

Institution: University of Plymouth
Unit of Assessment: UoA6, Agriculture, Veterinary & Food Science
<p>1. Unit context and structure, research and impact strategy</p> <p>This University of Plymouth (UoP) Unit of Assessment (19.8 FTEs) has centred its efforts, since REF2014, on fundamental and applied research activities that underpin innovation in food production and food security. Broadly, our focus is on the sustainability of the resources affecting food production, the integrity of ecosystem functions and services, and environmental protection of the food chain. Our research embraces ecological and environmental aspects of food sustainability related to plant and aquatic animal production and the safety of the human food chain from chemical hazards with particular emphasis on water quality. It includes work in interconnected areas of plant sciences, animal-plant interactions, food and nutrition, aquaculture, aquatic and terrestrial ecotoxicology, and environmental chemistry. This includes nanoscience and nanotechnology, environmental change monitoring, ecosystem management and animal (fish) welfare in accordance with the 3Rs vision.</p> <p>The University reviewed its research portfolio following REF2014 with the aim of mapping its research expertise against national and international challenges including food security, chemical safety, and climate change. The subsequent impact strategy was designed specifically to ensure that UoA6 research was relevant to the cornerstone of UK Government Policy of Public Goods (DEFRA 2019):</p> <p><i>“to support actions to improve soil health, water quality, air quality, increase biodiversity, mitigate climate change and enhance beauty, heritage and engagement with the natural environment”</i></p> <p>with reach and impact directly aligned with key UN Sustainable Development goals:</p> <p>#2: Zero Hunger #6: Clean Water and Sanitation. #12: Responsible Consumption and Production #13: Climate Action #14: Life Below Water #15: Life on Land</p> <p>Our research focus has been aligned with the University Research strategy (2017-22) to embrace real-world challenges, to advance and translate knowledge, and to drive innovation and enterprise. This has been achieved through :</p> <ul style="list-style-type: none"> • Establishing the new research groups, described in detail below, to develop a robust impact strategy; re-focussing interests in developing areas; and promoting interdisciplinary work. This gives clearer focus for staff and research students along with external visibility through the webpages of the academic Schools and two of the University’s strategic institutes, namely the Sustainable Earth Institute (SEI: Link) and the Marine Institute (MI: Link). • Ensuring that the developing resource and financial base from a variety of external and internal funding sources is sustained and secured beyond the current REF period. This is evidenced by the increased number of grant applications, and associated greater successes, with a 20% overall increase in grant income of £4.1M (57% per capita increase) over the current REF period. • Building on current strengths with strategic fit and developing new areas with potential impact by recruiting eight new staff (Boschetti, Buckley, Fauset, Littlejohn, Merrifield, Plessis, Roberts, Simões) and acquiring appropriate new infrastructure. Our laboratories have been extensively refurbished and new equipment has been acquired through the UoP Strategic Investment Fund (SIF) and Capital Projects Fund, and external agencies. This includes a Zeiss confocal microscope that is fully integrated with our state of the art focused ion beam scanning electron microscope, a refurbished aquarium, and advanced technology growth facilities where plants can be exposed to defined wavelengths of light using LEDs.

- Nurturing, supporting and expanding the responsibilities of **post-graduates and early career** researchers (ECR). For example, involving PGRs and ECRs in the peer-review process of grant applications; participating in interview processes for staff appointments; consultation on infrastructure developments; encouraging involvement with seminar organisation. There has been a strategic decision to support participation in national and international workshops; training through the Challenge of Science Leadership Workshop provided by commercial organisations (e.g. [Link](#)); advancing our equality and diversity commitment including full engagement with the Athena Swan agenda.
- Growing **postgraduate student completions** (see Section 2) and diversifying sources of funding, including an invitation to join the multi-institutional NERC Doctoral Training Partnership ARIES as a full partner, and increased applications (more than doubled) for peer-reviewed PhD applications, including Commonwealth Scholarships.
- Fostering pathways to support **knowledge and technology exchange** with industry and businesses (see Sections 3 and 4) and creating pathways that support technology exchange leading to the **commercialisation** of our research outcomes for the benefit of our stakeholders e.g. AstraZeneca, Lallemand, Wessex Water (providing support for the Impact Case Study led by **Comber**); fostering complementary and synergistic research partnerships and facilitating collaborations regionally (e.g. University of Exeter, Rothamsted Research North Wyke, Duchy College), nationally (Crop Health and Protection Innovation Centre) and internationally (Middle-East, Asia, Europe and South America: see Section 4).
- Enhancing the understanding of science through **stakeholder and public engagement**. For example, at international workshops as part of our EU projects, and participation in scientific show cases within and outside the University. Enhancing engagement with regulators and policy makers, including in the drafting of OECD nanoparticles regulations (**Handy**); organising major symposia (e.g. on nanotoxicology) involving international academics and stakeholders (**Jha, Handy**); and participating in International Panels on Climate Change (**Parmesan, Singer**) and Global Pharmaceuticals (**Comber, Hutchinson, Jha**). Encouraging **outreach activities** and engagement with national and international press and media have also been part of our impact strategy.

In 2017, research that is complementary and supportive of agriculture (including aquaculture) and food science was reorganised into coherent *Research Groups*, to reflect staff strengths in line with national and global priorities. The groups also enable working across the University with cognate disciplines:

- **Environmental and Applied Biology Research Group:** [Link](#)
 - Major theme: utilizing molecular and cellular approaches to understand fundamental life processes in plant and animal models to evaluate risks from natural and anthropogenic hazards to ensure global food security.
 - Comprising 7 academics covering the interdisciplinary areas of environmental and fish gut microbiology, ecotoxicology/ environmental biology, fish health and nutrition, plant physiology, alternative approaches to animal studies.
 - This research group is exclusively returned in this UoA.
- **Ecology and Evolution Research Group:** [Link](#)
 - Covering research investigating relationships between organisms and their environment to better inform scientific understanding and maintaining biodiversity.
 - Comprising 13 academics covering the areas of global change biology, taxonomy and systematics, plant-animal interactions, community ecology, population and conservation genetics, environmental physiology, evolutionary biology, coastal ecology and management.
 - Ten members of this research group are returned to this UoA covering the research areas of 'plant-insect ecology and animal and environmental biology' and the remainder are returned in UoA7.
- **Ecophysiology and Development Research Group:** [Link](#)
 - Covering research developing a cross-systems approach to understand environmental influences on the biology of individual organisms.

- Comprising 8 academic staff covering the areas of marine, plant and developmental ecophysiology and bioimaging.
- Two members from this group are included in this UoA complementing the areas of plant and animal physiology and the remainder are returned in UoA7.
- **Biogeochemistry Research Centre:** [Link](#)
 - Covering research to understand the behaviour, fate and impact of nutrients, organics and metals in the environment to support decision support tools for fluid modelling and management, forest ecology and carbon cycling, marine biogeochemistry and chemicals in the environment which impact on both UoA6 and UoA7.
 - Three of the staff of the 'Chemicals in the Environment' group within this multidisciplinary research centre, covering the areas of impact of chemicals in particular agricultural chemicals on food science and water quality, are included in UoA6 others have been included in UoA7.

Specifically, the core activities of staff in this UoA cover the following **themes**:

➤ **Plant-environmental interactions**

- Plant responses to stress and climate change; nutrient availability; transport of contaminants from soil to plants and responses to climate change variables (**Franco, Fuller, Hanley, Hill, Littlejohn, Plessis, Roberts, Buckley**)
- Development of Agri-Tech, 'Plant Factories' (**Fuller, Littlejohn, Plessis**)

➤ **Plant-Insect ecology, animal and environmental biology**

- Tree and crop ecology (**Fauset, Franco, Hanley, Ramsay**)
- Plant-insect-herbivore interactions; ecosystem management through pollinators (**Cotton, Ellis, Hanley, Knight**)
- Animal biology, ecological conservation and evolution (**Boschetti, Puschendorf, Simões, Knight, Ellis**)

➤ **Water quality, impact of contaminants on fish and human health**

- Aquaculture, fish gut biology, fish and human nutrition (**Kuri, Merrifield**)
- Environmental and aquatic organism microbiomes (**Bishop, Boden, Merrifield**)
- Impact of classical and emerging contaminants on fin fish and shellfish; potential risks to human *via* food chain (**Handy, Hutchinson, Jha, Readman**)
- Sources and impact of agricultural chemicals on food science and water quality (**Comber, Handy, Hill, Hutchinson, Jha, Readman**)
- Alternatives to live fish studies and fish welfare (**Handy, Hutchinson, Jha**)

The staff working on these themes come from the School of Biological and Marine Sciences (SoBMS) and the School of Geography, Geology and Environmental Sciences (SoGEES) in the Faculty of Science and Engineering. Thus, a strength of this UoA is that it fosters multi-disciplinary activities by integrating staff into a single community that focuses on fundamental and applied, cross-cutting exploration of critical environmental issues to reinforce confidence in agricultural and aquaculture innovations. This fits well with the holistic approach of the University's Strategic Institutes linking diverse research areas across and beyond the University to develop innovative approaches to build resilience to global challenges.

We adopt a coherent and **inclusive staff policy** embracing academic and technical staff, research students, and undergraduate students through research projects. This facilitates the continued research development of all staff and students and has led to co-authored papers, the award of PhD research degrees to technical staff (two) the progression of research students to postdoctoral fellows (five) and the progression of undergraduate students to research students and summer interns (four) through the Faculty's research internship programme. In particular, with the support of start-up/pump-priming research grants from internal as well as external sources such as the Seale-Hayne Education Trust (SHET), the Gatsby Foundation and the Nuffield Foundation, we

achieve early career researcher engagement (26% new academic recruitments in addition to post-doctoral fellows) with up to 10 undergraduates a year engaging in approved research internships. We recruit PhD and ResM students from across the world, including continental Europe, Middle-East, Africa, Asia and South America, and give extra support including mentorship to develop students from disadvantaged locations (e.g., Iraq, Syria, Lebanon). By maintaining a balance of PGRs, ECRs and academic staff, we have built a research community that exhibits confidence and cohesiveness and has engendered a lasting research legacy by ensuring members feel part of a vibrant and valued research community.

Our researchers characteristically apply a range of scientific and **interdisciplinary approaches** to their work to address key scientific issues. These include cross-disciplinary genomics, transcriptomics, proteomics, metabolomics and bioinformatics approaches (e.g. **Boschetti, Ellis, Fuller, Handy, Jha, Knight, Littlejohn, Merrifield**); biological imaging and plant fluorescence imaging (e.g. **Littlejohn, Handy, Jha**); synthetic and environmental analytical chemistry including ICP-MS, GC-MS, LC-MS (e.g. **Comber, Fuller, Handy, Hutchinson, Jha, Readman**). Multivariate statistical networks, computational modelling, bioinformatics and high performance computing (HPC) (e.g. **Boden, Boschetti, Jha, Merrifield, Roberts**) are extensively used. The University is committed to grow further interdisciplinary research and is continuing to invest in these areas.

The approaches adopted and the collaborations established with other organisations have enhanced the fundamental understanding of the subject areas covered (e.g. NERC and EU funded projects on Nanoparticles: **Handy, Jha**; BBSRC funded work on development of alternatives to live fish studies: **Jha**) and have also influenced our strategy to positively impact biological understanding which influences the regulations and the policies governing safe and sustainable production (e.g. water pollution related to pharmaceuticals and pesticides which has provided the foundation for our Impact Case Study focused on the research of **Comber**) (Section 4).

One of our central goals is to promote research with a potential impact on our subject base which can be applied to the industries underpinning the agri-environment. In this respect, we facilitate researchers to engage with industry in defining research objectives and to use the extensive human and physical facilities of the University to resolve issues of relevance. In this way, much of our research is “applied” in nature engaging in collaboration with academics, policy makers and industrial partners to achieve common objectives. Even our more fundamental research leading to a greater understanding of the ecology of the natural and farmed landscape has been applied successfully to generate reasoning and collect evidence to influence international thinking on Climate Change (e.g. on the “attribution” of climate change parameters on changes in natural ecosystems as described in our Impact Case Study centred on the research of **Parmesan**).

We embrace the University’s goal of compliance with the *Concordat on Open Research Data* and are aligned with the University’s Research Data Policy 2018 on ‘Open Access’ publication. All publications are up-loaded to ‘Symplectic Elements’, the University’s Research Information System with cross-communication to PEARL the University’s Research Repository. PEARL also holds electronic copies of all completed Research Theses. Journal articles and conference papers published since 1st April 2016 have all been deposited within 90 days of publication or for more recent publications, within 90 days of the date of acceptance. We comply with the University’s Research Data Management policy to ensure data integrity, discoverability and re-use throughout the lifecycle of research projects.

2. People

Staffing strategy and staff development

We maintain a structured mix of research leaders, early career researchers and researchers in training. We encourage team approaches and use mentoring processes to develop researchers to enhance the capacity of the interdisciplinary research teams. We endorse the University’s commitment to the Concordat to Support the Career Development of Researchers. Members of our research groups (**Fuller, Jha, Roberts**) have been instrumental in the University retaining the **European Commission’s HR Excellence Award** ([Link](#)).

There has been a natural turnover of academic staff since 2014 and we ensure that replacement appointments have the potential to complement existing research themes. For example, succession planning has ensured that staff within the *Environmental and Applied Biology Research and Ecology and Evolution Research Groups* entering retirement or semi-retirement (previously submitted, **Fuller, Franco, Singer, Davies** and not previously submitted *Lane, Donkin, Ramsay*) have been replaced (**Boschetti, Buckley, Fauset, Littlejohn, Merrifield, Plessis, Roberts, Simões: seven on Lecturer Grades; one as Professor and DVC**) synergising research capacity and strength. Out of these 8 appointments, three (**Boschetti, Fauset, Plessis**) were females. For both appointments of new staff and their promotion, equality and diversity are coherently embedded in our approach, both formally *via* a mandatory staff training course, and as an integral component of our day-to-day research activities in accord with the University's equality, diversity and inclusion policy [Link](#).

Our staff profile demonstrates a mix of ECRs (20%) and established staff (80%) with at least 45% at Level 7 (Lecturer/Res Fellow/Researcher) and 25% in Senior Management roles (Professor, Head of School, Deputy Vice Chancellor). Such a balance provides a healthy mix to maintain and develop this UoA for the future (Tables 1, 2 & 3).

Table 1. Gender, Disability and Ethnicity Profiles (% of FTE).

Gender		Disability		Ethnicity	
Male	79.8%	No	91.9%	BME	10.1%
Female	20.2%	Yes	8.1%	White	89.9%

Table 2. ECR and Employment Profiles (% of FTE).

ECR Status		Employment Basis		Employment Terms	
ECR	20.2%	Full-time	91.9%	Permanent	100.0%
Not an ECR	79.8%	Part-time	8.1%	Fixed-Term	0.0%

Table 3. Age Group Profile (% of FTE).

Age Group	
25-34	5.1%
35-44	45.5%
45-54	20.2%
55-64	23.2%
65+	6.1%

New staff and early career researchers are mentored through a probationary period and have access to a longer-term voluntary mentoring scheme within their Schools. A core part of our research mentoring process is assistance with grant applications, both in identifying suitable grant opportunities and in refining applications prior to submission. In particular, ECRs are encouraged to apply for pump priming grants to the Seale-Hayne Education Trust (an agricultural education foundation) as PIs with an established researcher as Col. With a "strike rate" of over 60%, these small grants help to boost confidence and begin successful avenues of research inquiry. In the event of grant applications not being funded, we assist staff in re-purposing for alternative sources of support and encourage critical reflective practice to increase likelihood of success in subsequent application rounds.

We always pursue a policy of **co-supervision of PGR students**. This provides both their security and complies with the "Statement of Expectations of Doctoral Training" (UKRI 2016) facilitating new staff to gain research traction quickly. We promote internal and externally funded PGR studentship awards where early career staff/researchers are given priority. As a strategic investment, for the last 7 years, the School of Biological and Marine Sciences awarded an average of 4 PhD studentships from its own resources, shared between UoAs 6 and 7, especially targeting

ECR staff. This incurred a total investment of above £504K over a 7-year period. These studentships are additional to other University or Faculty level funded PhD studentships (e.g. cross-Faculty collaborations).

Female staff are encouraged to participate in the University's Women's mentoring scheme. The University is committed to the implementation of its equality and diversity agenda and this commitment has been recognised through a Bronze Athena SWAN award to SoGEES in 2017 and to the SoBMS in 2020. We have also contributed to the Government Inquiry into "Impact of Funding Policy on Diversity" ([Link](#)). We ensure all research-facing activities and events consider equality and diversity issues, including the scheduling of events, and the career and gender balance of external speakers (and Chairs) in our seminar series.

For the 2014 REF submission for this UoA there were 30.8% professors (all males) and the proportion of female staff returned was 11.5%. During the 2014-21 period, the proportion of professors has gone down to 19% and the proportion of female staff has risen to 20.20% (1 senior lecturer, 3 lecturers and 1 Head of School as Professor). Realising the global problem of maintaining gender balance, a key part of our planning within and beyond the REF2021 period is to pay particular attention to gender balance at all levels of employment and to ensure equal opportunities for staff within the UoA. This includes provision of research mentors for all ECR staff as well as regular training programmes organised by the University (e.g. 'Springboard' course tailored for female ECRs). Furthermore, we are attentive to the examination panels for research students and make use of the database compiled by the Doctoral College to facilitate gender balance for *Viva Voce* panels.

As per the University policy, through a transparent process, annual opportunities for **career progression** have been provided within this UoA for staff belonging to different research groups. A mark of success is that in the REF period **Merrifield** was promoted to Associate Professor (Senior Lecturer), **Hanley** to Associate Professor (Reader) and **Comber, Hutchinson** and **Knight** to Full Professors. Research output and success have been key in these promotions.

Our outputs for the REF2021 assessment were evaluated internally and externally following the University's transparent and fair processes in accordance with the institution's Code of Practice. Over the current assessment period, there has been a substantial turnover of staff. Since 2014 REF (Cat A staff: 26; FTE: 24.45), 8 (30%) of the submitted staff retired and three (11.53%) moved or changed career. In the present cohort 26% are newly recruited staff, one as DVC, 7 starting their careers as Lecturers, demonstrating an investment in key research areas. Retiring staff have been retained in an Emeritus status or as Visiting Fellows (e.g. **Franco, Moody, Readman, Singer**) to enable the transfer of expertise and help with mentoring of new staff.

Research development funds have been made available from the Schools' strategic research accounts to support staff, particularly ECRs, to attend conferences so that they can network and build collaborative funding opportunities (e.g., **Fauset**: was supported to participate in Birmingham Institute of Forest Research Annual Meetings, 2019, 2020 which led to both support through the NERC Global Partnerships Seedcorn Fund and the establishment of joint PhD applications; **Plessis**: UK Plant Science Conference, Norwich, 2016). In addition, there are annual allowances to spend on equipment and consumables without justification for those staff who have directly-allocated time on grants of 5-10% for 3 years. Staff also have access to a competitive 6-month sabbatical leave process to supplement research time and further develop impact. Annual workload planning for academics explicitly includes research workload, in counterbalance to teaching and management commitments. Successful research areas have been prioritised for investment in infrastructure and facilities (e.g. plant tissue culture, aquarium and microscopic facilities). In addition to sabbatical policies staff are also supported through schemes such as maternity and parental leave.

Research students

This UoA is a vibrant training ground for researchers with 70 PhDs completions since REF2014, representing an average of 3.5 completions per FTE and 10 completions per annum. This is almost

a 30% increase from the 54 PhD completions that were achieved over the 2014 REF assessment period despite overall reduction in FTE during the current period (24.45 vs 19.80). We have also co-supervised more than 25 Research Masters students to completion, many in association with Duchy College of Agriculture.

Following completions of their PhDs during this REF period, many have advanced their career in a range of sectors within and outside the UK. These include working as academics (e.g. **Megson**: Lecturer Manchester Metropolitan University), Post-Doctoral Fellows (e.g. **Langan**: Baylor College of Medicine, USA; **Vassollo, Clark and Rihan**: University of Plymouth), Government Organisations (e.g. **Lees**: HSE), Public Body (e.g. **Rees**: Natural England), Research Organisations (e.g. **Dallas, Vernon**: Babcock International; **Pereira**: Sparos, Portugal; **Peggs**: Skretting, Norway), Charitable Organisation (e.g. **Pearson**: West Country River Trust), Environmental Consultancy (**White Halwyn**: JBA; **Tatsi** and **Bagnis**: Corteva; **Dawson** – APEM).

The Doctoral College (formerly Graduate School) develops and supports research and career development and provides regulatory support for PhD and Research Masters (ResM) candidates. This includes the compulsory attendance of the Research Methods level 7 module, which includes subject specific skills training, statistics and research ethics and research integrity (in fulfilment of the EU Concordat). Research students are also supported through the organisation of symposia and workshops at the Faculty and University levels and we routinely organise generic and specific programmes, workshops and conferences for our PGR community. We organise bi-weekly 'molecular breakfast' and 'bioinformatics' sessions which students attend as well as fortnightly School Seminars, post-graduate student-led Conferences, Research Group Meetings and an Internal Discussion Forum. For example, Plant Group Forum organises fortnightly meetings which spans ecology and agricultural themes to bring several of members together in a place for informal discussion enhancing the research environment and providing career development opportunities. PGRs are required to give presentations throughout their ResM/PhD programme during the Research Group Meetings and at School and University sponsored annual research events (e.g. Post-Graduate Poster Presentations, Research Festival). Best presentation awards are given at these events for encouragement and where appropriate bursaries are made available for them (e.g. through MI, SEI and through the Plymouth Marine Science and Education Foundation, PlyMSEF) to participate in national and international conferences. Increasing participation in outreach activities for PGR have further strengthened over the last 5 years. Furthermore, PGR representatives are full members of School and Faculty research committees where they can raise relevant issues and cascade information to other PGR students.

For all national and international conferences organised locally by our academics, PGRs can enrol free of charge. These opportunities provide them with the prospect to network and establish links with colleagues from around the world (e.g. **38th Annual Meeting of UKEMS, 2015**; **International Symposium on Nanotoxicology: Implications for Human and Environmental Health, 2017**). Where appropriate, PGRs are supported with the opportunity to visit research and commercial laboratories (e.g. Marine Biological Association (MBA), Plymouth Marine Laboratory (PML), Centre for Environment Fisheries and Aquaculture Science (CEFAS), FERA Science, Rothamsted Research) and be exposed to the industrial environment (e.g. Astra Zeneca, Elsoms Seeds, Lallemand, Langage Farm, Saputo) to enhance their expertise by knowledge exchange.

We routinely host generic and specific internal programmes (e.g. **Challenge of Science Leadership, Plymouth Nobel Sessions**) for our PGRs and encourage them to actively participate in such programmes, providing feedback on their performances to improve on the impact of their presentations. We also encourage active participation in our teaching programmes and have set-up specific routes to discuss career aspirations and to mentor them in their training programme choices. The Doctoral College also provides training programmes for PGRs through the Researcher Development Programme. These are recorded and logged online in the research activities log (GradBook: [Link](#)).

PGRs actively contribute to research outputs, as the lead authors during and after their PhD programmes (over half of the research publications in our discipline are co-authored with PGR students).

The display of our research on an Open Platform (PEARL: [Link](#)) facilitates international PGR student enquiries and leads to recruitment which contributes to a good cultural diversity. We are vigilant to maintain equal opportunities for development for all of our PGR students, are proactive to support them in the challenges and expectations posed by the UK science education system. We take particular care in supporting Research Ethics development both in the conduct of the process of research, and this is reinforced in GradBook, in peer-reviewed publications and other public output.

3. Income, infrastructure and facilities

A. Income:

Sources of Income:

Staff within this UoA have been extremely successful in attracting external funding from diverse sources. There has been a substantial increase (~20%) in income compared to the last REF period.

UKRI/RCUK/UK Government:

NERC: **Jha, Hutchinson, Knight, Roberts**; BBSRC: **Jha, Merrifield**; Newton Fund: **Merrifield, Fuller**; Innovate UK (Technology Strategy Board): **Boden, Kuri**; DEFRA: **Kuri, Handy, Hutchinson**; Commonwealth Commission: **Hutchinson, Comber**; FERA Science Limited: **Hutchinson**; GCRF: **Fauset, Fuller, Jha**; British Council GSIKE: **Fuller**

European Commission:

FP7, Horizon 2020: **Handy, Jha, Readman**; ERDF, Cornwall: **Fuller, Littlejohn**

Industry:

AstraZeneca: **Comber, Jha**; Saputo: **Comber, Hutchinson**; Wessex Water: **Comber, Hutchinson**; Int. Cu and Zn Associations: **Comber**; BioMar: **Merrifield**; Lallemand: **Merrifield**; Leiber: **Merrifield**; Evonik: **Merrifield**; Langage Farm: **Kuri**; Skretting: **Jha, Merrifield**; Perkin Elmer: **Comber**; inoTEX: **Comber**; Amepox: **Comber** HEMPEL: **Comber**; Malvern Instruments: **Comber**; Western Commodities: **Kuri**; Sole of Discretion: **Kuri**; Dairy Crest: **Hutchinson**

Charitable, Philanthropic organisations and NGOs:

The Leverhulme Trust: **Ellis, Hanley**; The Royal Society: **Boden, Hutchinson, Fauset**; Seale-Hayne Education Trust: **Boden, Comber, Fauset, Fuller, Hutchinson, Jha, Knight, Littlejohn, Plessis**; National Institute of Agricultural Botany CRWRT: **Littlejohn**; Natural England: **Comber**; Somerset Catchment Partnership: **Hutchinson**; Westcountry Rivers Trust: **Comber**; Presidents International Fellowship Grant, China: **Fauset**; Eva Crane Trust: **Knight**

Research grant success is accomplished through robust grant preparation and support processes with active participation of University Research and Innovation (R&I) specialist advisors. Research ideas within our research groups are developed through targeted mentoring and support for proposal preparation to individual staff. Grant capture is scrutinised as a standard item of the annual Personal Development Review (PDR) process which requires the development of an annual personal research plan. These are then actioned through the Research Groups, backed by the Research Group Leads and the Senior Management Team (Head of School and Associate Head Research). Potential proposals are discussed within research group meetings at an early stage and undergo rigorous internal peer review by nominated colleagues working in the most cognate research area and scrutinised for the resources requested. The Funding Advisory Services within R&I support the preparation of the grant applications by providing FEC costs and ensuring peer review prior to senior management (Head of School and Dean) sign off. In this way the senior management are kept in touch with the potential development of research in each sub-disciplines.

Income since last REF period:

During the current period, staff in the UoA have generated **£4,151,740** of research income from external sources. This is a 20% increase from the 2014 REF (total income £3,474,895) and a per

capita average rise from £133,649 to £209,684 per FTE. Over half of this income (52%) was from Research Councils and UK Central Government bodies and a quarter from the EU (27%) (Fig. 2). Improved success in these highly competitive funding environments is testament to the reputation of the quality of science undertaken by the staff in this UoA.

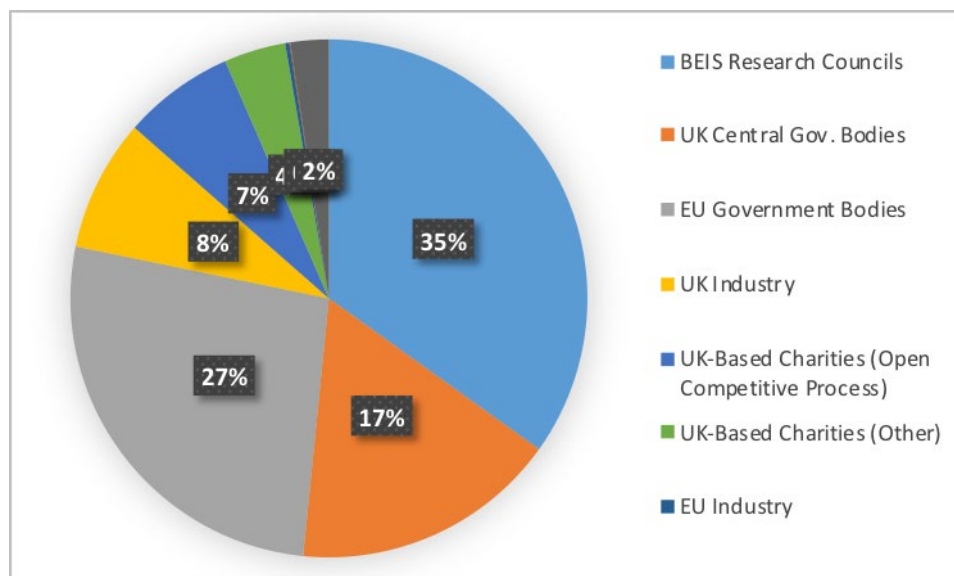


Fig 2. Sources and proportions of research income for UoA6 at UoP 2014 -2020.

B. Infrastructure & Facilities:

Strategic infrastructure investment supporting this UoA since 2014 REF includes purpose-built aquaria including Zebrafish facilities (£50K); Greenhouse/glasshouses (£1.1M) and plant physiology (£0.75M) laboratories. Substantial investment have been made for the refurbishment of controlled environment facilities (£250K), histology suites (£200K), plant tissue culture facilities (£100K) and their supporting laboratories. The 3rd floor of North end of the main science facilities block, the Davy building, was refurbished in 2016 at a cost of ~£3M and 2nd and 3rd floor of the South end, which include plant physiology, microbiology, molecular, histology research laboratories, and a teaching lab was completed in 2018 at a cost of ~£3M. Investment of £2 million second generation 'omics facility and behavioural and ecology suite to facilitate the use of modern molecular ecology tools prior to 2014 REF has strengthened the institutional capability for 'omics' work and facilities continue to be utilised by staff in this UoA.

Our researchers have benefited from investment in 'state-of-the-art' microscopic facilities. This includes purchase of a Zeiss 880 Airyscan Laser Scanning Confocal Microscope which facilitates sensitive live cell and high resolution imaging that can be used in concert with our Focused Ion Beam – Scanning Electron Microscope to perform correlative microscopy on samples across both platforms. The Plymouth Electron Microscopy Centre (PEMC) has also seen investment in two JEOL SEMs with elemental analysis and cryo capabilities, a JEOL TEM and a Zeiss FIB-SEM. Investment has also been deployed by the University to double the amount of technical support associated with this instrumentation.

UoA6 researchers share resources with staff included in other UoAs (especially UO A7). For example, the environmental analytical chemistry suite which includes: ICP-MS, ICP-AES, FAAS instruments, ion chromatography, High Temperature Catalytic Oxidation, voltammetry, HPLC and computing for speciation modelling for chemicals. These facilities have been re-awarded **ISO9001 certification in 2015 reflecting their capacity** to perform analytical work of highest scientific standard and precision. Facilities for characterising soils, water and natural particles (NTA, DLS, FFF etc.) also continue to be supported by the Faculty and we remain one of a few UK Universities with sufficient facilities to perform all in-house characterisation of nanomaterials. We also have

access to industrial-standard clean rooms in our Nano Fabrication Facility (**Wolfson Nanotechnology Laboratory**) with particular attention to design and manufacture of devices to monitor water quality and to the Materials Characterisation Centre. The ISO9001 accreditation continues to facilitate an “**Analytical Bureau**” provision for us to work with commercial clients (e.g. Perkin Elmer; Int. Cu and Zn Associations). Similarly, the Consolidated Radio-Isotope Facility (**CORiF**) is one of four **ISO 9001:2008 certified** centralised laboratories within the Faculty of Science and Engineering shared by staff being returned to different UoAs. Significant investment since the last REF has been made to upgrade this facility to include wavelength dispersive X-ray fluorescence (**WD XRF**) used for geochemical analyses of a variety of materials (soils, sediments) in addition to three state-of-the-art gamma spectrometers, two liquid scintillation counters, and a Laser Granulometer.

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

Engagement Nationally and Internationally: Our strategy has always been to engage with appropriate national and international researchers based at research institutions, HEIs, industries, government organisations and policy organisations. This has not only enabled us to deliver greater impact but also to provide our research students with opportunities for collaboration across the UK and globally. In this pursuit, researchers have all been engaged as either PIs or Co-Is on collaborative projects funded by many different agencies (see Section 3). Apart from scientific publications and reports, staff within this UoA are involved in delivering public-lectures and frequently receive considerable media attention. These include TV/Radio news and interviews, newspaper and magazine articles, and web-based articles & blogs, enhancing the public understanding of science and elaborating the impact of the work on broader society. The summary provided below indicate potential for continued growth and development within this UoA.

➤ **‘Plant-environmental interactions’ Theme**

The researchers in this theme (**Fuller, Littlejohn, Plessis, Roberts**) have been working with institutes within the UK (e.g. Universities of Nottingham, Exeter, Reading, Warwick, The Sainsbury Laboratory Norwich, The Sainsbury Plant Lab Cambridge) and internationally (China, Kenya, South Africa, Saudi Arabia, Spain) to develop the research base in plant physiology particularly in biotic and abiotic stress physiology. Research expertise of this group is also valued externally with ongoing consultancies with the Malaysian Palm Oil Board (**Roberts**) and DeTao Shanghai (**Fuller**). Locally, the members within the group have been collaborating with University of Exeter on funded PhD programmes on topics such as physiological responses to multiple stresses by abscisic acid in barley (**Plessis with Smirnov**) and fluorescence imaging for nutrition and disease (**Littlejohn with Talbot**). **Roberts** has also co-supervised PhD projects at University of Nottingham exploring role of F box proteins in aspects of plant (*Arabidopsis*) and crop development (*rice and maize*).

The research strategy has focussed on issues associated with South-West region and in particular to serve the development of the AgriTech sector. Recently (2018-21), this research group has been involved in utilising the Peninsular Partnership for the Rural Environment (PPRE) with the University of Exeter, Duchy College of Agriculture and Rothamsted Research (North Wyke) to develop the AgriTech strategy for Cornwall. This led to securing substantial EU-ERDF funding (£10.3M) amongst the consortium ([Link](#)). The research projects developed through this are driven as industry engaging and for this UoA has led to “Business Assists” for over 12 Cornish companies. It has also led to the establishment of a platform for engaging with farmers and growers for dissemination of research findings and technology transfer. As an example, the Plant Factory Cornwall and FIND projects (**Fuller, Littlejohn**) have led to new insights into controlled environment plant production and novel designs for LED light arrays for use in Plant Factory facilities ([Link](#)). These have been directly transferred to industry (Cornish Essential Oils Co Ltd.) and partner researchers in Saudi Arabia (Universities of Jeddah and Riyadh).

Examples of funded projects exhibiting regional, national and international collaborations:

- Plant Factory Cornwall: A controlled environment hydroponic growing system using LED lighting powered by solar panels for year-around production of high value vegetable crops and pharmaceutical herbs. Agritech Cornwall Project, ERDF; 2018-20; (**Fuller**)
- Delivering world leading marine science and technology in Plymouth. NERC. The project aimed to set up a partnership with PML, MBA and UoP to strengthen collaboration, innovation, and investment in Plymouth's world-class marine science; 2019-22; (**Roberts**).

➤ **'Plant-Insect ecology, animal and environmental biology' Theme**

The researchers within this theme have extensive network and collaborations nationally and internationally. These include the Ecology and Global Change research cluster, Leeds and Oxford University Ecosystems Lab (**Fauset**), Ghana Forestry Commission, Kofi Affum-Baffoe (**Fauset**), contributing to initiatives related to ecosystem services in farmed and semi-natural environments. Members (**Ellis, Knight**) have also wide range of collaborating partners on projects related to native bumblebee and honeybee diversity, both nationally (including the Universities of East Anglia, Royal Holloway, Sussex and Bangor, as well the Roslin Institute and the Earlham Institute) and internationally (National University of Ireland, Galway and University of Skovde, Sweden).

Hanley has been collaborating with the German Centre for Integrative Biodiversity Research (iDiv) Leipzig, through a Leverhulme Trust Grant. **Hanley** is also collaborating with NIOZ Royal Netherlands Institute for Sea Research and Utrecht University, The Netherlands co-organising Ecological Society of America Symposium Session on Plants and Coastal Flooding and co-edited the follow-up Specials Issue for Annals of Botany ([Link](#)). **Cotton** is collaborating with University of Copenhagen; Aarhus University, Denmark; Senckenberg Biodiversity and Climate Research Centre, Frankfurt, Germany on project using hummingbird-plant interactions as a model system to understand how biotic interactions vary across biogeographical or macroecological scales. **Simões** is collaborating with National University of Ireland (Galway), co-supervising a PhD project funded by the Irish Research Council on Diversity and ecology of squamate gut microbiome. As an Adjunct Lecturer, he is also collaborating with the University of Adelaide, Australia, supervising 2 PhD students.

Members of this theme have contributed to outreach work to beekeepers and urban pollinator conservation initiatives CICs (e.g. B4; Pollenize; Plan Bee exhibition at the Eden project). Researchers are also involved at national and international levels with a range of organisations including NGOs in several reports, panels and workshops operating at the interface of science, policy and conservation with particular reference to climate change research. The team has therefore made significant impact widely outside the scientific, regulatory and industrial communities. Examples of active, large grants within this theme:

- Geographical Patterns in Seedling Defence and Herbivore Interactions. The Leverhulme Trust; 2019-22; (PI: **Hanley**).
- Assessing the ecological vulnerability of natural defences and risks to agricultural land following seawater flooding. AXA Insurance Ocean Risk Scholarship. 2019-23; (Co-I: **Hanley**).
- Biodegradable Bioplastics - Assessing Environmental Risk (BIO-PLASTIC-RISK); NERC; (PI: **Thompson (UoA 7)**, Co-Is: **Handy, Hanley, Littlejohn & Plessis** with, PML and University of Bath); 2020- 24. This project has large agri-environment component.

➤ **'Water quality, impact of contaminants on fish and human health' Theme**

Researchers in this theme (**Comber, Handy, Hill, Hutchinson, Jha, Readman**) have extensive collaborations with the Universities of Nottingham, King's College London, Centre of Ecology and Hydrology (CEH), the Centre for Environment, Fisheries and Aquaculture Science (Cefas) on topics ranging from nanotoxicology (**Handy, Hutchinson, Jha, Readman**), radionuclide impact and transfer in the food chain (**Jha**) and water quality measurements including antibiotic resistance in seafood in the environment (**Jha**). In line with 3Rs principles, the group is also working to

develop alternative methods to reduce the use of live fish in experimental studies. **Jha** has been collaborating with AstraZeneca and has developed *in vitro* models which have great potential to replace live fish studies. Work in the group has also led to legislative reform leading to benefits and protection for society. The established expertise in food chain nanotoxicology has also led the group being involved with a range of stakeholders including industry, policy makers and regulators nationally (e.g. DEFRA, UK; Environment Agency, FERA, Natural England) and internationally (e.g. European Commission, OECD; INERIS, EMPHA, RIVM). The members have also been invited to contribute to policy review (e.g. UK Government Office for Science (GO Science) and internationally (e.g. OECD). In particular, **Handy** with input from others (**Hutchinson**) is leading an OECD group on establishing a new safety testing strategy for bioaccumulation hazards of nanomaterials and other chemicals in the agricultural food chain (**Handy, Hutchinson**). This participation has produced the first comprehensive review of the gut anatomy of animals in relation to nanomaterials ([Link](#)). The overall aim of this international collaboration through OECD is to build consensus on fit for purpose methodologies which will enable industry and regulatory agencies to access direct resources in order to address the growing concerns over the presence of nanomaterials in the food chain.

The group has built extensive collaborations to establish a knowledge base in water pollutants in river catchments and agricultural landscapes. The expertise developed with Wessex Water and Natural England on speciation and the fate of phosphorus led to the development of the Somerset catchment partnership on phosphorus and other chemicals in the environment (**Comber**). Similarly, assessing impacts of dairy production on catchment waters has led to a partnership development with the Westcountry Rivers Trust and Saputo on remediation of low acid events within the West Dart catchment and remediation of polluted mine sites (**Comber**). Similar partnership has been established with Atkins Ltd. to assess fate and impact of pharmaceutical concentrations in sewage effluent (**Comber**). These networked research endeavours have helped develop and reframe the Water Framework Directives with direct interaction of agricultural practices in the aquatic environments. The group has also been involved in several other national and international initiatives originating from collaborative research and development including: Animal alternatives in environmental risk assessment (Cefas, NC3Rs, Environment Agency, Home Office: **Hutchinson**); Developmental toxicity of flame retardants and fungal toxins in fish (FERA Science Limited, Defra: **Hutchinson**); Risks of chemicals to seabirds (RSPB: **Hutchinson**); Future of the Sea project (UK Government Office for Science: **Hutchinson**; [Link](#)).

Merrifield has expanded the University's international collaborations in Aquaculture and fish health (e.g. with Universidade de Chile with a jointly funded project through RCUK-CONICYT hosting bilateral research exchanges and visits of academics and researchers). In addition, **Merrifield** has long-standing similar collaborations with Universidade de Porto; Norwegian School of Veterinary Science, Universita Politecnica delle Marche, Italy; Chinese Academy of Agricultural Sciences; Catalan Institute for Water Research, Spain; Yalova University, Turkey; He has significantly contributed to the scientific understanding of the gut health of fish in relation to feedstuffs. This work is translated to industrial partners e.g. Lallemand Inc. who sponsor a permanent researcher based in the School of Biological and Marine Sciences.

In addition to funded collaborations listed below, members of the group have several ongoing international collaborations. This includes collaboration on taxonomy, physiology, biochemistry and genomics of a range of sulphur-oxidizing bacteria with University of South Florida, Georgia Institute of Technology, Atlanta; Hebrew University of Jerusalem (**Boden**).

- Bioaccumulation studies with fish and rodents using a range of nanomaterials; NanoFase: Horizon 2020; 2015–19; (**Handy**); [Link](#)
- Sustainable Nanotechnologies (SUN; EU FP7). Plymouth to conduct chronic effects studies with fishes; 2013-17; (**Handy**); [Link](#)
- Transversal Actions for Tritium (TRANSAT; EU Horizon 2020); 2017-21; [Link](#) (**Jha**)
- 3D *in vitro* models as effective alternatives to live fish studies; BBSRC, NERC, IPA with AstraZeneca; 2014-17; (**Jha**); [Link](#)

- Elucidating the potential interaction of manufactured nanoparticles with polycyclic aromatic hydrocarbons: An integrated toxicogenomics approach; NERC; Collaborative Project involving University of Nottingham, King's College London, International partner in Italy; 2014-18; (**Jha**); [Link](#)
- Legacy wastes in the coastal zone: Environmental risks and management futures; NERC High Light Grant; 2019-22; (**Comber**, Lead Partner: University of Newcastle)
- Comparative assessment of soil phosphate and heavy metal accumulation in paddy wetlands in Southern Highland Tanzania; Commonwealth; 2019-22 (**Comber**)
- Optimising biogas production using novel technologies; Innovate UK; 2016-17; (**Boden**)
- Low Cost, High Quality, Algal Biomass for Aquaculture Feed; 2017-19; Innovate UK; (**Merrifield**; Project led by Commercial Partner)
- Mucosal health and microbiota during sea lice parasitism; BBSRC; 2016-18; (**Merrifield**)
- Development of evidence-based functional date products for sport nutrition; KTP with Western Commodities; 2013 -16; (Innovate UK); (**Kuri**)
- Product development, quality, and efficiency improvement; Innovate UK, DEFRA and KTP with Langage Farm LLP; 2013 -16; (**Kuri**)

Role in advancing the science and engagement with regulatory authorities

The wide ranging collaborations of our researchers has led to significant contributions to the research base enabling our staff to play leading roles to further advance the science for societal benefits. For example, staff serve as Editors and members of editorial boards for prestigious journals as summarised below:

Agronomy (**Fuller**), Annals of Botany (**Hanley**), Annual Plant Reviews online (**Roberts** – founding Editor-in-Chief), Aquaculture International (**Merrifield**), Aquaculture Research (**Merrifield**), Ecotoxicology (**Handy, Jha**), Ecotoxicology and Environmental Safety (**Handy**), FEMS Microbiology Letters (**Boden**), Mutation Research (**Jha**), PLoS One (**Merrifield**), Journal of Fish Biology (**Handy**).

Researchers also serve on national and international committees contributing to the development of the national and international research base and to enhance the impact of our work.

Defra Expert Committee on Pesticides (**Hutchinson**), Field Studies Council Education Strategy Committee (Chair and FSC Trustee: **Hutchinson**), NC3Rs Ecotoxicology Working Group (**Hutchinson**), NERC Advisory Network (**Hutchinson**), NERC Peer Review College (**Comber, Jha, Hutchison**); OECD Environmental Test Guidelines (Member of Bioconcentration Expert Group: **Hutchinson**); UK Government Office for Science – Futures of the Sea (Marine Pollution Evidence Review Science: **Hutchinson**); Society of Experimental Biology Council (**Littlejohn**); OECD Working Party on Manufactured Nanomaterials (**Handy**); OECD Environmental Test Guidelines Expert Group (**Handy, Hutchinson**); EU Nanosafety Cluster (**Handy**); UKWIR Chemical Source Apportionment-GIS (SAGIS) Project Steering Group (**Comber**); UKWIR Chemical Investigation Programme Project Steering Group (**Comber**); World Aquaculture Society Publication Committee (**Merrifield**); BBSRC Bioscience Skills and Careers Strategy Advisory Panel, and DTP3 Advisory Panel (**Roberts, Fuller**); Vice Chair on the EU MSCF Environment and Geoscience panel (**Knight**); Member of the Biology Advisory Committee of the Malaysian Palm Oil Board (**Roberts**).

Our researchers also contribute to the research base by serving on peer assessment panels of international grant awarding bodies including:

The United States Department of Agriculture (**USDA**); Agence Nationale de la Recherche; (**ANR**); The Netherlands Organisation for Scientific Research (**NWO**); Research Council of Norway; The Portuguese Foundation for Science and Technology (**FCT**); The National Agency for the Evaluation of Universities and Research Institutes (**ANVUR**), Italy; The Israel Science Foundation (ISF); The Polish National Science Centre (**NCN**); Superior Council of the National Fund for Scientific & Technological Development (**FONDECYT**), Chile; Western Regional Aquaculture Centre (**WRAC**), USA; Czech Science Foundation (**GACR**); National Research Foundation (**NRF**),

South Africa; Russian Science Foundation (**RSF**); Ministry of Education, University and Research (**MIUR**), Italy; Fonds de la Recherche Scientifique (**FRNS**) Belgium; Latvian Council of Science (**LZP**); Marie Skłodowska Curie Actions (**EU**).

Staff also serve extensively as PhD External Examiners at other Universities across the UK, Europe (e.g. Univ. Copenhagen, Denmark; Maynooth Univ., Ireland; Universite D' Aix-Marseille, France) and the Rest of World (Univ. Malaysia Terengganu, Sindh Agricultural University, Pakistan; Univ. of the Punjab, Indian Institute of Science, India; Univ. of the S. Pacific, Fiji; Univ. Johannesburg, SA).

The UoA is committed to support its **ECR and newly appointed lecturers** to take forward the research agenda beyond the current REF period. They have already been successful in attracting external funding. Some recent examples are given below:

- Improving energy efficiency of a plant factory: can plant growth be sustained under high temperatures when exposed to specific light spectra? £8,900, Seale Hayne Education Trust (SHET), **Fauset**, 2020-22.
- Leaf temperature control of canopy tree species in a tropical forest. Presidents International Fellowship Initiative - Chinese Academy of Sciences, £5500, **Fauset**, 2019-20.
- Network for Monitoring Canopy Temperature of Forests – netCTF. NERC Global Partnerships Seedcorn Fund £100,000, (**Fauset**), 2020-22.
- Biodegradable Bioplastics - Assessing Environmental Risk (BIO-PLASTIC-RISK); NERC; £1 million, **Plessis (Co-I)**, 2020- 24.
- Evolutionary dynamics of reptile vision: How are complex traits lost and re-innovated during ecological transitions? DP180101688; Australian Research Council, Discovery Project. A\$371,347, **Simões**, 2018–21.
- FIND: Fluorescence Imaging for Nutrition and Disease, Agritech Cornwall Project, European Regional Development Fund £172,077, **Littlejohn**, 2018-20.
- Rice transgenic lines, National Institute of Agricultural Botany (NIAB); £12,000; **Littlejohn**, 2020-21.

Impact on global science:

Over the REF 2021 period, staff within this UoA have published 598 papers in peer-reviewed journals with 11,082 citations and a field weighted citation impact (FWCI) of 1.80. This indicates that UoA's publications have been cited 80% more than would be expected based on the global average for similar publications. 20.6% of these publications are in top 10% most cited worldwide and 48.0% publications in top 10% journals. Over two thirds of the publications showed international collaborations (Fig. 3) and 11.4% publications indicated both academic and corporate affiliations (Elsevier SciVal, Data Captured on 27/01/2021). This publication record highlights the strengths of our collaboration and emphasises the contribution of our researchers to the global scientific knowledge base.

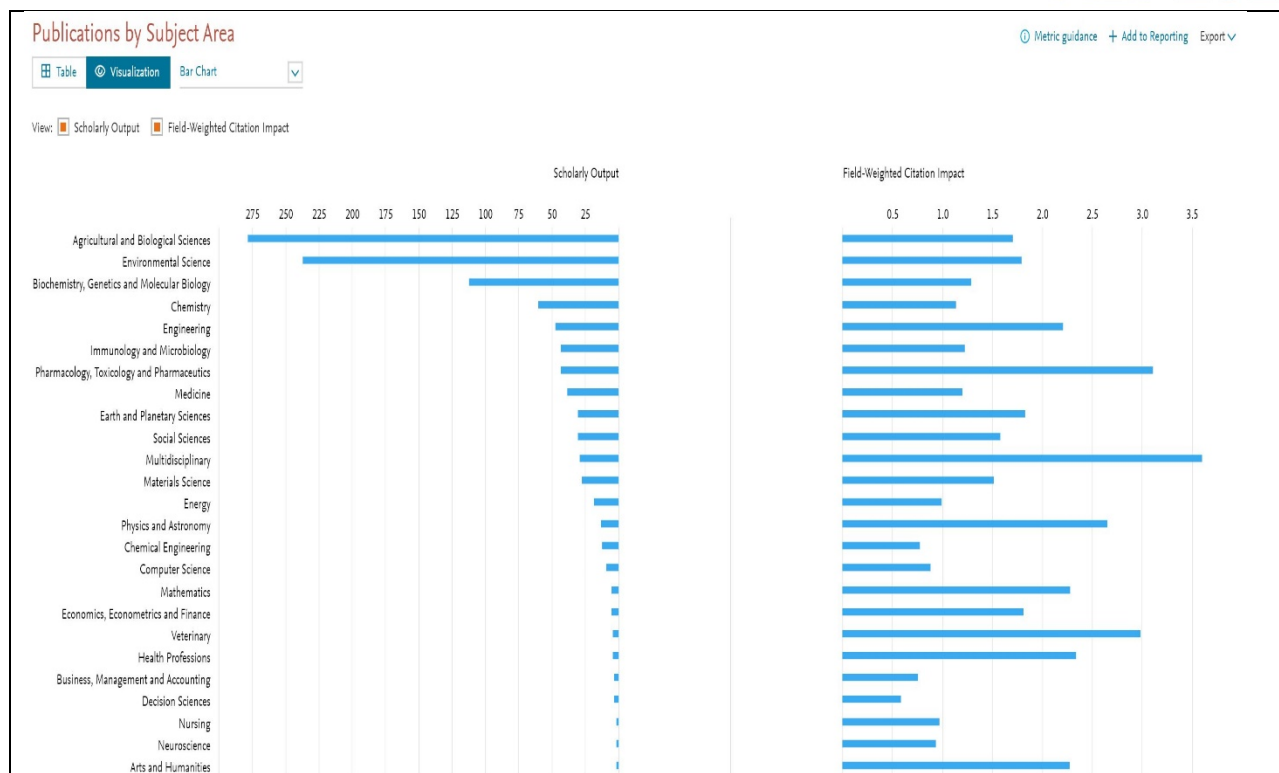


Fig.3. Field Weighted Citation Impact of subject grouping publications (2014-20) within University of Plymouth, UoA 6 (Source: SciVal; Date captured 27 January 2021).

The 5-year strategic vision for UoA6 research is to:

1. Continue to invest in internationally-leading research areas, develop and strengthen new multi-disciplinary research to tackle national and global challenges.
2. Further strengthen collaboration with regional, national and international partners to further reinforce world-leading and impactful research in terms of its breadth and significance.
3. Continue to bolster the 'one team' philosophy of the University whereby all academics, researchers and technical staff work collectively in developing the impactful research.
4. Enhance PhD numbers by capitalising on internal, external funding opportunities and new collaborative partnerships.

Continuing the enhanced income during the current REF period, staff within the UoA have achieved recent (**from August 2020 to February 2021**) success in securing funding including the following grants:

- *Biodegradable plastics as emerging environmental pollutants (BIO-PLASTIC-RISK)*, 2020-24, NERC £1.4M to UoP (PI: *Thompson*, UoA7; Co-Is: **Handy, Hanley, Littlejohn & Plessis**).
- *Wherefore the magic? Investigating the origin of psychedelic compounds in nature*. The Leverhulme Trust; 2021-24; £242,910; 2021-24 (PI: **Ellis**, Co-Is: **Hanley, Littlejohn**).
- *Nanoharmony: Towards harmonized test methods for nanomaterials*. EU: H2020. €202,985 of €3M; 2020-2023. (PI: **Handy**) [Link](#)
- *Development of nanotechnology enhanced products for medical emulsions and related applications*. Knowledge Transfer Partnership with Advanced Development & Safety Laboratories limited (ADSL); 2020-23; £157,481 (PI: **Handy**).
- *Spatial Variation in seedling defence*, The Leverhulme Trust, 2020-23; £171,046; (PI: **Hanley**).
- *Reconstructed Soils ID*, ERDF INTERREG, 2021-2023, €2.8M with €875K to UoP; (PI: Fitzsimons, UoA7; Co- **Littlejohn**).