Institution: Liverpool John Moores University

Unit of Assessment: 7 – Earth Systems and Environmental Sciences

1. Unit context and structure, research and impact strategy

1A – Context & structure

The restructuring of the Faculty of Science, at the end of 2019, enabled the formation of the *School of Biological & Environmental Sciences* (BES). BES emerged from a subset of staff formerly associated with the *School of Natural Sciences & Psychology*, some of whom were returned to *Anthropology & Development Studies/Anthropology UoAs in previous* REF/RAE submissions. Subsequent to the establishment of the new school, we appointed seven new staff, in order to reflect our developing academic landscape more accurately. As a result, we now have an almost complete overlap between our School's awarded degrees and the current research interests and activities of our academic staff and aligned a strong and coherent research-informed profile to our programmes. The new structure provides the effective matrix for the integration of existing pockets of excellence into a newly-formed cluster including **61 Cat-A academics**, two thirds of whom have been appointed within this REF cycle, focusing on challenges and solutions to fundamental problems facing our planet's ecosystems, particularly those relating to human activities. Overall, our burgeoning, interdisciplinary academic cohort finds its natural placement within the Environmental Sciences, hence leading to our decision to submit our research profile under UoA7.

Synergies within our research unit are facilitated by and articulated into **four research groups** of similar size, which serve as vital fora for nurturing new project ideas, but also remain dynamic and agile to cross-group and cross-university collaborative initiatives. The four research groups and associated leaderships are:

Behavioural Ecology & Physiology (BEP – *Leads: A. Reddon, S. Zajitschek***)**: BEP members investigate functions, mechanisms and development of behavioural and physiological interactions between organisms and the environment, with particular focus on communication, cognition, phenotypic plasticity, epigenetics, neurophysiology, photosynthesis and adaptation to climate.

Biodiversity & Conservation (BioCon – *Leads: S. Mariani, S. Dalrymple, R. MacLeod***)**. BioCon scientists explore biodiversity patterns across the globe, with emphasis on how they are shaped by anthropogenic change. A diverse range of novel biomonitoring approaches are employed to provide evidence-based solutions to vulnerable habitats and endangered species, and devise management plans for sustainable resource use.

Evolutionary Anthropology & Palaeoecology (EAP – *Leads: N. Koyama, A. Wilshaw***)**: EAP researchers place emphasis on understanding the evolution of humanity in the context of past and present environments. Human variation is assessed at genotypic and phenotypic levels, and the role of humans as agents of ecosystem change is explored through the ages.

Geography & Environmental Science (GES – *Leads: C. Hunt, L. Edwards***)**. GES members investigate past, present and future challenges facing people, by exploring the changing environmental and social worlds, and the processes and structures that shape them, employing a wide range of approaches, ranging from geochemical profiling and satellite imaging to economic valuation and qualitative social science techniques.

Collectively, our strength lies in our key, common focus on managing a delicate ecosphere sustainably, while using a diverse and eclectic range of disciplinary approaches to achieve this shared goal. Environmental change affects all levels of biological organisation, in different ways across space and time, shaping the trajectory of our existence. The understanding and management of such a complex and dynamic system requires multiple perspectives, interdisciplinary integration, adaptability and perseverance. We possess the required blend of expertise and the appropriate collaborative culture for the sustained delivery of timely and world-class environmental research.

1B – Research Strategy

The current university-wide strategy for research and scholarship identifies three broad areas around which the LJMU research base can meet the challenges of the Anthropocene: *Technology Innovation*, *Health & Well-being* and *Culture & Society*. Our research unit represents the **environmental dimension that underpins these themes.** We employ a wide range of cutting-edge technologies, from latest-generation DNA sequencing to drones and satellite imaging, for assessing and monitoring biodiversity, investigating adaptations, and combating poaching and illegal wildlife trade. We blend archaeological and palaeoecological approaches with behavioural and socio-ecological analysis to understand how humans interact with their environments, and how they can become architects of a sustainable future. Our research strategy for 2021-2026 period builds on these existing strengths and identifies the paths for their sustained success.

Below we outline the key goals of our research strategy, followed by the thematic areas that will enable us to achieve them.

Goals:

⇒ **Sustain excellent science through increased extra-mural funding** – While our income generation in recent years shows a decisively increasing trend, our ambitions require greater and more consistent grant income from the UK Research Councils, EU Framework Programmes and major charities. It will be one of the key responsibilities of the research groupings to foster brainstorming and work with the Research and Innovation Services to identify the academics that are best placed to target specific calls. We will then complement our existing internal peer-review process with a short, directed, mini-sabbatical leave system to provide applying investigators with the time and focus to turn in high quality bids.

⇒ **Involvement in formal doctoral training schemes** – PhD students are the life blood of research departments and, especially in the Environmental Sciences, their development and achievements are prerequisites for a sustainable and resilient future. Building on our recent success, spearheaded by our Doctoral Academy operations and career development pathways (see more in section 2), we will aim to secure participation in a thematic doctoral network that reflects our research mission. We will target the European Innovative Training Networks (ITN) and prepare for the next round of NERC Doctoral Training Partnerships (DTN).

⇒ **Attract and support early-career fellows** – Our research profile can be substantially enhanced through the expansion of our postdoctoral population, especially by supporting independent fellows. We will attract and select suitable candidates for prestigious national schemes with UKRI and the Leverhulme Trust, as well as the Marie Skłodowska-Curie European and Global Individual Fellowships.

⇒ **Consolidate international partnerships and raise their profile** – Our academics collectively engage with hundreds of international collaborators (see details in section 4), but these partnerships deserve greater visibility and could be further explored to deliver wider benefits, including securing research and outreach funds from trans-national bodies. We will work with the LJMU International Partnerships Office to produce Memoranda-of-Understanding with key international organisations where current and future projections indicate potential for stronger and broader participation.

Themes:

- **Innovative Environmental Monitoring** – Our unit has played a key role in literally launching drones into the conservation arena. We have demonstrated the effectiveness of using remotely operated vehicles in monitoring **endangered wildlife**, combating **poaching**, and measuring and mapping **landscape cover**, in some of the world's most emblematic forests. This line of work has created opportunities for collaboration with the Astrophysics Research Institute, rapidly advancing the field, and securing major UKRI funding (>£1M) over the REF period. It is expected that this field of studies will remain a major beacon for LJMU and that it will undergo further expansion into aquatic habitats and synergies with molecular approaches. At the same time, researchers at BES are leading advances in the burgeoning field of environmental DNA (eDNA), which avails of high-throughput sequencing techniques to reconstruct biodiversity patterns from the DNA fragments that all organisms shed in their surrounding environment. Marine biodiversity monitoring is a major focus of this theme, but studies also examine riverine and terrestrial communities. With two active NERC grants and several PhD projects, our unit is catalysing the transition of eDNA science from the method development stage to two main

directions: i) **operational biomonitoring applications**; ii) **understanding ecological processes**. The vast and expanding range of potential eDNA applications and the existing large and robust collaborative network in place will cement this research area as a key strength for the next REF cycle.

- **Changing Environments & Communities** – In line with LJMU's commitment to address the global climate emergency – which also led to the introduction of the first undergraduate degree entirely focused on climate change studies – a significant investment of our research base goes into investigating key phenomena shaping major environmental changes in our biosphere, from large scale **glacial processes**, to **carbon storage** in peatlands and tropical forests, **hydrological cycles**, as well as the **reconstruction of human and natural palaeoenvironments**. In parallel, and interwoven with the more physical side of climate impacts, we have substantial capacity in the study of the **human dimension of environmental change**. We investigate how human communities, past and present, respond to and cause dramatic alterations of their environment; we assess the socio-economic consequences of **resource degradation**, flooding, desertification, pollution, over-exploitation and invasive species; we consider **inequalities** that determine disproportionate effects of climate change on different demographics; we also focus on comprehensive solutions, such as the **blue economy** and the **natural capital** approach, to illuminate the path to a sustainable future.
- **Social & Reproductive Behaviour** – Understanding how animals interact and communicate with each other has long been a core theme at LJMU, and will continue to play a fundamental role in expanding our knowledge of **emotions**, **cognition**, **conflict**, **attraction**, and the mechanisms that hard-wire animal **decision-making**. We carry out studies involving humans, other primates, birds and fish, in controlled experimental conditions, as well as in large field stations, and using modelling approaches. Our long-established collaborative networks in this field will support a steady flow of research outputs, which will continue to feed into conservation applications, deepen our understanding of the animal brain, and sustain research-led teaching in our popular programme in Animal Behaviour.
- **Ecophysiology & Adaptation** – We boast a remarkable portfolio of investigations that focus on how organisms adapt to their environments, at the **morphological**, **physiological** and **genomic** levels, using humans, mammals, insects, reptiles and plants as study systems. Research in this area includes studies of **metabolism**, sleep, seasonality, **circadian rhythms**, the genomic architecture of **insecticide resistance**, and the optimisation of **photosynthesis efficiency**, which all have major health and well-being implications. This research strand also embraces the analysis of **evolutionary signatures** on the geographical and environmental ranges of organisms, as a window through which the adaptive trajectories can be observed and modelled.
- **Forensic Science** – Several BES researchers apply biological knowledge to inform policy and legal disputes, using a wide range of forensic tools, which include morphological and chemical **analysis of bones**, the **recovery of micro-organisms**, diatoms, pollen, parasites from the environment, and the application of various **DNA fingerprinting** techniques. Such technologies are increasingly embraced by statutory governmental and international bodies, especially for the purpose of combating illegal wildlife trade, seafood fraud, carving an important niche for sustained applied projects with considerable societal impact.

1C – Impact Strategy

While constituting a new unit, our academics already exhibit a high degree of coherence in translating research findings into actions of significant societal benefits. Research projects in the fields of natural resource management and environmental protection have routinely benefitted from collaborations with governmental agencies and statutory bodies for environmental stewardship. Biodiversity conservation research has been regularly supported and endorsed by environmental NGOs and charitable trusts. Some technology-led studies have also involved private companies, and our expert knowledge has also served in an advisory capacity to national and regional governments. Public outreach, through media (and more recently social media)

engagement, public seminars, festivals, exhibitions and writing for lay audiences has been a substantial commitment for most of our staff.

The impact case studies (ICS – REF3 form) presented for this assessment exhibit continuity between some key 'legacy' features of our School (e.g. primatology, habitat conservation and restoration, threatened species) and the pathways that will define our future success (e.g. enhancing environmental monitoring, mitigating the impact of climate change, reconciling human well-being with nature conservation). The five examples range from high profile conservation initiatives to secure the survival of **critically endangered species** (i.e. Sumatran orang-utan, ICS1), to the contribution to widely applicable **international protocols** (IUCN reintroduction guidelines, ICS2), through protecting and restoring habitats that provide **essential ecosystem services** (i.e. carbon storage, ICS3; **landscape remediation and water quality**, ICS4), as well as jump-starting **habitat and biodiversity monitoring** through the use of drones (ICS5). The ICS supporting evidence gives a flavour of the current reach and future potential of our impacts, which are of interest to organisations including the *United Nations Environment Programme* (UNEP), the *International Union for Conservation of Nature* (IUCN), the *World Wildlife Fund* (WWF), the *Endangered Species Trust*, the *US National Center for Atmospheric Research* (NCAR), the *U.S. Forest Service*, the *Scottish Environment Protection Agency* (SEPA), and *Natural Resources Wales* (NRW).

Our approach to impact for the coming years will entail: i) nurturing the many existing partnerships, ii) further expansion into hitherto unexplored real-world applications, iii) close monitoring of the strands that promise to be most influential, and iv) cementing and intensifying stakeholder engagement throughout the impact journey. Actions will articulate along the following pathways:

- **Governmental Agencies, International Panels** – Environmental stewardship and monitoring will be a key feature of governmental and trans-governmental agendas for years to come. Agencies will require specialist advice, innovative solutions, and clear, robust operational protocols. Our research on land and water, across every habitat on Earth, will generate findings that will inform management actions and advice at national and international levels. For instance, DEFRA, the Environment Agency, Natural England, NRW, SEPA, ICES, the IUCN, the IPCC and UNESCO have all benefited from engagement with our staff, including D. Bourke, P. Byrne, S. Dalrymple, S. Evers, B. Fruth, S. Mariani, S. Wich.
- **NGOs, Charities, Foundations** – Civil society action has played, and will continue to play, a major role in triggering positive change on the Environment. NGOs have lobbied and advocated for urgent and emblematic causes, while several Foundations have financially supported important investigations that led to policy change. Many of our academics carry out research that generates the kind of robust evidence required to inform advocacy and push for environmentally-aware policy action. Some examples include Mariani's involvement with the Pew Charitable Trusts Marine Programme, Fruth's and Wich's long-standing work with the WWF, as well as more local and regional engagements with the British Trust for Ornithology (R. MacLeod) and the National Trust (C. Bowe, D. Bourke).
- **The Public** – From our own evolutionary trajectory and the climatic changes that shape our living space and resources, through the discovery of biodiversity refuges and remarkable adaptations, all the way to the unveiling of revolutionary ways to look at our planet, our research endeavours represent a considerable source of imagination for the general public. With the fast progress and affordability of digital technology, we plan to boost our projects with explanatory videos and use social media platforms to disseminate our updates. With a new press team and several staff with extensive experience of media outreach and science communication, we will further invest in offering a view into our research to the broadest possible audience. Some recent ongoing projects that include a citizen science component, such as the '*Spot the Spider Monkey*' British Science Week 2020 Zooniverse project (Wich), and the '*DNA Divers* ' initiative that involves British divers in environmental DNA research (Mariani), can serve as beacons for illuminating this avenue.
- **Industry/Private Sector** – Besides instances of specific studies carried out in collaboration with industry partners (e.g. BASF, Rae; PEPSI, Webster), we engage with industry networks to contribute to sustainable solutions to modern production systems. Examples include Evers' advice to the Roundtable for Sustainable Palm Oil (RSPO), multi-stakeholder actions to

improve European seafood trade (Mariani with SeaTraces), participation in consultations to devise the Greater Manchester Borough Council's regional fuel poverty strategy (Simcock), and providing advice on placing the Natural Capital at the heart of the Liverpool City Region Combined Authority's industrial strategy (Bowe). We expect to broaden our synergies with the industry sector in the years to come.

- **Internal Support** – LJMU provided nearly £30,000 to directly assist the academics tasked with developing our Impact Case Studies. Our Research and Innovation team earmarks staff time to liaise with academics and external stakeholders, in order to explore and develop partnerships. We will harness this institutional support in view of shaping and improving the multiple existing impact avenues that are being developed through our research activity.

2. People

2A – Staff

Following the process specified in LJMU's Code of Practice for REF2021, 89% of staff in BES have been designated as having significant responsibility for independent research, which include 59.5 Cat-A FTE, quite evenly distributed among the four Research Groups. Of the 41 academics that joined BES during this REF cycle, half have been appointed within the last three years, and most are at an early career stage (27% of the total Cat-A FTE). This shows the clear institutional **commitment to invest in this area** and build a coherent research unit, with a blend of experienced and early career staff, tailored to our stated goals. Notable examples of early/mid-career staff that progressed to thriving senior positions during this REF cycle are proof that our environment breeds, recognises and rewards academic excellence (e.g. Piel and Wilding, promoted to Reader in 2019 and 2018 respectively; Byrne, Evers, Falkingham, Meloro and Rae, all promoted to Reader in 2020; Bishop, Hunt and Fruth, promoted to Professor between 2016 and 2020)

We shape our **staff development and growth** strategy around the VITAE Research Development Concordat, along the three pillars of Environment, Employment and Career Development, which helps making our working environment transparent, inclusive and dynamic to the transformations ongoing in the academic world.

Environment and Culture – Every staff member is made aware of LJMU's commitment to facilitate research success in a fair, balanced and transparent way. Institutional practices are made clear to all staff both through their line managers and, periodically, by Research & Innovation Services. Research performance is encouraged, rather than imposed, placing much emphasis on the mental health and wellbeing of our staff, reviewing and revising workloads and combating discriminatory and bullying practices. All staff across the seniority range receive compulsory training in relation to equality, diversity and inclusion, and research integrity. The research groups promote a collaborative culture whereby many staff co-produce outputs and offer peer-reviews of ideas and proposals. The group structure also provides the platform for regular consideration of institutional practices and bottom-up critique and proposals are then fed back to the Faculty Research & Knowledge Transfer Committee (FRKTC), where Research Leads have good representation.

Employment – Our recruitment is transparent, merit-based and inclusive. There is an emphasis on positive action to attract under-represented groups, and a pronounced internationalisation, with 11 of our 20 SRIR staff appointed since 2018 coming from nine countries outside the UK (Argentina, Brazil, Canada, Germany, Italy, Portugal, Slovenia, Spain and the USA). Newly appointed research staff are assigned a line manager who provides orientation and assistance during the induction, settling and probation period. A wide range of training and support modules are available to staff, and the benchmark for probation and periodic appraisal are carefully commensurate with career stage and take into account the nuances of each employee's commitments, workload and personal circumstances. New staff automatically receive a research allocation (80 hours) topped by a 'role development' allocation (~40 hours) protected for 3 years, which together amount to 20-25% of their FTE.

Professional and Career Development – We receive robust support from the career development initiatives run by the Research Innovation Services. These events include a

stimulating array of workshops and modules running around the calendar year, focusing on honing key research skills, such as grant writing, paper writing, public outreach and social media strategies. In the year prior to this submission, BES staff attended 45 of these sessions. The ACTivator programme, which was awarded the 2019 *Developing Excellent Practice Award* at the UK Staff Development Forum, provides structured support especially for early-career researchers, assisting them to build their own independent research programme. The Knowledge Exchange & Commercialisation Team offers that crucial bridge between research and real-world operationalisation that is increasingly relevant to environmental scientists in the Anthropocene. This provides our academics with a broader and more dynamic perception of their own professional influence, expanding opportunities for translating environmental knowledge into practical applications.

Equality, Diversity, Inclusion

We are one of three UoAs belonging to the Faculty of Science, and as a newly formed entity we are committed to follow the path of other schools in obtaining the Athena Swan charter, a process that our working group had to temporarily suspend in the wake of the covid-19 pandemic, but which has now been re-initiated. We are well placed, with 34% of women among Cat-A staff, which goes up to 50% when considering the new appointments made since 2018. Among our staff, 7% have a declared disability, while 5% are non-white and 5% identify as LGBTQ; to improve our make-up, we embrace the many initiatives of our institutional Equality, Diversity & Inclusion (EDI) Team: we are one of the three schools university-wide that have appointed an **EDI coordinator** (N. Koyama), who is leading, with our Academic Programme Leads, a thorough process of Curriculum Decolonisation. This action has now also been expanded and a new formative mandatory EDI module is being embedded in the training programme of all Post-Graduate Research (PGR) students, aimed at understanding in depth the long history of discrimination and marginalisation suffered by minoritized groups, and to identify concrete actions to transform environmental research into a truly inclusive endeavour. Our unit shows significant engagement in allyship and mentorship programmes, where staff and students belonging to traditionally disadvantaged groups are paired with staff from a privileged background, to facilitate reciprocal learning and understanding, with the ultimate goal of narrowing the achievement gaps and establishing a safe academic environment.

2B – Research Students

The University runs two internal schemes awarding PhD scholarships: the *LJMU-VC Scholarships* are specifically awarded based on excellence and potential to generate REF outputs and impact, while the *Match-Funded Scholarships* are supported when a supervisory team manages to secure partial investment from an external partner. BES members – who account for **7%** of the University's FTE – have been awarded **16% of the former and 25% of the latter**, over this last REF cycle, hence demonstrating that our research portfolio is internally perceived as a core strength deserving investment, and that our academics are externally recognised as leading figures in their respective fields.

Management – we currently have over **60** registered PGR students in BES, and **29** completions within the REF period. PhD progression and completion are now being boosted by a recent overhaul of the Doctoral Academy procedures. A new online platform, **eDoc**, provides a secure and auditable system for logging all events pertaining to the doctoral student's journey, from the establishment of the full supervising panel and the 'programme approval' (in the initial three months), through the various meetings with, and feedback from, the supervisory team, all the way to the key milestones of the First Progress Review (6 months), the Confirmation meeting (between 12-15 months), the Annual Reviews, the Pre-Submission Review (three months prior to submission), and the *viva voce* examination. Two PGR Tutors (C. Mettke-Hoffmann and P. Falkingham) are tasked with fostering and maintaining high quality research activity in our research student population, in line with University regulations. The PGR tutors guide and assist the students throughout their journey and represent them, alongside two PGR students, at Faculty Committee level.

Development – All our doctoral students benefit from a thorough Research Development Programme (RDP), which is aligned with the VITAE Researcher Development Framework and entails a remarkable range of workshops focused on many technical and transferable skills, running all year round for all cohorts. A more intensive 'summer school' is run by the Doctoral Academy every July, and final-stage students can avail of a residential 'Thesis Boot Camp' to assist during the last writing stages. We also promote and help develop the PGR culture and community through organisation of regular seminars and the Faculty Research Day. This practice allows identification of exceptional performance beyond what is expected from a PGR student, but also helps flagging and supporting students who are encountering more challenges, triggering a set of action points to help the student get back on course and work towards completion in time.

Achievement – We provide PGR students with an engaging and rewarding research environment, as shown by the many opportunities they have to expand their knowledge, grow in confidence, and obtain major success in terms of awards, prizes and high-impact publications. Some examples include: i) Kasim Rafiq, who secured several external grants for his studies on the role of tourism in monitoring wildlife in protected areas, went on to publish a returned output in *Current Biology* and wrote a *Conversation* piece; ii) Chris Brodie, who collaborates with CEFAS to explore the effectiveness of environmental DNA in monitoring pelagic fish stocks, contributed to the BBC Radio 4 *Costing The Earth – the eDNA Revolution* programme; iii) Patrizia Onnis won the best presentation prize (€1500) at the International Mine Water Association (IMWA) conference in Pretoria, RSA, 2018.

3. Income, infrastructure and facilities

3A – Infrastructure & Facilities

We are institutionally backed with a range of research support initiatives that enable us to carry out research to the highest standard. The LJMU Code of Practice for Research is designed to map against REF criteria and international standards. We follow a robust ethics approval process, and a shared, auditable platform for risk assessments (which have been swiftly revised and expanded during the covid-19 pandemic to allow the return of laboratory activity with contained disruption). We are steadily progressing towards an open research environment, using the *Symplectic* platform for the management of scholarly activity, which allows regular, semi-automatic uploading of outputs and associated data and meta-data, and encourages open access (OA) compliance (which is very high for our unit, with over 85% of total outputs deposited). Our Library has secured OA deals with major publishers in the Life & Environmental Sciences (e.g. *Wiley, Springer, PLoS*), and the Research Support team regularly runs clinics and workshops on grant writing, impact and innovation. On the backdrop of this organisational fabric, our academics have access to a wide range of **high-end research facilities**.

The University has invested approximately **£10M, since 2015**, to refurbish biology and environmental science labs between the James Parsons and Life Sciences buildings (Fig. 1) and purchase new key equipment to match the profiles and aspirations of the four research groups. These facilities are managed by six Senior Research Officers and seven Technicians and, in line with the University's climate emergency commitment and ambitious carbon targets, use electric supplies from renewable sources.

The infrastructure that underpins our research can be subdivided into the following components:

a) Life Sciences Laboratories: Over three completely renovated floors, we host 12 laboratories dedicated to the disciplines of biochemistry, genomics, microbiology, microscopy and molecular biology. We have several High-Performance Liquid Chromatography (HPLC) instruments, Quadrupole Time-of-Flight (Q-ToF) Mass Spectrometers, and two Scanning Electron Microscopes (SEM) complete with X-ray back-scattering detector systems. We have self-contained separate DNA isolation rooms for both ancient and environmental DNA, multiple thermocyclers, RT-qPCR, Tapestation, Genome Analyzer, Illumina and Nanopore sequencing workstations. We also have ample -80°C biobanking facilities and portable freezing and liquid nitrogen preservation units for field sampling. This state-of-the-art equipment was instrumental for our staff to produce multiple remarkable ancient DNA studies in journals such as *Nature*,

Current Biology, *PNAS*, *eLife*, and secure prestigious new grants, such as the NERC-funded project 'SpongeDNA'.

Fig. 1: *The new Life Sciences Building (left), an Illumina sequencer (centre), a SEM suite (right).*

b) This text has been redacted

c) Drone Lab: Wildlife and landscape monitoring at LJMU is powerfully supported by a world-class drone lab, featuring six drone flight simulators, several workbenches for building and customising drones, aided by design software, cutting machine and 3D printers. The University also has a closed netted area on campus and a private flying field adjacent to one of the city's largest parks for testing flights and training of staff and research students. Drone activity enhances conservation projects primarily focusing on: i) estimating distribution and abundance of vulnerable species, ii) mapping land cover and changes therein, iii) anti-poaching surveillance. Such capacity places LJMU in the top echelon of drone-based conservation research nationally and globally, and most recently led to securing over £1M STFC funding for monitoring terrestrial megafauna and peat fires. Recent synergies are now also exploring the role of drones as remote samplers for environmental DNA.

d) Environmental Sciences Laboratories: A broad range of environmental and anthropological research takes place in several wet and dry labs, which include: i) two positive pressure laboratories for wet chemistry, palynology and solvent extraction for GCMS, ii) a facility with laser particle sizer, carbon and nitrogen analysers, furnaces, p-XRF, iii) equipment for atmospheric gas sampling including ultra-portable greenhouse gas analyser (CO_2 and CH_4), ground-penetrating radar, automatic water samplers and soil micromorphology, iv) ample microscopy suites with transmitted light, reflected light, polarising, and UV-fluorescence, all equipped with image capture. We also house a vast GIS lab, a specialist laboratory for handling human remains and animal bones, as well as four CONVIRON *Genesis* plant growth chambers.

a) External Field Sites & National Capability Access: Our research teams benefit from an extensive network of collaborations that offer unparalleled access to field sites for: i) tropical endangered species research (e.g. Brazil, Costa Rica, Congo, Tanzania, Zimbabwe, South Africa, Indonesia, Malaysia), ii) palaeoanthropology and palaeoecology (Mexico, Spain, Sudan, Egypt, Iraq, Malta), iii) island ecology (Caribbean, Azores, Canaries, Balearic, Ionian, Mascarene). Through our collaborators, we also have access to marine surveys run by CEFAS, the British Antarctic Survey (BAS), Marine Scotland, the Icelandic Marine Research Institute, Fisheries & Oceans Canada (DFO), and the South African Institute for Aquatic Biodiversity (SAIAB).

3B – Income Profile

We attracted nearly £4M of extra-mural research grant funding during the last REF interval, of which around half came from traditional UK Councils and EU frameworks, and the other half being distributed among a variety of charities, local, regional and national governments, and industry. As a new unit, built around a majority of recently appointed academics, we aim to expand and consolidate our influence as a significant national force in the Environmental Sciences. Some key achievements demonstrate that we are in a strong position to significantly improve our income performance in the 2021-2027 period:

- We have recently secured several **UK Research Council grants**, as both Principal Investigators and Co-Investigators; these include five NERC (Mariani, Byrne, Bowe) and two STFC (Wich) projects, three of which will complete between 2023 and 2024. The appointment of 'rising stars' early-career researchers in the last few years means that we will stand good chances to attract more funding under 'new investigator' schemes.
- We have been successful at attracting **Leverhulme Trust Fellowships** at both senior (Brown, island phylogeography, 2014-2015; Edwards, glacier remote sensing, 2019-2020) and early-career stage (van Asperen, forest palaeoecology, 2013-2016; Nichols, social behaviour, 2018-2020), and we currently have an application pending. Several staff have also consistently attracted smaller pots of pump-priming grants from prestigious **charities and learned societies** (e.g. The Royal Society, The Royal Irish Academy, The Wellcome Trust, The National Geographic, The British Council, The British Ecological Society, The Physiological Society, The Royal Horticultural Society). Such avenues will continue to be a key target in the years ahead.
- We have obtained funding from various **EU schemes**, including EU H2020, COST actions, and EU Regional Development Funds. The outlook over the next REF cycle is comforting, given the permanence of the UK in most European funding frameworks; this will give us the opportunity to leverage on our vast collaborative network in order to secure important EU awards, including supporting staff that are in a promising position to submit bids for the ERC Starting/Consolidator/Advanced grants.

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

4A – Research Network & Contributions

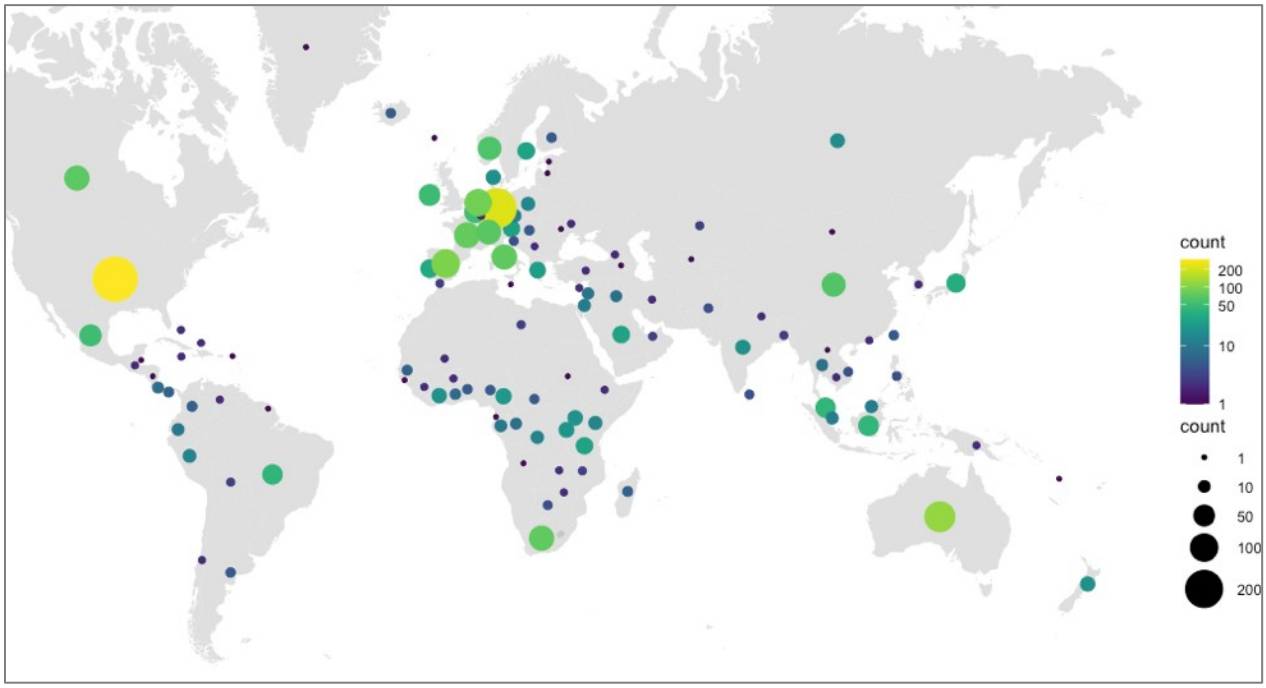

Fig. 2: *Global map of country affiliations for LJMU UoA7 collaborative papers since 2014.*

One of the greatest strengths of our unit is the diverse range and global reach of our research partnerships. These include universities and research institutions in at least 115 countries across all continents, as exemplified by our map of academic collaborations (Fig. 2), based on 857 international outputs generated by our UoA7 staff during this REF period.

This impressive reach gathers particular importance in the context of our mission to meet the challenges to our planet's ecosystems. The study and the tackling of deforestation, habitat degradation, overfishing, poaching, biodiversity loss, invasive species, climate change impacts, etc. are global endeavours, which typically require transnational engagement and scalable, transferrable solutions; it is therefore apt that our research outputs reflect widespread participation

in regions and habitats all across the globe. It is also noteworthy that our publications are co-authored not just with colleagues in the traditional research-intensive strongholds in Europe, North America and Australia, but also with a wide range of scientists and practitioners in many developing countries, which are often faced by some of the greatest ecological emergencies and have long suffered from traditionally unfair practices in academic research, especially in terms of formal recognition in scientific outputs.

During the REF2021 interval, academics in our unit have published a substantial number of papers in **highest-profile journals**, such as *Nature, Science, Nature Communications, Science Advances, Current Biology, PNAS*, as well as consistently publishing in top discipline-specific outlets. This continues to help consolidate our global collaborations and is testimony to our contribution to scientific advancement in the Environmental Sciences. Our **citation profile** particularly demonstrates how our research outputs are influencing the global scholarly community. According to the latest *2020 THE World's University Ranking*, LJMU sits **30th** and **34th** in the UK, for citations, respectively in Geography and Biology (ranking **1st** and **2nd** in the country among the 'young' universities).

The strength and breadth of our international partnerships present a number of further major advantages. First, having established fruitful collaborative links with research stations and survey platforms for many years offers unrivalled opportunities for **long-term research programmes**. These programmes are made possible through robust agreements that include:

- Field sites in Indonesia (A. Engelhardt, S. Evers, S. Mariani, S. Wich), Malaysia (S. Evers, S. Wich), Brazil (L. Figuereido-Passos, S. Mariani), Costa Rica (F. Aureli), Congo (B. Fruth), Egypt (J. Irish), Iraq, Malta (C. Hunt), Spain (M. Mulero-Pazmany), Tanzania (A. Piel), Zimbabwe (L.Traill), Madagascar (S. Wich), and island systems in the Caribbean, South Atlantic, and Western Indian Ocean (S. Mariani), among others. Some of these have underpinned high-profile discoveries on great apes (Fruth, Piel, Wich) and Neanderthals (Girdland-Flink, Hunt, Irish), others are pioneering DNA-based monitoring of shark populations (Mariani).
- Multi-annual surveys and development programmes run by leading organisations, such as the *British Antarctic Survey* (BAS – Edwards, Kiriakoulakis, Mariani), the *National Oceanographic Centre* (NOC – Edwards), the *US Geological Survey* (Byrne), The *International Council for the Exploration of the Sea* (ICES – Mariani, Webster), the *World Wildlife Fund* (WWF – Fruth, Wich), the *International Union for Conservation of Nature* (IUCN – Dalrymple, Fruth, Wich, Wronski).
- Access to world-class collections and facilities include the Wellcome Trust Sanger Institute (Martiniano, Wilding), the Max Planck Institute (Buck, Fruth), the Natural History Museum London (Buck, Irish, Mariani, Martiniano), and the Liverpool School of Tropical Medicine (Weedall, Wilding).

Another substantial enabling feature of our collaborative network is the provision of exceptional opportunities for cultural enrichment, portfolio expansion and scientific growth for both staff and PGR students. Thanks to their reputation in the field, our academics have secured engagement with various leading research teams, nationally and internationally, which resulted in high-profile co-authored outputs, even when the main funding is located in partnering organisations at home or overseas. This long-term synergistic approach has, on several occasions, promoted the formation of consortia that resulted in bids for substantial funding schemes. Highlights include: i) partnership with the *Anopheles gambiae 1000 genomes project* (Ag1000G) run through the **Wellcome Trust Sanger Institute** (Wilding), ii) the *Deep Connections* project funded by the **National Research Foundation of South Africa** to map coelacanth habitats using environmental DNA (Mariani), iii) a co-investigator role on an **NSF-funded grant** at Brown University on dinosaur tracks (Falkingham), iv) a collaboration on the Fragsus **ERC award** on the 'rise and fall' of ancient island civilisations, with Belfast, Cambridge and Malta (Hunt).

For PhD students and early-career researchers, the existence of several long-term collaborations provide an ideal platform for fieldwork experiences, tackling major environmental challenges, and contributing to global awareness of the causes that motivate their research endeavours. The collaborative spirit of our unit is embedded in the career journey of most of our PGR students, whose projects entail at least a component of their studies to be carried out in association with

external partners, and in most cases involving input from non-academic stakeholders, in view of maximising the real-world impact of the research.

4B – From Academic to Socio-economic Impact

Our standing in the academic community is corroborated by significant involvement in the editorial boards of respected international journals including the *Journal of Animal Ecology* (Bielby), *Behaviour* (Reddon), the *Journal of Zoology* (Bielby and Reddon), *Ecological Solutions & Evidence* (Dalrymple), the *Journal of Soils and Sediments* (Byrne), the *Journal of Archaeological Science* and *JAS Reports* (Hunt), *Frontiers in Comparative Psychology* (Swaney), the *American Journal of Physical Anthropology* (Irish), *Reviews in Fish Biology & Fisheries* and *Frontiers in Conservation Science* (Mariani), the *Journal of Unmanned Vehicle Systems* (Wich), the *Herpetological Journal* (Brown), and the widely distributed *Scientific Reports* (Nowack) and *PLoS One* (Meloro).
Active engagement with learned societies is reflected in fellowships of the Linnean Society (Wilding), the Geological Society (Hunt), the Royal Entomological Society (Gunn and Williams), and the Royal Anthropological Institute (Roberts), and in key position in advisory boards (Dalrymple) and review college (Bielby) of the British Ecological Society.

Importantly, the staff in our unit are committed to escalate tangible **real-world impact outside the realm of academia**, as shown through their various engagements with international panels and policy organisations. Conservation action is reflected in membership of IUCN executive committees, commissions and specialist groups (Dalrymple, Fruth, Wich, Wronski), advisory capacity to UN Environment Programmes (Evers, Wich), the International Council for the Exploration of the Sea (Mariani), the South Asian Institute for Advanced Research and Development (Gagnon), the Kruger and Hwange African Wildlife Parks (Traill), and the regular stakeholder engagement with statutory bodies for nature conservation in the UK (Byrne, Mariani).

The following three main areas summarise the main remits of our impact activity, which we expect to expand and develop as detailed in section 1 of this document:

- **Conservation Policy** – Biodiversity loss and natural habitat destruction imperils ecosystem services and our own existence. Evidence-based solutions are therefore essential to avert the biodiversity crisis and must be enshrined in local, national and international regulations. We engage with governmental, non-governmental and transnational organisations in order to translate our findings into tools that can support improved management actions and legislation. Some of the areas where we exert influence include: i) protecting refuge habitats for iconic endangered species, along the lines of the recent high-profile struggle to safeguard the future of Sumatra's orang-utan; ii) advising on best practice for species introductions and population management (e.g. Dalrymple, Figuereido-Passos, Traill, Wronski) and iii) combating illegal wildlife and seafood trade through the integration of technological and socio-ecological approaches (e.g. Mariani).

- **Environmental Stewardship** – A sustainable future requires major behavioural shifts in human societies; as environmental scientists, we can play a key role through stakeholder engagement and by finding the appropriate register to assist decision-makers in choosing the bold management decisions required to secure a healthy and resilient planet.
  Climate change will stand as the biggest challenge in the forthcoming years: our unit produces positive impact in this area, from advising on sustainable, innovative practices for agricultural, forestry and fisheries resources (Bowe, Evers, Bourke, Mariani, Symonds, Webster, Williams), to devising mitigating strategies for the disproportionate damage that climate can have on disadvantaged groups, such as ethnic minorities, the disabled and the poor (Kosanic, Germond-Duret, Simcock).
  Environmental monitoring is at the core of our ability to measure and respond to changes in the biosphere. Our research groups have devised a vast array of innovative monitoring techniques, from chemical and plastic pollution (e.g. Byrne, Kiriakoulakis) and organismal hormonal responses (Engelhardt, Nowack), to environmental DNA approaches (Mariani, Galvez-Bravo), camera traps (MacLeod, Piel) drone technologies (Mulero-Pazmany, Wich), and

remote sensing (Edwards, Gagnon), all of which are currently at different stages of technological readiness for operational, applied settings.

- **Public Engagement** – Our unit has been and will continue to be very active in connecting with the broadest possible audiences. We have an astonishing track-record in public outreach, which spans from local schools and trusts, to museums, science festivals, global news outlets and TV documentaries. We curated exhibitions on human evolution in our own city's World Museum (Irish); we contributed to major international documentaries, with topics ranging from primate conservation (Wich) and seafood fraud (Mariani) for the BBC, to renowned extreme fishing adventures (Mariani) for *Discovery*. Our primary research is regularly covered by national and international press and other media, and is frequently translated into lay articles on *The Conversation* (a dozen of our academics have authored multiple pieces) and learned society magazines.

  Making scientific breakthroughs accessible to the general public is fundamental to gain trust and show that **science can improve everyone's life**. This is particularly important in the Environmental Sciences, where science communication has the power to strengthen the connectedness between Nature and human societies. Further progress will continue to be made as advances in digital technologies allow generation and distribution of progressively more nimble and effective outreach products. In the future, we expect that these efforts will typically stretch beyond serving as dissemination tools, increasingly forming core aspects of the research process itself.