taxonomic expertise will be required.

Table A1: Indicative minimum number of person days required for biodiversity baseline sampling **per site** (Trinity's Main Campus; Santry Sports Grounds; Iveagh Grounds, Crumlin; Trinity Hall and Trinity College Botanic Gardens, Dartry; Islandbridge Boathouse and St. James's hospital).

Task	Autumn	Winter	Spring	Summer
Walk sites, verify existing habitat classification	2			
Identify habitat features	2			
Meet with Ground's Staff to ascertain current management	1			
Create habit maps in GIS	10			
Collate existing species data	1			
Make species sampling plan for each taxonomic group		3		
Plant surveys (including bryophytes)			6	6
Fungi and lichen surveys	3		3	
Bird surveys - 1x per month	4	4	4	4
Bat surveys			4	4
Other mammal surveys	4		4	
Amphibians and Reptile surveys		4	4	
Invertebrate sampling and identification				
• **Moths (1x month):**			21	21
• **Pan traps/Pitfall traps/slug shelters (2x month)**			42	42
• **Tree beating/Sweep netting/Flight intercept traps (2x month)**			36	36
• **Walking transects/hand searches of vegetation/logs (2xmonth)**			12	12
Data collation, database entry and submission to NBDC.	3	3	12	12

Table A2 Detailed breakdown of invertebrate sampling effort required per year.

Trapping details	person days
Moths (1 trap @ 1 x month):	
Day 1 go to site and set up	0.5
Day 2 collect, identify in field and photograph unknowns	1
Day 3+4 identify micromoths and other species	2
Number of months of sampling (1 sample event per month)	6
Number of people needed per day	2
Total	42
Pan traps/Pitfall traps/slug shelters (2 sample points each @ 2 x month):	
Day 1 go to site and set up	1
Day 2 ID slugs, collect pan/pitfall traps, return to lab, sort and refrigerate/store	2

Day 3+4 identify	4
Number of months of sampling	6
Number of sample events per month	2
Total	84
Tree beating/Sweep netting/Flight intercept traps (2 sample points each @ 2 x month):	
Day 1 go to site – Set up flight intercept traps, identify known species from tree beating and sweep netting, destructively sample unknown species	2
Day 2 go to site – Collect flight intercept traps, return to lab, sort and refrigerate/store, identify	2
Day 3 identify unknown species from all three methods	2
Number of months of sampling	6
Number of sample events per month	2
Total	72
Walking transects/hand searches of vegetation/logs (2xmonth)	
Day 1 go to site – Set up transects and photo/identify, conduct hand searches	2
Number of months of sampling	6
Number of sample events per month	2
Total	24