

Institution: Edge Hill University
Unit of Assessment: Biological Sciences
<p>1. Unit context and structure, research and impact strategy</p> <p>1.1 Biological Sciences at Edge Hill University (EHU)</p> <p>Biological science research at EHU sits within the Biology Department. We are a small UOA with 9.5 FTE academic staff with a trajectory of growth since 2013, which is set to continue (a further two new ECR appointments since census date), demonstrating vitality and future sustainability. Our mission is to develop world class and innovative biological research that significantly benefits wider society, whilst providing a supportive environment to nurture the next generation of research scientists. We believe that instilling a passion for biological exploration should begin at an early career stage and place high importance on research training for postdoctoral and postgraduate researchers, and also our undergraduates.</p> <p>Our research comprises three interlinked themes of biology:</p> <ol style="list-style-type: none"> Ecology, incorporating population and community ecology, sustainable ecosystem management, conservation, parasite-vector interactions and climate change modelling. Genetics and evolution, including taxonomy, speciation, gene expression, antibiotic discovery and vector biology. Biomedical science, incorporating research into rare skin diseases, gene and RNA therapies, microbial infections and pregnancy complications. <p>Since REF2014 EHU has been in period of growth that has seen it place greater emphasis on research. It has recruited research-active academics and supported their development as researchers. Previously, biology research was situated in a multi-disciplinary natural sciences department; however, EHU recognised the potential to develop research and teaching in the discipline and established the Biology Department in 2012. It employed research active staff, established state-of-the-art research facilities, hired skilled technicians and funded PhD studentships. Since REF2014, we have seen significant growth in research outputs, income and training provision. Consequently, we are now in the position to make our first REF submission to the Biological Sciences UOA.</p> <p>1.2 Achievement of strategic aims</p> <p>Over this REF cycle our strategic aims have been to:</p> <ol style="list-style-type: none"> Strengthen research capacity to facilitate excellent research under our two established themes of ecology, and genetics and evolution and to develop our emerging theme in biomedical science (section 1.2.1). Establish a nurturing and productive research culture that provides training and development opportunities for our biologists, irrespective of their career stage or background (section 1.2.2). Develop research with significant wider impact, consolidating links in our existing networks of beneficiaries in ecology, genetics and evolution, and developing the biomedical science theme (section 1.2.3). <p><i>1.2.1 Strengthen research capacity</i></p> <p>EHU has supported a significant number of new academic appointments to our UOA; more than doubling in size from four FTE in REF2014 to 9.5 in REF2021. We have recruited staff who are active researchers by ensuring new staff have post-doctoral experience. Appointments have been strategic, allowing us to develop the biomedical science theme (3.5 FTE), whilst consolidating existing strengths in the fields of ecology (3 FTE) and genetics and evolution (3 FTE). Crucially, this has been coupled with significant investment in infrastructure for the UOA,</p>

amounting to £17m since 2013 (section 3.2). This has allowed us to broaden substantially the scope of our research.

1.2.2 Establish a nurturing and productive research culture

We have achieved this by encouraging opportunities for collaboration and development amongst colleagues of different career stage or subdiscipline of biology. For instance, early career researchers (ECRs) join PhD supervisory teams at the earliest opportunity, paired with more experienced colleagues in a mentor role (section 2.2). Our UOA research coordinator has established internal peer-reviews of draft funding bids by experts in their sub-discipline and by biologists from a different research theme. Our postgraduate coordinator has introduced an annual forum providing opportunities for presentation of research by our postgraduate researchers (PhD and MRes) with peers from other disciplines (section 2.3). Together with EHU's Research Office and Graduate School, these coordinators initiate development opportunities for staff and PGRs on best practice for research design, management and implementation to ensure professional and ethical standards are met (sections 2.2, 2.3). Such a sharing of good practice means our researchers draw on a body of experience across the sub-disciplines of our UOA and beyond, to ensure that our research is conducted with integrity, and to support their professional development. Our approach to managing and promoting research ethics are outlined in section 3.

1.2.3 Develop research with significant wider impact

Wider impact has long been central to our research; in REF2014 our research was one of the two impact cases for the Geography and Environment UOA. Our aim is to develop research with global significance, which aligns with local, national, and for the first time, international challenges (e.g. UN Sustainable Development Goals) (section 4.3). We achieve this by working closely with research users from the outset, including them in research planning such that they may shape questions and outcomes, thus we are able to develop practical, evidence-based solutions. The success of this strategy is exemplified by our impact cases. Research led by **Ashton**, working with Natural England, on genetic connectivity of meadow plant species has revealed the importance of landscape scale fragmentation to grassland conservation. Further work revealed optimal grazing regimes to maintain invertebrate diversity in grasslands of European conservation importance, where previous research on management focused solely on plant diversity. This research has changed conservation practice implemented by NGOs and informed management guidance released by government agencies both nationally and locally. Research led by **Strode** determined that insecticide treated bed nets (ITN) have a greater efficacy against insecticide resistant malaria vector mosquitoes than non-ITNs, despite some mosquitoes increasing resistance to pyrethroid insecticides. This has directly inspired NGOs, such as the Malaria Consortium, to advocate for the continued procurement of ITNs. It has also been used by the World Health Organisation as evidence for the continued benefits of ITN distribution to reduce malaria cases in Africa and to reassure the 50% of African households already in possession of ITNs.

1.3 Demonstrating research strategy success

The aim of our small, but highly motivated team of academic staff is to carry out excellent and impactful research, train researchers and engage in their own development. By strengthening our research capacity, establishing a nurturing research culture and putting impact at the forefront of our research, we have seen:

- 1) Significant research-related career progression:
Evidenced by **four academics being promoted to reader and one to professor** in a UOA of 9.5fte (section 2.2).
- 2) Increased numbers of postgraduate awards:
Evidenced by a substantial increase in PhD awards, from one in REF2014 to nine in REF2021.
- 3) Greater success in grant capture:

Our UOA has experienced significant growth in research funding, totalling £383k in income. We now lead large external grants for the first time, with postdoctoral appointments.

- 4) Growth in high-quality outputs in international peer-reviewed journals:
Article publication has increased from 85 in REF2014 period to 134 in REF 2021 period, including articles in the world's top 5% of most highly-cited papers (e.g.: **Batke** et al, 2016; **Oxbrough** et al, 2017; **Strode** et al, 2014), and we experienced a 45% increase in the number of outputs per year in peer reviewed journals.
- 5) Wider impact resulting from our research:
We are **expanding engagement with research users**; for the first time this includes biomedical impact with broad-ranging international beneficiaries (section 4.3).

1.4 Strategic aims post-REF2021

Our mission is to develop our small and vibrant research community in a way that produces excellent and innovative mono- inter- and multi-disciplinary research, academic and wider impact relevant at local, national and international levels. To achieve this, our strategic aims for the next REF cycle are to:

- 1) Ensure sustainability and vitality of each research theme, initiate and maintain fruitful interactions with the Data Science STEM Research Centre, and promote a cohesive ethos amongst all members of the UOA as we grow by generating research income and investing in the next generation of researchers (**SA.1**).
- 2) Maintain our core ethos of researcher development and training at all career stages in an inclusive way, promoting equality and diversity (**SA.2**).
- 3) Continue to produce research with wider impact in our established themes of ecology, and the genetics and evolution themes, and grow wider impact in the biomedical science theme by working closely with Edge Hill University Medical School (established 2020) and engaging with research users at all stages of the research process (**SA.3**).
- 4) Conduct work with high levels of integrity and ensure open and reproducible research (**SA.4**)

We will actively promote greater cohesion within and between our existing research themes by developing more formal research groups for each and by optimising collaborations (**SA.1,3**). To build on the current *ad hoc* researcher meetings, we will establish an internal and external identity for each, promote its research and researchers, develop collaborative opportunities and provide training for ECRs and PGRs (**SA.2**). These research groups will have a fluid membership recognising the interlinked nature of our research themes (e.g. ecological genetics or evolutionary biomedical science). Each group, led by a core team of academics and PGRs, will meet regularly to implement strategy for developing and promoting open research, collaboration and wider impact (**SA.1,2,3,4**). The groups will seek to strengthen and develop existing collaborations (e.g. Medical School, Computer Science Department, Geography Department), which already co-supervise PGRs (section 4.1). An important element of our strategy is to develop new and emerging inter- and multi-disciplinary collaborations, particularly between UOA members and EHU's STEM Data Centre (with Geography and Computer Science disciplines) and the newly formed SustainNET - a multi-disciplinary network seeking research solutions to global sustainability challenges.

As a small UOA, developing cross-institution collaboration, including shared use of our research infrastructure, is an important mechanism to sustain and further develop capacity for research (**SA.1**). Individual researchers will build on existing successful collaborations (sections 3.2.2, 4.1), and research groups will target emerging opportunities established by EHU: a recent example of the latter is an agreement with Chongqing Normal University, China, to establish joint research programmes with co-supervised PhDs.

We will enhance our approach to equality issues and promote diversity in our research and its impact across all academic levels (**SA.2**). This will include seeking Athena Swan accreditation

for our department, ensuring diversity in presenters at research seminars and ensuring that training activities for academics, PGRs and students on our taught programmes are open and accessible to all. These activities will be led by newly appointed Equality and Diversity Champions (EDCs), including academic, PGR and UG representatives. Working with the research groups, they will coordinate initiatives to promote equality and widening participation, core values of EHU, to our aspiring biologists. We will be focusing on attracting under-represented groups to work and study at Edge Hill. Given our relative under-representation of ethnic diversity, the EDCs will help to identify strategies to tackle this, as well as engaging with other under-represented groups: this will be an action throughout the new REF period (and already evidenced by post-REF2021 appointments which have increased our ethnic diversity).

Following the principles outlined in the EHU's Statement on Open Research, our researchers have begun developing a UOA-specific strategy to ensure best practice on reproducibility whilst contributing to open research (**SA.4**). Data management planning, using DMP Online, is a requirement for research design for all projects, including PGR which stipulates how data will be archived and curated to facilitate open access, typically using EHU's data repository following FAIR principles (findable, accessible, interoperable, re-usable). We prioritise the use of gold open-access publishing, using the many deals the University has, and we ensure all researchers are aware of any new agreements: the UOA has also secured OA funding from the University (which received no transition funds). The University prioritises gold OA for research that is of particular benefit to countries on the ODA list. If gold-OA is not possible, we commit to green-OA or self-archiving. We encourage greater use of open-source software (e.g. R statistical computing) and archiving of outputs/data to facilitate reproducibility. Academics and PGRs will be trained in these principles by departmental research and PGR coordinators and our newly established research groups will have an important role in sharing and developing best practice in conventions across biological sub-disciplines.

We will promote sustainability by increasing external research income, delivering larger projects and establishing a post-doctoral community (**SA.1**). Indeed, we see developing postdoctoral opportunities as key to research development; these researchers can mentor PGRs, whilst engaging in supervised professional development (**SA.2**). We will continue to seek out key collaborators to develop excellent and impactful research on smaller-scale research projects which provide solutions to problems of regional or national importance (**SA.3**). Research beneficiaries will be included in the early stages of project development to ensure end user-relevant impact (**SA.3**). We will continue to provide the opportunity for researchers at all career stages (including PGRs, MSc, UGs) to be involved in high quality research with impactful outcomes (**SA.2**).

2. People

2.1 Staffing strategy, equality and diversity

We are a diverse and vibrant UOA, with researchers from a variety of backgrounds, career stages and biological sub-disciplines. Our academics hail from six countries and so we benefit from a wide range of international perspectives. Our staffing strategy supports our vision to produce high quality, innovative and applied research; the knowledge created is transferred through teaching and impact activities. We recruit on merit, prioritising talented individuals who show promise for lifelong learning and development, and add breadth and depth to our UOA, whilst being inclusive of protected characteristics; this reflects our commitment to **the principles of the 'Concordat to support the career development of researchers'**.

We proudly follow in the footsteps of EHU's early commitment to enhancing opportunities for women. Our UOA has promoted women and endorsed female leadership: e.g., our senior academic team, with significant roles in decision-making in the UOA, comprises one professor and four readers with a 3:2 female:male gender ratio. Overall, we have a 50:50 female:male ratio (compared with sector average of 44:56). 10% of our staff have disclosed a disability (sector average is just 3%), and 10% of our staff identify as BAME against the sector average of

14%. 70% of our staff are in the 35-49 years age category and reflect our more concentrated age profile. The age profile is partly a product of our small size and reflects our policy to employ academics with significant postdoctoral experience who can drive research growth. All bar one of the seven staff recruited during this REF cycle are in their first teaching post and four of these were ECRs on appointment (since the census date we have appointed a further two ECRs). We are proud of the support and development we offer that has resulted in staff arriving as ECRs and achieving promotion (including three to readerships). Our commitment to promoting diversity is also reflected in our PGR community; our ten PhD students hail from five different countries with 40% identifying as BAME.

Our UOA takes a flexible and inclusive approach to working patterns, aiming to support staff in achieving academic success whilst benefitting from a positive and productive work-life balance reflecting their individual needs. Our staff can utilise weekly working-from-home days (pre-COVID19), informally agreed flexible working hours, phased return after extended periods of leave (e.g. maternity or sickness) and days *in lieu* for weekend teaching or research travel. We facilitate academics managing workload around personal circumstances. This strategy benefits all staff to achieve a work-life balance, but is particularly important for those with a disability, caring responsibilities or those who undertake a significant degree of weekend teaching or research fieldwork. Reduced research and impact activity due to extended periods of leave is not a barrier to promotion: two staff members have taken maternity leave during the REF cycle and both have progressed (to senior lecturer and reader respectively). Furthermore, recruitment to a 1.0 FTE post was reduced to 0.5 FTE following a request to accommodate personal circumstances: the incumbent subsequently gained an internal research grant and promotion.

2.2 Staff development

Our approach to staff development reflects our research ethos - to provide a supportive environment to nurture our researchers, no matter their career stage or background. Our support is focused on induction, development and progression so people can realise their potential. We have seen significant progression since 2014, with 60% of our staff promoted and 50% to a role explicitly recognising research leadership and excellence. Within these, two ECRs have progressed from lecturer, one to senior lecturer, the other to reader. More experienced researchers have achieved promotion; one reader to professor, and three (who arrived as ECRs) from senior lecturer to reader, demonstrating the success of our progression pathways for academics at all career stages.

Career development and progression are strongly encouraged by UOA managers, with needs identified through EHU's annual performance and development review (PDR). Integral to the review is encouraging research(er) development and success, whilst maintaining a good work-life balance. Our development strategy has two key elements:

1) Developing research leaders. We believe in learning-by-doing, and so we allocate research leadership roles, such as UOA research coordinator, to early or mid-career researchers, under the mentorship of more experienced colleagues. On arrival, staff are given a mentor/buddy, generally from a different research cluster, to foster interdisciplinary exchange. Our academics attend EHU's researcher-development workshops (e.g. on research project management, leadership, ethical governance) and our PGR coordinator leads annual training on supervising PGRs in biology. This training typically sets scenarios (e.g. ethics, risk assessment, personal or progress issues) and the staff team discuss solutions. Both internal and external funding bids can be peer-reviewed before they are submitted to the Research Office for institutional peer review. We ask both experienced academics and ECRs to carry out reviews, so that all may benefit from the process. We also prioritise ECRs as lead PGR supervisor, under the mentorship of a more experienced colleague.

We continued our inclusive ethos in our REF preparations. All academics and fellows were involved; we value the opinions of all researchers, no matter their career stage or background; further, it is a useful development exercise. REF5b was a collaborative effort; small academic

groups, each with diversity in career stages and biology subdisciplines, developed individual sections. The UOA coordinators integrated these into the narrative. The coordinators ensured that all staff understood the REF Code of Practice, particularly that inclusion of outputs or identification of SRR had no bearing on career progression. Staff members submitted up to 10 outputs for peer review by two colleagues: for the purposes of training and transparency, reviews were available to all. We established a REF2 advisory group of four academics reflecting different career stages, including ECR, age profiles and nationalities and with gender balance. The group calibrated peer-review scores and additional reviews, including external peer review, were sought to help settle disagreements. This group made final recommendations to EHU's REF Decision Panel based on merit, with consideration to exemplify excellent research from all three themes and EDI representation as identified in REF Code of Practice procedures for selecting outputs. As a small team, minor changes influence the balance of outputs selected across our staff; however, the outputs selected broadly represent the equality characteristics of our UOA: a balance of 59:42% female to male (staff gender ratio 50:50%); the 35-49 age range (70% of staff) contributing 80% of outputs, and ECRs (20% of staff) contributing 17% of outputs. This data supports our approach to staff research development, encouraging all to succeed in a flexible way that meets their needs; all staff with SRR have been able to contribute fully to outputs for submission, even where several protected characteristics (identified by the sector as reducing research productivity) intersect.

2) Supporting academics to do research. All new staff are given a 33% reduction in teaching allocation in their first 12-18 months to establish research plans. For more experienced staff there is a fluid approach to teaching timetabling, such that planned research deadlines can be avoided or teaching delivery delegated. ECRs are encouraged to apply for EHU's competitive Research Investment Fund (RIF) in their first year. RIF has several strands, including targeted seed-funding for ECRs, and pump priming and impact related projects for more experienced researchers: e.g. when ECRs **Oxbrough** received £44k for teaching relief and a research assistant for 12 months, resulting in several publications, and **Charnock** was awarded £37k to support a research assistant and consumables for research that is ongoing. Staff have used internal research support funds for short sabbaticals and teaching buy-out. Nearly all staff members, including part-time and fixed-term staff, have received support from University funds (£349k in total during the REF cycle) to carry out research, including international fieldwork travel or conference travel, where required. These funds have been central to researchers' profile development and promotion, and this support has been vital in establishing this new department.

The UOA encourages academics to undertake external or internal training to develop new research skills, and academics are expected to identify conference opportunities at annual review. Indeed, since 2014, the UOA has provided a substantial sum - £140k, to support research training, research related travel and conference attendance, with an additional £9k funded through the RIF. Finally, EHU has supported significant investment in facilities and infrastructure to directly support the research of new staff and ECRs (section 3.2).

Our small size means that informal social gatherings of staff and PGRs occur regularly and contribute to a welcoming atmosphere and a sense of belonging; these are critical to maintaining the wellbeing of our researchers. We use informal opportunities to provide mentorship to new staff. For instance, all academics share offices, and we pair new staff with more experienced academics, and usually from a different research theme. This approach enables new staff to integrate easily into the UOA, ensures cohesion between sub-disciplines, provides opportunities for development of cross-disciplinary research and allows sharing of experiences that are different among sub-disciplines.

2.3 Research students

Investing in PGRs is core to our vision to ensure the sustainability of the discipline, both generally and at EHU, and helps maintain the vitality of the UOA. PGRs are vital to our community and we take pride in the high quality and range of research training we provide. Our

PhD students are predominantly funded through EHU's GTA scheme which provides them with a rounded academic experience. **Vitae's Researcher Development Framework** (RDF) informs our approach to researcher development. After enrolment, PGRs attend training on developing hypotheses, project design and implementation, ethics, governance, professionalism, integrity and wider impact (*RDF all domains*) provided by the Graduate School. These activities are supplemented by our PGR coordinator who provides training on conventions specific to biology on ethical and H&S procedures, laboratory use, scientific conduct, publication process and bias. Initial supervisor meetings guide PGRs through project planning including consideration of literature, methods, ethics and wider impact. This latter aspect encourages students to identify impact beneficiaries and design an impact plan. The success of this is evidenced by our impact cases, with PGR research integral to both (*domain D*). Training is monitored through annual learning needs analysis with supervisors to identify training needs. PGRs can attend in-house training delivered by technicians or as part of M-level courses. External training funded through the UOA has included cutting edge molecular biology techniques at the German Cancer Research Centre or the latest bioinformatic tools on metabolite discovery at the John Innes Centre, UK (*RDF domain A*).

Our PGRs meet with supervisors formally at least 10 times per year, meetings which are complemented by informal gatherings of PGRs, supervisors and other UOA researchers facilitated by shared spaces (e.g. over coffee) (*domain A*). We view these as important opportunities for encouraging exchange among the research groups (*all domains*), as well as promoting wellbeing.

Our GTAs are supported by teaching mentors and we consider development of science communication key to building a successful academic career (*domain B*). Over three years they progress from mentoring small undergraduate groups to delivering classes. GTAs attend key modules on the Post-Graduate Certificate in Teaching in Higher Education (without fees) and several have completed the full PGCTHE and become HEA fellows, thereby enhancing their employability. Non-GTA PGRs are also given the opportunity to undertake teaching activities as paid demonstrators and, latterly, tutors and can also undertake the PGCTHE. Under supervision, PGRs have the opportunity of mentoring undergraduate research projects, an excellent learning experience.

Our PGR coordinator organises an annual PGR conference which gives students the opportunity to present their work to an audience of researchers from the UOA and other disciplines (Physical Geography, Computer Science), promoting exchange of ideas amongst STEM subjects (*RDF domains B, D*). All PGRs are expected to attend our research seminar series and attend conferences to present research. National conferences are funded by the UOA and international ones jointly with the Graduate School's PGR Bursary Scheme.

Our MRes students enjoy the same range of development opportunities as our PhD researchers, including external training and conference support. Our MRes students complete a substantial piece of research, with 6 months of data collection. The high quality of research skills they develop whilst studying with us is evidenced by 43% of MRes graduates going on to PhD study and 36% working as professional scientists in industry or academia. Some MRes projects have been published in peer-reviewed journals.

The diverse range of nationalities in our PGR community is testament to being able to attract the best international candidates but we strive to expand the pool. In the future we will look to expand the promotion of PGR opportunities beyond our own networks and via social media to work with the International Office and Student Recruitment to reach under-represented groups.

Alongside our commitment to academic and PG researchers, our ethos is inclusive: we support post-doctoral technicians to engage in research projects towards achieving an independent research career and also provide our UGs and PGTs with research opportunities, developing a project from proposal planning through to production of a thesis in journal style. They have won external funding and presented their work to research users.

3. Income, infrastructure and facilities

1.1 Research funding and strategies for generating income

To support our capacity building (strategic aim 1) we are increasingly focusing on grant capture. We have done this by:

- a) Focusing on improving the quality of bids through use of internal funds and 'proof of concept' mechanism along with staff development (see section 2.2);
- b) Researching opportunities for external funding, e.g., LEP/local priorities, UKRI Roadmap, industrial strategy, global challenges;
- c) Establishing track record through successful bidding for modest amounts;
- d) Seeking out prospective collaborators (academic and industrial) as bids partners (see section 4.1);
- e) Submitting bigger bids to the research councils and other funders with higher cost-recovery rates and which support post-doctoral researchers.

To deliver our strategy, the expectation is that academics will submit one small (£10-50k) funding bid per year and one large (£50k+) bid every three years. We encourage all new staff, particularly ECRs, to apply for internal funding to help develop their independent research profile, to develop proof of concept or basic data collection to strengthen bids. We have supported our researchers to target income from research councils (e.g. peer review, writing time), as well as seeking opportunities with industry and non-governmental organisations (NGOs).

This strategy has led to significant success; our researchers have secured a total of £389k in income over this REF cycle, 50% of which was generated by ECRs. This includes two British Council Newton Fund Grants: **Fernández-Martínez** was awarded £77k to lead research on the identification of natural products from Colombian actinomycetes in collaboration with researchers at Corpogen NGO, Colombia and **Strode** was awarded £134k to lead research on insecticide resistance status of the mosquito vectors of dengue in partnership with the Universidad de Antioquia, Colombia (impact case). Recently, our aim to provide postdoctoral training was achieved for the first time when **Fernández-Martínez** was awarded a BBSRC project grant (£411k, Grant Ref: BB/S016651/1) to explore the production of cryptic antibiotics in *Streptomyces* strains. As PI, she leads a team of researchers from the John Innes Centre and Strathclyde University. We have also generated income from commissioned research: **Strode** reviewed the impact of insecticide resistance on the effectiveness of insecticide-treated nets as a malaria control intervention for the World Health Organisation (WHO) (£19k). **Tagalakis** has begun working with Nanogenics, a siRNA therapeutics company, on a £50k contract.

We have continued working with national NGOs to deliver impactful research, often supported with match-funding or in-kind contributions from EHU. For instance, **Oxbrough** received £43k from the Scottish Forestry Trust for a collaborative PhD with Forest Research, on functional diversity in plantation forests, with the same amount provided by EHU. **Ashton** received £6k from Natural England as a contribution towards for an EHU-funded PhD on hay meadow connectivity (impact case).

We were awarded £349k in internal funding through EHU's competitive schemes. This has included 12 research projects, ranging from £6k to £44k, providing support for pump priming/proof of concept studies. £84k was from EHU's allocation of the Global Challenges Research Fund (GCRF), for research benefiting economic development and wellbeing of developing countries. As a result of our successes with external bids emerging out of these internally supported projects identified above, our academics have benefitted from EHU's external-funding reward scheme which offers a percentage (up to £10k) of the award value to the PI who can use it for research-related activities including professional development, open access and equipment.

3.2 Infrastructure and facilities

Our UOA has received significant investment in infrastructure and facilities to support our research from both EHU and external funders, reflecting the institution's ongoing commitment to strengthen research and teaching in biology. This has come in two phases, £4m to extend and equip the Biology building in 2013 and £13m to build the TechHub building in 2017. The TechHub is part-funded (£3m) through the Lancashire Enterprise Partnership. The TechHub hosts STEM research, with 30% dedicated to a 40-user capacity open plan laboratory to support research across our three themes. It also houses specialist laboratories for DNA sequencing, histology, human cell culture and microbiology, with an equipment investment of £1m. Our staff led the design of these purpose-built research laboratories and acquisition of state-of-the-art equipment, and we ensured our research spaces would allow academics, researchers, PGRs, MSc and undergraduate students to work side-by-side in a collegial fashion, reflecting our commitment to research training for all.

3.2.1 Research facilities

Ecology: we have invertebrate and plant science laboratories, accommodating 14 permanent researchers and 14 'hot' desks for UGs. Both are equipped for processing field samples (e.g. plants, soils, invertebrates) and traditional taxonomic identification, including investment of over £25K in high powered microscopes, specimen reference collections and identification guides. The plant science laboratory was established in 2017 for ECR, **Batke**, with a £30k investment in state-of-the-art LED growth lights, hydroponic systems, physiological equipment and environmental sensors (e.g. light, temperature, relative humidity, CO₂ and air pollution). Using these facilities, he has developed a PhD project, in collaboration with Universidade Federal de Alfenas in Brazil and EHU Computer Science Department, to investigate the effect of light, temperature and relative humidity on the growth and establishment of epiphytic bromeliads in pasture and forest systems in the Brazilian rainforest. These facilities, along with the TechHub, have been fundamental to the impact case of **Ashton**: taxonomic facilities were used to identify thousands of invertebrate specimens to species to determine the impact of grazing on biodiversity, and the molecular facilities in the TechHub were used to resolve molecular markers for the meadow plant species *Rhinanthus minor*, a key underpinning piece of research.

Genetics and evolution: two climate-controlled insectaries (£110k) were established in 2013 to facilitate the research of **Strode**. These permit the rearing and study of mosquito species that are vectors of malaria, dengue, Zika and chikungunya, and their acquisition helped secure research funding of £211k (a combination of external, British Council Newton Fund, and internal funds). They have been fundamental to the impact case led by **Strode**, with reared specimens used for the screening of dengue mosquito vectors from Colombia for resistance to chemicals used in public health campaigns and to inform surveillance action. A Containment Level 2 microbiology laboratory facility with capacity for four researchers, established in 2017, supports the research of **Fernández-Martínez** on antibiotic discovery, including testing antimicrobial activity of extracts from newly isolated *Streptomyces* strains against ESKAPE pathogens (pathogens resistant to some of the commonly used antibiotics). The facility has a DEFRA licence (Licence No. 110215/374210/0) which allows the import of soil samples from locations worldwide. It has also allowed **Oxbrough** and **Fernández-Martínez** to establish links with commercial partners to provide testing for presence of plant pathogens in commercial timber.

Biomedical science: our newest research theme, established 2016, has been supported with investment of £190k for a new tissue culture laboratory including a histology pipeline, primary and stem-cell cell culture facilities and bench-size 4x4L full-automated bioreactor. Using the bioreactor, **Eckl** has developed novel research exploring plant-based recombinant protein production for topical rare skin protein replacement therapy. She has used the primary cell culture facilities, including a new cell sorter (FACS machine), to collaborate with the University of Huddersfield on replacement therapy research for rare inherited skin conditions. **Charnock's** research to enhance understanding of blood vessel formation from stem cells in the placenta, and identify new therapeutic targets, has used the TechHub cell culture facility to develop an *in*

in vitro model of the process, supported by protein and molecular analysis (Western blotting and qPCR), flow cytometry and histology pipelines.

3.2.2 Cross-HEI shared or collaborative use of infrastructure

Our facilities are made available to researchers beyond our UOA, either through collaborative projects or directly supporting other's research. Academics from Psychology, in collaboration with **Eckl**, are investigating genetic polymorphisms, the bioavailability of alcohol and cannabis and their implications for cognitive performance and brain activity using TechHub facilities.

Tagalakis' commissioned research with Nanogenics is made possible using TechHub equipment and includes in-kind contributions of consumables and equipment from the company, highlighting how this emerging research involves significant engagement with an industrial partner.

We have made significant use of facilities beyond the institution to develop our research. For instance, **Eckl's** research on skin diseases uses Illumina HiSeq sequencing systems and bioinformatics platforms for NGS and homozygosity mapping at Cologne Center for Genomics. **Oxbrough** and **Fernández-Martínez's** ongoing research on functional diversity of soil bacteria has used the Biolog Phenotype MicroArrays at Strathclyde University to determine carbon use. **Tagalakis'** research on genetic therapies for glaucoma is made possible through a collaboration with King's College London, using their patient cell Biobank and ophthalmology surgery expertise. **Batke's** taxonomic work on Honduran ferns uses herbarium facilities at the World Museum Liverpool and University of Zamorano, Honduras, and **Ashton's** research on bacteria in bird nests has used the NERC Biomolecular Analysis Facility at Sheffield to undertake metabarcoding.

3.3 Operational infrastructure

Our UOA has seen significant growth in the scope and number of research projects. To support this, EHU's Research Office provides guidance on contracts, budgeting, funding calls and impact development, the last led by the Research Impact Manager who works with our researchers to ensure projects embed wider impact as an outcome at the project planning stage.

Within our UOA, researchers are supported by the research coordinator, an academic, who organises peer review of funding bids, provides guidance on individual research plans and coordinates research strategy. The departmental ethics committee, which comprises a selection of academics, researchers and technicians, has been instrumental in streamlining and updating our ethical procedures and developing training across all academic levels. In 2018, the University recruited a Biological Safety Officer (BSO) who is responsible for overseeing safe working practice, compliance with legislation and advising on research ethics and risk assessments. The BSO is trained to postdoctoral level, and plays a key role supporting researchers to set up new projects. The BSO and biomedical academics have established new protocols to facilitate human tissue research compliant with the Human Tissue Licence (HTA). The BSO is the person designate for HTA at EHU and is a member of the Liverpool Central NHS committee, gaining wider sectoral perspective. Administration support has increased from 1 FTE to 3 FTE during this REF period, including a dedicated research support administrator and a departmental administrative manager with responsibility for supporting research staffing, contracts and budgets. These posts provide vital support to academics, freeing them to concentrate on the science.

To complement the increase in research activity, the University has made strategic investment in technical support staff. In 2014, the Biology Department had five technical staff, with four dedicated to teaching activities and one to research. Since then, technical staff have increased to eight, six of whom are directly involved in supporting research. Established technicians have undergone training for maintenance of specialised equipment, and new technicians have been recruited for their expertise in our research themes. In some cases, the level of expertise is high (post-doctoral) and they have been 'bought out' of teaching preparation duties to provide dedicated technical support to research projects. The TechHub Biotechnology floor has a

dedicated laboratory manager whose role is to oversee the day-to-day operation of the lab including ensuring staff and students are working to appropriate safety standards, overseeing consumable ordering, facilitating equipment training for lab users and improving sustainability in the use of consumables.

4 Collaboration and contribution to the research base, economy and society

4.1 Scientific Networks/Collaborations/Partnerships

As a small UOA, successful collaboration plays a significant role in achieving our strategic aims to strengthen research capacity and ensure wider impact, and to ensure sustainability and vitality of our research in the future (section 1.5). We have established over 50 national and international collaborations with universities and research centres in recent years, as well as local partnerships. We encourage new in-house collaboration initially through informal discussion and local dissemination activities (e.g. postgraduate forum, research seminars). A key mechanism to develop these is through shared postgraduate supervision. For instance, **Tagalakis** co-supervises two biomedical science PhD students with the Medical School (UOA3). Emerging in-house interdisciplinary collaborations include **Fernández-Martínez** (genetics) and **Oxbrough** (ecology) joint supervising an MRes project on antimicrobial resistance levels in soil which led to a publication, and **Batke** (ecology) and **Strode** (genetics) publishing on a global surveillance tool for *Aedes* mosquitoes. Through dissemination activities led by the recently established STEM Centre, research collaborations have developed with other UOAs, such as **Powell** co-supervising PhDs on savannah dynamics using remote sensing with the Geography Department (with a paper published) and **Batke** co-supervising a PhD with Computer Science on climate sensing using machine learning algorithms to understand epiphyte community dynamics in rainforests.

National and international collaborations are well funded through both UOA and RIF, including supporting conference or networking trips and teaching relief (section 2.2, 3.1). This flexible approach has allowed us to respond quickly to national and international priorities. For instance, **Oxbrough** and **Fernández-Martínez** gained funding to support a PhD project on soil functioning, following publication of conservation research priorities by the Woodland Trust. **Strode** gained British Council Newton Fund support to better understand insecticide resistance in the mosquito *Aedes aegypti* which was responsible for the WHO declared global health emergency Zika pandemic (2016), and **Ashton** developed a PhD project in response to priorities identified by Natural England and the National Trust on conservation grazing in upland habitats (impact case).

UOA and institutional support for networking has directly led to established collaborations. The UOA funds membership of the International Union of Forest Research Organisations (IUFRO) for **Oxbrough**. She has led the IUFRO sub-division on Forest Biodiversity for several years and through this network developed an EHU Global Challenges Research Fund project, on which she is PI, investigating ecosystem functioning in eucalypt forest plantations in collaboration with the Universidad de Buenos Aires, Argentina. This work addresses UN Sustainability Goals 12 and 15, for the numerous ODA recipient countries that commercialise this tree species. **Strode** received funding to attend the 2020 EU *Aedes* Invasive Mosquito (AIM) Cost Action annual meeting and began an AIM-COST Short Term Scientific Mission to review and model the likelihood of establishment of the dengue mosquito *A. aegypti* at European ports alongside collaborators at Public Health England and UC Louvain, Belgium. **Batke** was funded to undertake several visits to Honduras, and through this is now lead author on the first fully illustrated Flora of the Pteridophytes of Honduras in collaboration with Zamorano University, Honduras. **Ashton** and **Powell** co-supervised a PhD on the conservation genetics of the marsh fritillary butterfly with a scientist from key stakeholders, Natural England. The project arose from discussion at a British Ecological Society symposium, attendance at which was funded by the UOA.

4.2 Contributions to the Research Base

As part of generating a vibrant research culture (strategic aim 2), our academics are supported to make a significant contribution to the biological science research base nationally and internationally, which also provides excellent networking opportunities. They are highly respected members of their research communities which is reflected in their external activities. They have examined PhDs at UK institutions (Leeds, Manchester, Harper Adams, Nottingham, Plymouth, Southampton, UCL and King's College London) and beyond (Spain, Italy, Sweden and Estonia). All of our academics are affiliated with learned societies, including recognised fellowships: **Tagalakis** and **Eckl** are Fellows of the Institute of Biomedical Sciences, **Tagalakis** is a Scientific Member of the British Society for Nanomedicine, **Oxbrough** is a Fellow of the Royal Entomological Society and **Batke** is a Fellow of the Linnaean Society and full member of the Chartered Institute of Ecological and Environmental Management. **Batke**, is a founding member of the Epiphyte Inventory Group which brings together 27 scientists from across the globe. We take active roles in the learned societies in which we hold membership. **Oxbrough** and **Strode** organised the national meeting of the Royal Entomological Society in 2018 at EHU; 120 delegates from 12 countries attended. **Fernández-Martínez** co-organised the Actinomycetes Genetics and Natural Product Discovery Workshop at Universidad Técnica Federico Santa María, Chile in 2018; 100 delegates attended from across Latin America. She is currently co-organising a Royal Society sponsored international workshop for 2021 in Mexico which aims to mentor 30 promising Latin American researchers on genome mining of natural products. **Ashton** organised a symposium on Ecological Genetics at the International Botanical Congress, Shenzhen, China in 2017. **Tagalakis** was co-organiser of the Physical Delivery, Therapeutics and Vector Development special sessions for several annual American Society of Gene and Cell Therapy meetings. Invitations to speak include **Fernández-Martínez** as plenary at the Colombian Biochemistry and Molecular Biology Congress in Bogotá (2018) and **Oxbrough** at the National Institute for Agricultural Research (INRA) in France (2017) and the Swedish University of Agricultural Sciences (2016).

Our researchers contribute towards the sustainability of the discipline. They regularly review grant applications; organisations include the BBSRC (**Fernández-Martínez**, **Eckl** and **Strode**), EPSRC (**Tagalakis**), NERC (**Oxbrough**), MRC (**Charnock**, **Eckl**, **Tagalakis** and **Strode**), the Wellcome Trust (**Strode**), the British Ecological Society (**Oxbrough**, **Batke**) and the Cystic Fibrosis Trust (**Tagalakis**). International grant reviewing includes the French National Research Agency (**Tagalakis**), the Netherlands Organisation for Scientific Research (**Fernández-Martínez**) and EU-COST Actions (**Oxbrough**). Our academics contribute significantly to the peer-review process, reviewing manuscripts for over 100 international journals such as *The BMJ* (**Eckl**), *Molecular Microbiology* (**Fernández-Martínez**), *Biodiversity and Conservation* (**Batke**, **Oxbrough**), *Advanced Materials* (**Tagalakis**), *Journal of Applied Ecology* (**Oxbrough**) and *Restoration Ecology* (**Ashton**). **Oxbrough** is on the Editorial Advisory Board of the journal *Forest Ecology and Management*, and **Tagalakis** is the Review Editor on Nanobiotechnology for the journals *Frontiers in Bioengineering and Biotechnology*; *Frontiers in Molecular Biosciences*; and *Frontiers in Materials*. We have also acted as Guest Editors for special issues of *Forest Ecology and Management* (**Oxbrough**) and *Pharmaceutics* (**Tagalakis**).

A key strategic aim is to ensure our research is reproducible and our approach is detailed in Section 1.5. Central to this will be ensuring reproducibility of our research, such that our methodologies, raw data and analytical outputs can be scrutinised and used by our peers in academia and by wider society, thereby ensuring the knowledge we generate is accessible to all. We encourage all staff to deposit such materials in our data repository (Figshare) for transparency and this will be a priority for the future. PGRs receive training on issues around reproducibility and confirmatory bias to ensure that they are fully cognisant of the issues.

4.3 Contribution to economy and society and relationships with key research users.

Our strategic aim 3 is developing research that has wider impact at its core by seeking solutions to economic and societal problems identified by industry, government or NGOs. Our two impact cases are exemplars of this approach – **Ashton** on sustainable management of grassland

ecosystems, and **Strode** on controlling disease-carrying mosquitoes. Beyond these, we continue to develop and embed the goal of having wider impact across our themes. For example, **Fernández-Martínez** is a scientific advisor for the company Perfectus Biomed, where she has advised on the generation of mixed species biofilms using *Pseudomonas aeruginosa* 10434, *Staphylococcus aureus* 8325 and *Candida albicans* MYA 2876. This led directly to development of new antimicrobial assays to test for the presence of these bacteria. **Oxbrough** is collaborating with Forest Research and the Forestry Commission to publish recommendations for national forest management, directly arising from recently completed research. Outputs include an article in the *Quarterly Journal of Forestry*, a leading practitioner publication. **Tagalakis** sits on the Scientific Advisory Board of Nanogenics; his expertise on nanobiotechnology has helped develop a product that is planned to enter a clinical trial in 2023.

Recently established research provides evidence of continuation of our impact strategy. **Powell** is collaborating with South African National Parks on a vegetation remote sensing PhD project, the outcomes of which will inform how Kruger National Park manages fodder availability for large grazers. **Oxbrough** and **Ashton** are supervising a PhD on the habitat requirements of one of Britain's rarest butterflies, the High Brown fritillary, with stakeholders from Butterfly Conservation involved in shaping the research questions. **Eckl** provides expertise to the British and German Ichthyosis support groups, advising patients and families on the impact of rare skin conditions, their genetics and therapies. **Fernández-Martínez** and **Oxbrough** have recently received funding from Forest Research and the Woodland Trust to determine soil microbial functioning in mixed forest ecosystems research. Outcomes will directly inform management to enhance soil ecosystem functioning, impacting future planting decisions. **Charnock** is working with Liverpool Women's Hospital to identify therapeutic targets that can normalise foetal growth. Expected impact includes benefits to babies by reducing death rates, disability and neurodevelopmental abnormalities, and also informing health care providers by providing new treatment options. **Oxbrough**, in collaboration with University of Buenos Aires and the Ubajay Forestry Company, has established a project to explore enhancing beneficial predators and pest control in Argentine eucalypt plantations.

Networking with key end users is key to continuation of our impact strategy and staff are supported to create and otherwise engage with networking opportunities. For example, **Oxbrough** hosted the North West Tree Health Meeting at EHU in 2019, attended by over 150 practitioners and researchers. Directly arising from this, **Oxbrough** and **Fernández-Martínez** have begun a new collaboration with the largest supplier of biomass fuel in the United Kingdom, Stobart Bioenergy and A.W. Jenkinson Forest Products, to explore the efficiency of large-scale processing treatments to eradicate fungal pathogens from infected trees. Outcomes are expected to provide a more efficient processing mechanism for these companies. **Tagalakis** is a member of COST-Action Darter, a Pan-European consortium of researchers from academia, industry and the public and private sectors who address problems with delivery technologies for nucleic acid-based therapeutics. **Tagalakis** provides expertise to the Ormskirk Cystic Fibrosis Trust, the NHS Blackpool Trust and the Blackpool Adult Cystic Fibrosis Centre.

Finally, we believe we have a responsibility to share our passion for biology beyond academia and named impact beneficiaries; as such we are actively involved in national and international outreach activities: **Fernández-Martínez** has participated in the international Antimicrobial Resistance Awareness day in Colombia (2018), the Natural Products and Drug Discovery Microbiology Today podcast (2019), the Big Bang Fair Birmingham (2015) and the "Antibiotic Hunters" stand at local School's Science events. In 2015 **Oxbrough** established the national Forest Insects group for the Royal Entomological Society. Around 50 delegates from academia, NGOs and government organisations attend the annual meetings, providing a platform for research users and researchers to network. **Oxbrough** has presented her research on spiders to the West Lancashire Wildlife interest group and **Tagalakis** participated in a local fundraising event for the Cystic Fibrosis Trust (2019). **Powell**, **Oxbrough** and **Ashton** have published research, in lay language, in the nationally circulated *British Wildlife* magazine.