

Institution: Bangor University (10007857)
Unit of Assessment: 7 - Earth Systems and Environmental Sciences
<p>1. Unit context and structure, research and impact strategy</p> <p>1.1 How research is structured</p> <p>Bangor University's College of Environmental Sciences and Engineering (CoESE), established in 2018, is at the centre of Bangor's ambition, since REF2014, to advance research excellence in environmental science. Our submission to UoA7 spans two Schools, the internationally recognised School of Ocean Sciences (SOS) and the newly formed School of Natural Sciences (SNS), plus interdisciplinary Centres of Excellence including the Centre for Environmental Biotechnology (CEB), Centre for Applied Marine Sciences (CAMS) and Biocomposites Centre (BC). They comprise one of the largest groupings of environmental scientists in the UK (83 Category A staff; 75.3 FTE) benefitting from shared premises, the Environment Centre Wales, with the NERC core-funded UK Centre for Ecology and Hydrology (UKCEH). We provide international leadership through world class research and delivery of impact ranging from global environmental change to sustainable food production.</p> <p>Our UoA7 research activity is led by staff across diverse disciplines, allowing fundamental understanding of the physical environment (Research Theme 1: Earth Systems Science and Physical Oceanography) and its relationship with basic biological processes (Research Theme 2: Microbiology, Biogeochemistry and Biotechnology). Theme 3 (Evolution, Physiology and Behaviour) explores the biology of organisms at a higher level, which feeds into extensive research in resource management, sustainable food production and the interface with social sciences (Theme 4: Sustainable Use, Conservation and Ecology of Natural Resources). These themes address fundamental and applied questions delivering impact of international excellence; they overlay the school/centre structures to create strong multi-disciplinary groups that foster inter-disciplinary research, build on existing strengths, and enable us to respond to the needs of industry, policy makers and society.</p> <p>Since the creation of CoESE, Bangor has established strategies that allow staff to respond rapidly to developing societal challenges (particularly those crossing disciplines), develop intra- and inter-institutional collaborations and produce research outputs and impact of the highest international level. Key strategic aims are to: a) recruit and invest in talented environmental scientists who can provide leadership in disciplinary and interdisciplinary fields (see section 2); b) develop strategic links with government, industry and NGOs across the environmental sciences in order to develop true partnerships and a joint vision in developing fundamental research to address applied problems; c) place achievement of research impact at the heart of our research agenda; d) invest in infrastructure to attain strategic research objectives and lever research funding (see section 3); e) facilitate the expansion of national and international networks (see section 4); f) continually grow post-graduate student numbers, explore innovative funding mechanisms to support interdisciplinary PhDs, and train excellent researchers able to address the environmental challenges faced by society globally; g) foster careers of technicians, post-docs and other early career researchers.</p> <p>Our strategic vision is guided through the CoESE Research Committee led by the College Director of Research (Healey) supported by staff from the University Research Innovation and Impact Office. The Research Committees of the component Schools, each with 8-10 members made up of staff from ECR's to Professors representing disciplines across the environmental sciences, provide bottom-up input to the research strategy.</p> <p>Our strategy has resulted in a strengthening of our position within the environmental field during the current REF period, evidenced by an increase of 23% in number of PhDs awarded per FTE per year, and an increase of 32% in external research income per FTE per year</p>

compared with REF2014 (when calculated on the equivalent basis of the Category A FTE submitted to UoA7 in REF2021 – change in submission composition explained in section 1.2).

1.2 Achievement of strategic aims for research and impact during the REF period

In REF2014 we made joint submissions to UoA6 and UoA7 with Aberystwyth University. Subsequently, Bangor's restructuring into CoESE has allowed us to focus investment and resource toward achieving our REF2014 strategic vision of providing leadership of environmental sciences within Wales through 'addressing the grand environmental challenges of the 21st Century' and hence make a single, Bangor UoA7 submission. We have delivered world-class research and impact through development of strengthened and new collaborative pan-Wales activities (detailed below), the consolidation of numerous areas of strength including physical oceanography and fundamental ecology (across terrestrial and marine realms), and the strategic development of a number of priority research areas.

Our performance within the Welsh Government-funded Sêr Cymru National Research Network for Low Carbon Energy and the Environment (NRN-LCEE) and BEACON+ (Biorefining Centre of Excellence, a GBP12,000,000 pan-Wales project with Aberystwyth and Swansea focussed on the conversion of biomass and biowastes into biobased products) exemplify national strategic leadership. NRN-LCEE (2013-2022) is a GBP7,000,000 pan-Wales initiative, directed from Bangor by **Thomas**, then (phase 2) by **Jones-J**. Five of its eight competitively awarded research clusters across Wales were led by Bangor: Resilcoast, QUOTIENT, Multi-Land, Climate Smart Grass, and Cleaner Cows. By the end of the NRN-LCEE, Bangor researchers had won competitive funding for 30 projects, leveraging GBP6,130,000 from RCUK, EU and other sources. Collaborative delivery through BEACON+ and via NRN-LCEE projects demonstrates the ongoing close research partnership with Aberystwyth University and the synergistic benefits of inter-institutional and interdisciplinary collaborations.

Within Bangor we have strategically prioritised investment in multi-disciplinary research, e.g. the application of fundamental oceanography and marine mammal ecology in renewable energy development, with a strong link into engineering (UoA12); the integration of fundamental microbiology and advanced modelling into forest and agricultural science and in biotechnology; a major strengthening of remote sensing and spatial modelling with cross-cutting applications across marine and forest resources and conservation; the social science interface informing environmental and conservation policy (UoA21). A notable component of our multi-disciplinarity is that over 40% of our researchers collaborate across the four research themes, forming a resilient reticulate research network.

Our goal of providing leadership in environmental sciences through the REF2021 period is evidenced below, within and across the Research themes. (All category A and B staff are listed below, category B underlined; * indicates new appointments during this REF period; only Bangor category A/B staff authors of cited papers are named):

Earth Systems Science and Physical Oceanography (*Austin, Baas, Butler, Davies-A, Gibbons, Green, Lenn, Patil, Rippeth, Robins*, Rosa*, Scourse, Valbuena*, van Landeghem*)

Bangor's *Physical Oceanography* group have a track record of over 5 decades of world-leading research, largely focusing on shelf seas and oceanic mixing processes. Over the current REF period they have used novel turbulence measurements to characterise key mixing processes in the open ocean (**Lenn,Rippeth**.2014 *Geophysical Research Letters*; **Rippeth**.2019 *Journal of Physical Oceanography*). They have compiled the first pan-Arctic Ocean map of turbulent mixing and shown the importance of the tide in supporting mixing hot spots (**Rippeth,Lenn,Green**.2015 *Nature Geoscience*), identifying the mechanisms responsible (**Rippeth,Green**.2017 *Geophysical Research Letters*). Specifically, they have focused on the increasing role of intruding Atlantic water heat in driving sea ice retreat, identifying a sea-ice regime shift in the Barents Sea (**Lenn**.2018 *Journal of Physical Oceanography*) and the growing importance of oceanic heat in

the eastern Arctic (**Rippeth.2020 *Journal of Climate***). **Lenn** leads the Changing Arctic Ocean project PEANUTS (NERC/German Federal Ministry), which applies these techniques to investigate the impact of changing mixing regimes on Arctic Ocean primary production. **Green** has developed the global tidal modelling capacity to cover deep time simulations, and led international collaborations that discovered a 'tidal super cycle' linked to continental drift (**Green.2018 *Geophysical Research Letters***), weakened tidal mixing during Cryogenian glaciations (**Green.2020 *Nature Communications***), the potential role of tides in osteichthyan evolution and the fish-tetrapod transition (**Green.2020 *Philosophical Transactions A***). Through collaboration with NASA, he is addressing questions about the evolution and habitability of an early Venus (**Green.2019 *Astrophysical Journal Letters***).

The Sediment Dynamics group assesses and predicts flow and seabed dynamics. **Baas** led the multi-institutional NERC COHBED project that investigated the role of 'sticky' biological polymers in ripple and dune stability. This has revolutionised understanding of bedform evolution (**Baas.2015 *Nature Communications***), including in the deep ocean (**Baas.2020 *Geology***) leading to development of improved numerical models for sediment transport by industry. **Austin** led the EPSRC WASP project that quantified wave energy dissipation across rocky platforms for the first time (**Austin.2018 *Journal Geophysical Research***).

Much of the work of this group provides underpinning for cross-theme strengthening, including linkage to other UoA's. For example, **Austin** and **Rippeth's** work on marine turbulence measurements, **Green's** tidal modelling and **Baas** and **van Landegham's** seabed mobility modelling are strongly linked to Bangor's marine energy research (UoA12). **Robins'** expertise in particle tracking has been integral to much of our fisheries and aquaculture research. Also, earth systems-based remote sensing and modelling (e.g. **Gibbons**-natural resources; **Patil**-hydrology) adds excellence in innovative applications within Theme 4, including forest structure (**Valbuena.2020 *Global Change Biology***) and conservation (**Rosa.2015 *Conservation Biology***) assessments.

Microbiology, Biogeochemistry and Biotechnology (Al-Dulayymi, Bird, Braganca, Charlton, Curling, Fenner, Freeman, Golyshin, Golyshina, Hill, Johnson, McDonald-J, Ormondroyd, Jones-D, Smith, Spear, Thomas-D, Tverezovskiy, Tverezovskya, Wang, Yakunin*)

Golyshin, Yakunin and **Golyshina** have a long and successful record of research in extremophiles, environmental microbiology, metagenomics and enzyme discovery for applications in biotechnology. This collaborative work laid the foundation for the creation in 2017 of the Centre for Environmental Biotechnology (CEB) and has resulted in advances in the isolation and characterization of new extremophilic taxa (**Golyshin.2016 *ISME Journal***; **Golyshina, Golyshin.2017 *Nature Communications***) as well as discovery of the first methanogenic halophilic archaea (**Golyshin.2017 *Nature Microbiology***). **Yakunin** and **Golyshin** have made important contributions to enzyme discovery (over 1000 cloned, expressed and characterised enzymes, e.g. **Yakunin.2016 *Nature Chemical Biology***) partly through leadership at a European level through the INMARE Project (24 academic and industrial partners) and have applied these to key biotechnology processes (**Yakunin.2020 *Journal American Chemical Society***).

Our work in biogeochemistry links across research themes and builds on long-standing close collaboration with UKCEH. In plant-soil-microbial interactions we provide leadership at national and international levels undertaking the most extensive survey of below-ground life in Europe (**Jones-D.2019 *Nature Communications***) within the Welsh national Glastir Monitoring and Evaluation Programme, and discovering new N-cycling processes in the warming Antarctic (**Hill, Jones-D.2019 *Ecology Letters***). **McDonald-J** is rapidly assuming international research leadership in the microbiology of the bacterial pathogens of forest trees; collaboration with the *Forest Research* agency has produced notable advances in discovery of the identity and functioning of the bacteria responsible for acute oak decline (**McDonald-J.2018 *ISME Journal***; **McDonald-J.2019 *Microbial Genomics***). **Freeman** is a long-established international leader in carbon cycling, with an emphasis on peatland where he, with **Fenner**, has made major

advances in understanding the mechanisms determining their carbon dynamics and greenhouse gas fluxes (**Fenner, Freeman.**2020 *Nature Climate Change*), also applied to impacts of aquaculture (**Freeman.**2019 *Nature Climate Change*). Our biogeochemistry extends to polar sea ice, e.g. in establishing the first metabolic pathway for production of extracellular polymeric substances in polar diatoms (**Thomas.**2018 *ISME Journal*).

The Biocomposites Centre (BC), led by **Charlton** (Biorefinery), **Ormondroyd** (Materials) and **Tverezovskiy** (Chemistry), has been at the forefront of research, development and commercial application of bio-based alternatives to synthetic materials leading to significant impact on manufacturing industry (further details in section 1.3).

Evolution, Physiology and Behaviour (*Bishop, Braig, Carvalho, Comeault*, Crandell*, Creer, Ellison*, Foote*, Georgiev*, Holland*, Malhotra, Mulley, Papadopulos*, Shannon*, Steele, Turner-G, Webster, Whiteley, Wuster*)

We use leading-edge molecular and bioinformatic approaches across diverse taxa and habitats to tackle significant and timely issues in evolutionary biology and molecular ecology. Advancing knowledge of speciation mechanisms and conservation genetics are primary objectives. **Turner-G** is an expert in African cichlid fish evolution, with recent groundbreaking research revealing the genomic architecture (**Turner-G.**2015 *Science*) and evolutionary processes underpinning the world's most extensive recent vertebrate adaptive radiation (**Turner-G.**2018 *Nature Ecology Evolution*). **Papadopulos** has significantly advanced understanding of the importance of geographic modes of island speciation (**Papadopulos.**2015 *Evolution*) and causes of variation in speciation rates amongst lineages (**Papadopulos.**2017 *PLOS Biology*). **Comeault** applied evolutionary genomics to mechanisms of parallel speciation (**Comeault.**2014 *Science*), **Foote** to convergent evolution (**Foote.**2015 *Nature Genetics*) and rapid ecotypic divergence (**Foote.**2016 *Nature Communications*) in marine vertebrates, and **Georgiev** to speciation in hominid gut microbiota (**Georgiev.**2016 *Science*) and the origin of the main malaria parasite (**Georgiev.**2014 *Nature Communications*). Applied molecular ecology is led by **Creer**, an established global pioneer in high-throughput identification of biodiversity. His NERC Highlight Topic and Standard grants led to breakthroughs in biodiversity insights derived from freshwater eDNA (**Creer.**2017 *Nature Communications*), human allergic disease and aerial grass pollen (**Creer.**2019 *Nature Ecology Evolution*).

Across CoESE we have a demonstrable track record in the behaviour and physiology of animals with a strong emphasis on animal movement. High impact work by **Bishop** on the environmental physiology of flight has revealed that contrary to predictions, high altitude flight has a significant cost (**Bishop.**2015 *Science*) and that frigate birds track atmospheric conditions during transoceanic flights (**Bishop.**2016 *Science*). **Holland's** work on navigation led to the first functional demonstration of polarized light use in a mammal (**Holland.**2014 *Nature Communications*) and use of magnetic declination to solve the longitude problem by migratory birds (**Holland.**2017 *Current Biology*). Through bioacoustics **Shannon** demonstrated that elephants can determine ethnicity and gender from cues in human voices (**Shannon.**2014 *PNAS*).

Sustainable Use, Conservation and Ecology of Natural Resources (*Cameron*, Chadwick, Cross, Cordes*, Davies-T, Gibbons, Gimenez, Healey, Heenan*, Hiddink, Hold*, Hockley, Jenkins, Jones-J, King, LeVay, Malham, McCarthy, McDonald-M, Markesteijn*, Pullin, Richardson*, Rosa*, Sinclair, Skov, St.John*, Turner-J, Waggitt*, Warren-Thomas*, Valbuena*, Willcock*, Williams-A, Williams-G**)

Bangor has an exceptionally integrated portfolio of research, built on the first three themes, that links the fundamental ecology of natural systems with their conservation and sustainable use, right through the value chain to food (both marine and terrestrial) and forest products.

Ecological science has been an internationally recognised strength at Bangor for more than 70 years, including a strong University-UKCEH partnership, reinvigorated through seven recent

appointments (section 2). One of the largest applications of Bangor's ecological science has been in *forest and shrubland ecosystems*, particularly in understanding current and future impacts of climate change. In temperate systems, ecophysiological research has led to new discoveries on the impacts of elevated CO₂ on leaf gas exchange (**Smith.2016 *Global Change Biology***) while in *tropical rainforests* major discoveries have been made showing the impact of land cover change on carbon emissions (**Healey.2020 *Global Change Biology***), thermal sensitivity (**Willcock.2020 *Science***) and asynchronous carbon sink saturation in African and Amazonian forests (**Willcock.2020 *Nature***). Another area of strength is in the integration of biogeography and ocean/landscape ecology modelling. This has provided fundamental advances in the evidence base for conservation (**Hiddink.2019 *Nature Climate Change***; **McDonald-M.2016 *Science***; **Cameron.2019 *PNAS***; **Rosa.2016 *Current Biology***).

In marine and coastal environments notable new discoveries have been made about the major ecological impacts of prey-size plastics (**Williams-G.2019 *PNAS***) and night-time lighting (**Davies-T, Jenkins.2015 *Biology Letters***). Strategic investment in the *Reef Systems* research group has advanced understanding of coral reef productivity and dynamics over local and latitudinal gradients, distinguishing natural variation in microbial (**Williams-G.2016 *Nature Communications***), benthic (**Williams-G.2018 *Current Biology***) and fish communities (**Heenan, Williams-G.2016 *Proceedings Royal Society-B***) from human-induced change. The group link ecological theory with conservation solutions, including the implications of bleaching for fish assemblages (**Richardson.2018 *Global Change Biology***).

In *Conservation and Forest Policy* **Jones-J** (new director NRN-LCEE) provides international leadership. The group has achieved major advances in understanding human impacts of conservation policies including payment for ecosystem services (**Jones-J.2020 *Nature Communications***; **Hockley, Gibbons, Jones-J.2016 *Global Environmental Change***) and oil palm certification (**St. John.2020 *Nature Sustainability***). **St. John** is also advancing fundamental understanding of human-wildlife conservation conflict (**St. John.2018 *Nature Communications***) and **Warren-Thomas** (NERC-IIASA Collaborative Research Fellow) has provided a critical assessment of the effectiveness of carbon payments for protecting tropical forest (**Warren-Thomas.2018 *Nature Comms***).

Research into *sustainable food production* spans *marine and terrestrial*. The *Sustainable Fisheries and Aquaculture* research group is delivering globally important outputs with impact (e.g. **Hiddink's** global syntheses of fishing effects on seabed ecosystems (**Hiddink.2017 *PNAS***) provides underpinning for his impact case study (ICS) on Sustainable fisheries). Aquaculture research at Bangor has a long-held focus on sustainability; several industrial, regulatory and UKRI projects with links to the *Microbiology, Biogeochemistry and Biotechnology* research theme have led to critical understanding of catchment-level impacts on safety of shellfish stocks (ICS on viral pathogens). **Chadwick** plays a leading role in major national (e.g. Rothamsted Research) and international (e.g. Chinese Academy of Sciences) collaborations in agricultural systems determining nitrous oxide emissions (**Chadwick.2018 *Science Total Environment***) leading to the ICS on UK greenhouse gas inventory. The award of a series of major UKRI and EU grants has led to important insights into high-yield farming emissions (**Chadwick.2016 *Nature Climate Change***), complemented by new modelling evidence of the benefits of diversification (**Gibbons.2019 *Environment International***).

Investment in priority research areas

Within and across the four research themes we have made strategic decisions to develop priority foci through investment in facilities and staffing. **Molecular Ecology, Biotechnology, Marine Resources, Conservation** and the intersect between **Animal Physiology and Behaviour** have been grown over the REF2021 period in staffing (23 new Category-A, section 2) and infrastructure (GBP25,400,000 for 5 new capacity-building/delivery research centres, section 3) through investment of internal and external resources. These areas now provide the focus for our challenge over the coming REF period to both maintain national and international leadership, and meet the demands of a radically changing research landscape, by providing the centre of attraction for high calibre staff and funding. In addition, a sixth strategic focus for

investment is **Aquatic Pollution** where we will coalesce our expertise in microbiology and biotechnology to address real world challenges of plastic and virus contamination of the environment to achieve societal benefit aligned with the UN's Sustainable Development Goals. Recent establishment of Bangor's new Plastic Research Centre of Wales will be a major focal point of this work.

1.3 Achievement of impact arising from research

Our Impact Strategy set out in REF 2014 was to increase the utility and accessibility of our science to provide the evidence to better inform decision making across the environmental sector. We appointed both College- and School-level Directors of Impact and Engagement in 2015, and prioritised the development of external partnerships with Government and Intergovernmental agencies (e.g. UN-FAO, UNEP), environmental NGOs (e.g. Conservation International, the Nature Conservancy (TNC)), industry, local/national land users/advisors (e.g. Woodland Trust) and the general public. The achievement of impact has become embedded within our staff's research philosophy, a significant driver for which has been Bangor's global leading expertise in the application of systematic review through **Pullin's** major role (founder and current Chief Executive) in the Collaboration for Environmental Evidence and leadership of the Centre for Evidence Based Conservation at Bangor.

We prioritise **early engagement with users and stakeholders** to explore and understand their needs. Many of our longstanding partnerships with overseas NGOs (e.g. LI-BIRD, Nepal) and overseas government departments have been active for sufficient time to have changed government policy. This is demonstrated by the Global rice breeding ICS and Turner's work in the Cayman Islands, which has led to their Government expanding the area of no-take MPA protection from 14% to 45% of coastal waters, demonstrating best practice in the Caribbean region. The Centre for Applied Marine Sciences (CAMS) is an excellent example of our proactive approach to interfacing with end-users (e.g. Minesto, Stena, Shellfish Association GB, and over 100 other companies), delivering on technology transfer and economic development through over 40 externally funded staff. Major funded projects (see section 3) are based on collaborative research with fisheries (contributing to both the Viral pathogens and Sustainable fisheries ICS's), marine renewables and aquarium sectors.

The **self-funded Biocomposites Centre (BC)**, which focuses on biomaterials and biorefining, is based on a similar approach through direct collaboration with large multinationals, SMEs, micro businesses and research institutes. We have supported industrial implementation of biorefineries and development of a biorefinery-based economy through the BEACON development and knowledge exchange programme (GBP5,700,000 to Bangor during this REF period). BC has demonstrated the effectiveness of impact-centred contract research embedded within academic structures, leading to numerous success stories including research on non-toxic wood preservation leading to major commercial investment in a new timber modification enterprise (Lignia Ltd). Innovate UK funding has been secured to develop the world's first Medium-density fibreboard recovery system. BC's research-to-impact expertise has led to collaboration with over 100 SME's, created 35 new jobs and directly informed government bioeconomic strategy. Current industry-collaborative research on synthesis of chemical intermediates for the pharmaceutical, animal healthcare and agrochemical sectors, and development of wool as insulating medical packaging have high commercialisation potential.

Our flexible research structure outlined above enables an **agile approach to opportunities** identified by end-user partners. This model is exemplified by the NERC-funded VIRAQUA projects (includes staff across 3 research themes), which provided the basis for our rapid response to the national priority of research to improve COVID-19 monitoring as featured in the Environmental virus monitoring ICS.

1.4 Progress toward an open research environment

Bangor has made significant progress in developing an open research environment, going well beyond the REF requirements. Our approach, which follows the **Concordat on Open Research Data**, has become embedded in our research philosophy through the Research Committees, through staff development activities at University, College and School levels and through individual projects/staff disseminating best practice.

IMARDIS (The Integrated Marine Data and Information System ~GBP1,500,000-2,000,000) is an example of best practice developed in response to the recognition that marine industries in Wales were limited by lack of timely access to relevant data. It provides a single point of access to data, products and services derived from the collaborative research carried out between Welsh industries and Bangor University. IMARDIS adopts established UK metadata standards and is INSPIRE compliant, ensuring data are harmonised with existing UK (e.g. NERC Data Archive Centres) and European (e.g. EMODNet) data infrastructures.

A wider benefit of IMARDIS is in spreading a data-sharing culture and prompting a step change in adoption of best data management practice, demonstrated by numerous examples across the College. For example, the Benthic Impacts Tool (BIT), a decision-support tool to quantify the impact of bottom-towed fishing activity (featured in the Sustainable fisheries ICS), is freely available through the JNCC website. Further, numerous staff use GitHub to host full open-source code. The datasets on which much of our science rests are publicly available through a variety of platforms including Dryad Digital Repository, the British Oceanographic Data Centre, the National Center for Biotechnology Bioinformatics and the European Nucleotide Archive.

1.5 Support of a culture of research integrity

Bangor University is committed to the highest standards and complies with the Concordat to Support Research Integrity. We have a vibrant College Research Ethics committee (with representatives from across disciplines and career stages) with responsibility for ensuring that ethical issues raised by our research are properly considered and addressed from the project design stage. The committee provides training on research integrity and ethics (annually for PhD, MSc and BSc researchers). We also hold research ethics seminars where issues are shared and discussed among researchers. The committee is responsible for reviewing research conducted in the College to ensure that the dignity, rights and welfare of human participants are upheld. Animal welfare in research is monitored by a separate body.

2. People

2.1 Staff

Staffing strategy

We have a dynamic, collegiate and supportive working environment that values staff at all stages of their careers. There are 83 Category A staff in UoA7, of whom 73 conduct teaching and research (13 Lecturer, 22 Senior Lecturer, 11 Reader and 27 at Professor grade), with 10 others on research-only contracts. We attract and retain staff operating at the highest international levels; for example, **10 staff are listed in the top 130,000 researchers globally** based on 23-years of Scopus data with self-citations excluded.

Academic Appointments

Over this REF period, the appointment of **23 new Category-A staff** (35% female; 7 Fellows; 13 Lecturers, 1 Senior Lecturer, and 2 Professors) **with excellent research profiles has added to the vitality of research in this UoA**. To enable the development of staff research, we enact a policy that all Teaching and Research academic appointments (except short-term cover) are

permanent positions. We continue to attract international talent from the EU and further afield (to >40% of these posts). We have also attracted Research Fellows with independent funding (66% of whom are female), with particular support for those leading to permanent academic appointments, including BBSRC Future Leader Fellowship (**Ellison**), Leverhulme Trust Early Career Fellowships (e.g. **Crandell**), Marie Skłodowska-Curie COFUND Fellows (e.g. **Heenan**, **Markesteijn**, **Foote**), and to Individual Fellowships (e.g. NERC/IASA, **Warren-Thomas**).

Strategic appointments to enhance capacity in the **priority research areas** outlined above, particularly relating to UKRI's professional skills needs in the environment sector have been demonstrably successful:

Growing strength in the field of **Conservation** has been enhanced through 5 new appointments, particularly targeted at increasing social science research capacity. These include: **St John** (whose work on conservation social science subsequently won an ERC starting grant) and **Willcock** (who quickly gained two interdisciplinary grants from the ESRC on ecosystem services) and two others submitted to UoA21 (Sociology). To achieve our strategy of establishing technical strength in the physical assessment of threatened habitats, in 2018 we appointed **Rosa**, who links remote sensing with modelling spatial data, and **Valbuena**, who models LiDAR data to quantify ecosystem structure and biomass stocks. These appointments were immediately successful, e.g. **Rosa** recently won a H2020 award and generated the successful fellowship of **Warren-Thomas**) and **Valbuena** was awarded an International Union of Forest Research Organisations Outstanding Doctoral Research Award in 2019.

In developing strength in **Marine Resources**, we prioritised appointment of physical-science staff to underpin both biological resources (fisheries and aquaculture) and renewable energy. **Lenn**, an expert in observational oceanography and remote sensing, moved from a NERC Independent Fellowship to a lecturing position in 2015 (lead of NERC Changing Arctic Oceans project 2019-2021 and co-I on NERC ArctiCONNECT project 2020-2023); **Robins** was appointed Lecturer in 2017 (lead of NERC UK Climate Resilience project 2020-22) and through expertise in shelf sea modelling provides important linkage with UoA12 (Engineering) where our marine renewable energy staff are submitted. This energy focus is extended by the appointment of **Waggitt** and **Cordes**, with expertise in top-predator interactions with tidal energy structures. **Williams-G** (appointed in 2015) has brought international excellence (e.g. 4 Nature-family journal papers, 6 Philosophical Transactions/Proceedings Royal Society, 3 PNAS, since 2014) and reinvigorated the reef systems group.

Our strategic focus on Biotechnology led to the establishment of CEB in 2017. Appointment of the senior academic **Yakunin** in 2018 cemented our expertise in enzyme discovery and extended it to protein biochemistry and biotechnology applications. This appointment facilitated CEB's access to new grants (NERC, ERA CobioTech, Capacity Building Acceleration Award) and expanded collaboration with industrial partners (e.g. Bayer, ALMAC, Evonik) in biocatalysis, plastics recycling and food processing.

Our position as a leader in **Molecular Ecology** across diverse systems has been enhanced since 2014 through investment in 3 new positions adding applications in molecular parasitology (**Ellison**) and invasive species genetics (**Comeault**). **Papadopulos**, appointed in 2017, is a leader in integration of genetics, genomics and ecological analyses/experiments, and brought immediate success with 2 NERC grants totalling almost GBP1,000,000.

We have further strengthened capacity linking **Animal Behaviour to Physiology** through 4 new appointments including **Georgiev** (Director of the Zanzibar Red Colobus Project) and **Holland**, who has established himself as a leading international researcher in animal navigation (promoted to Professor in 2020) with a focus on cognitive processes and sensory mechanisms leading to a series of high profile papers. **Crandell** brings innovative research on animal movement through application of engineering principles, while **Shannon** is a leading researcher on behavioural effects of anthropogenic noise.

Supporting staff to develop their research careers

The central pillar of staff development is performance development review (PDR). All staff meet a senior colleague annually to review achievements, discuss plans and remove constraints. This feeds into school-level assessment of workload allocations (agreed in consultation with staff). Furthermore, mentoring is now embedded within the culture of CoESE: our academics take advantage of the College and University schemes, and we actively mentor individual research projects and publications (e.g. via a formal, College-led mentoring system for staff developing all UKRI grants).

Supporting staff in the establishment and maintenance of external networks through conference presentations, workshop attendance and other activities is a high priority. The school research committees administer funds to support staff in external activities (totalling over GBP60,000 per year), including those targeted at research grant acquisition or outputs/impact; more than 85% of applications were funded. We support applications for sabbaticals every 5-6 years, recognising their importance for research career development. The many successful examples include: **Jenkins'** 9 months in Brazil developing regional and national contacts, which led to a number of successful UK-Brazil collaborative grants and promotion to Professor; **Jones-D** at University Western Australia, which forged ongoing collaboration in cutting-edge NanoSIMS technology and **Jones-J** at the Cambridge Conservation Initiative (yielding a series of high profile collaborations) and International Union for Conservation of Nature (generating international research impact).

Support for new and early-career staff is an important strategic component of staff development. We prioritize projects proposed by Early-Career Researchers (ECR's) in selection for Doctoral Training Programmes (DTP), e.g. **in the NERC-funded Envision DTP, 3 of the 8 projects selected in each round by Bangor are ring-fenced for ECRs.**

We also support ECR's (e.g. **Rosa**) to apply for a place on the *Welsh Crucible*, a pan-Wales Higher Education Funding Council for Wales/university-funded programme, to develop their research innovation, interdisciplinarity and impact. **UoA7 staff are integral to University-level career development initiatives targeting ECR's**, e.g. through the University's Researchers Development & Concordat group (**Willcock**) and Research Leadership programme. The latter was developed in 2018 by a team including **Jenkins** and **Thomas** to provide training, mentoring and support in research career development: 8 (5 male, 3 female) of our staff have participated in the past 2 years.

All of this has contributed to Bangor's success in the European Commission "HR Excellence in Research" award, which we have held since 2012 (renewed every 2 years with external review every 4 years). **Success in staff development is evidenced by 46 promotions (89% promoted due to 'Research Excellence')** that include 1 Research Fellow, 3 Senior Research Fellows, 3 Lecturers, 5 Senior Lecturers, 11 Readers and 13 Professors. **This is a >30% increase in promotions over the previous REF period.**

2.2 Research students**Recruitment and funding**

We have substantial investment from diverse national and international sources in PGR training since 2014, including by UKRI (44 studentships), EU (32), Government departments, charities and industry, contributing to 246 post-graduate research students recruited to UoA7 (2014-2019). Bangor co-leads (**Jones-D** and **Chadwick**) the joint NERC/BBSRC-funded (GBP3,300,000) *STARS Centre for Doctoral Training* in soil science (2015-2022), a consortium of 8 universities (Bangor, Cranfield, Edinburgh, Kent, Lancaster, Nottingham, Sheffield and Southampton) and 4 research institutes (British Antarctic Survey, British Geological Survey (BGS) and Met Office). We were also awarded the second round of NERC funding for the *Envision DTP* (total value GBP10,000,000, 2019-2027; increased from GBP6,500,000, 2014-2022; Bangor PI **Healey**), which brings together 3 universities and 3 research institutes with

industry and NGO partners to train a new generation of environmental scientists, funding 5 PhDs per annum to Bangor on average. Envision has funded joint PhD studentships across Bangor schools and with our partners at Lancaster and Nottingham Universities, BGS, UKCEH and Rothamsted Research. These doctoral training schemes also support global research collaborations facilitated by internships, exchanges and fieldwork opportunities with Case partners in both government (e.g. National Oceanic and Atmospheric Administration (NOAA), Welsh Government) and non-government (e.g. The Nature Conservancy) organisations.

Bangor also leads the *Knowledge Economy Skills Scholarships [KESS] scheme* (European Social Fund), which funds PGR scholarships for collaborative research between Welsh universities and industry. KESS 1 (2009-2015, GBP31,500,000) funded 14 PhDs and 19 Research Masters to UoA7 in Bangor, while KESS 2 West Wales (2015-2023, GBP40,400,000) and the recently awarded KESS 2 East Wales (2019-2023, GBP16,000,000) deliver another 54 PhDs and 6 Research Masters to UoA7. In addition, we were partners in FONASO Erasmus Mundus (2010-2016; GBP5,800,000) Joint Doctorate Programme “Forests and Nature for Society” and continue to attract excellent students on government-funded scholarships from around the world including Nigeria, China and Turkey.

At the census date we had 177 PGR students across UoA7, with an increase of 23% in numbers of PhDs awarded per FTE per year since REF2014 (when calculated on the equivalent basis of the Category A FTE submitted to UoA7 in REF2021).

PGR training and support

We firmly believe that research students perform best when fully supported. Bangor University’s **Doctoral School** is responsible for the University-wide policies and practices that underpin research degrees, and provides a comprehensive training and development programme incorporating key concepts from the Researcher Development Framework. For example, the University offers a PGCertHE aimed at PGR students that provides key skills for future academic careers. In line with the QAA Quality Code, the Doctoral School provides training on supervision and examining for research supervisors, which is obligatory for probationary staff, and for all staff intending to supervise UKRI and KESS-funded studentships (**52 UoA7 staff have undertaken supervisor training in this REF period**). A team-based approach to PhD supervision is mandatory to ensure early-career supervisors are mentored by more experienced staff.

We have continued to improve the training and support available to PGR students, formalising and standardising procedures through the **CoESE Postgraduate Research Committee** led by **Hockley**. All students have at least two supervisors and a committee consisting of an internal examiner (an expert in their field) and a Chair (a senior member of staff). The Chair also acts as the student’s personal tutor providing a backstop of pastoral support. PGRs also have full access to student advice and counselling services.

Following University and College guidelines, all PGRs receive inductions at university and college levels (held 3-times per year) as well as targeted refreshers for 2nd and 3rd years. A training needs assessment is completed by new students in conjunction with their supervisor, and regularly updated. Skills training is offered at school, college and university (Doctoral School) level. These cover generic skills (e.g. research integrity, ethics procedures), and provide a range of specialist courses (e.g. Python programming, GIS, systematic reviews, data visualisation, social science methods). Training is also delivered via Envision DTP, STARS CDT and KESS programmes (e.g. Envision programmes include Research Skills and Techniques delivered by Lancaster University, Careers Advice from UKCEH, Geoscience Modelling from BGS, and many others). Each year, PGRs present their research plans/results to an audience of staff and peers. The schools also provide support to attend external training, and to supplement PhD Scholarships (e.g. Drapers’ Company and Sir William Roberts) where a shortfall between a scholarship bequest and UKRI standard rates exists. This has enabled disadvantaged students to conduct fieldwork across Wales, as well as attend key conferences and *Women in Science* training events.

Our goal, through skills development, is to foster the next generation of environmental scientists, not solely for academia but also for industry. For example, we run the STARS CDT Professional Internships for PhD Students (PIPS), a one-month placement with industry, government (e.g. Defra, Welsh Government) or research organisations (e.g. RBG Kew). This is supported by annual industry-focused career workshops and fairs. **STARS and Envision also funded UK National Productivity Investment Fund placements aligned to the UK's industrial strategy. Via KESS 1, Bangor completed 73 PhD and 84 Research Masters projects across Wales, all linked with local company partners. KESS 2 has continued in similar fashion and will partner over 500 businesses with academics and postgraduate research students.**

Monitoring and outcomes

Students meet their supervisors frequently but at least one meeting per month must be logged in the student's online record. We also have dedicated support staff who focus entirely on college PGR matters (1.5 FTE).

Students meet their committee at least annually for a formal progress review. The review ensures students have access to the resources/training they need and monitors progress, as well as giving feedback on plans as they develop, and checks how the supervisory relationship is functioning.

PGR representatives meet regularly with academic PGR leads (3 in this UoA covering different subject areas) and help foster a healthy working environment. We also actively use the Postgraduate Research Experience Survey (PRES). Overall satisfaction is very high with **the two schools scoring consistently at or above the sector and Russell group benchmarks. The average overall satisfaction 2017-2020 (weighted by response rates across schools) was 85%, above the Russell Group benchmark of 82%.** Each year staff and PGR representatives meet to review the PRES feedback and draw up an action plan to address issues raised. **These actions earned us a high commendation for the Doctoral School in the 2018 university QAA audit.**

2.3. Commitment to equality and diversity

We value the talents and skills of all staff and seek to ensure the working environment, and opportunities for career progression, are fully inclusive. Bangor University **won the 'Employer of the Year' (public sector) category in the Chwarae Teg 'Womenspire' awards in 2016.** Both Schools are fully committed to the Athena SWAN charter. SOS was awarded bronze in 2018 while SNS, as a new academic unit, submitted an application in April 2020. The former School of Environment, Natural Resources and Geography (which comprises a large proportion of SNS) gained bronze in 2016. The University-level Athena SWAN working group is chaired by **McDonald-M**, four SOS staff have been members and that School has ambitious action plans in place for progression to Silver.

Across the staff submitted to UOA7, 27% (and 16% of Readers or Professors) are women, levels that partly reflect national challenges with diversity in STEM subjects. That said, **the Dean of College (McDonald-M), Head of SNS (Whiteley) and Director of NRN-LCEE (Jones-J) are all women, and women occupy other key research leadership roles in both schools (e.g. Fenner and Cordes: respective School Directors of PGR)**, ensuring visibility and representation both internally and externally. Also, indicating trajectory, women comprise 53% of current PGRs, 36% of new hires and 25% of promotions to professor or reader since 2014. Four UoA7 PGRs have been awarded Women in Science/Equality & Diversity scholarships. We strive to improve gender balance through enhancing recruitment and promotion processes. Since 2014 all staff chairing recruitment panels must have completed training on Unconscious Bias (new module recently rolled out for all staff) and all interview panels have at least one female member. The University's online Equality training is mandatory for all staff.

We promote staff uptake of University flexible working policies to balance caring responsibilities and career progression. Currently more men than women take up part-time working, reflecting an environment where this is not seen as disadvantaging one's career. We support staff taking parental/adoption leave; maternity pay is available from the first day of employment and pre- and post-maternity support is offered to improve retention of staff returning from parental leave. Staff on parental leave are properly covered, to avoid parental-leave guilt, and have a reduced teaching load on return to work. Staff in UoA7 (**Cameron**) and the College/School Women's Network, established in 2015, were key in establishing these university-wide policies. Female staff took advantage of NRN-LCEE's 'returners' fellowships for staff returning from long-term absence for maternity/paternity, adoption, health or caring (e.g. **Van Landeghem** 2016-2018 to support her work on marine sediment mobility) and proposal writing fellowships for staff out of contract (e.g. **Hold** who used this to gain GBP1,500,000 from the European Maritime and Fisheries Fund).

Leadership is provided by College and School/Centre Equality Champions (e.g. **Spear**). College staff are active in the increasingly influential University LGBT+ Network. Support is provided to meet needs identified by Equality and Diversity self-assessment teams. The full range of Equality and Diversity criteria are important in the conduct of PDR and linked staff training, the sensitive PGR allocation to offices, timing of meetings and seminars in core business hours, unisex nappy-changing facilities, communal staff/student eating and recreation facilities, and provision of funding for staff and PGR development needs (including conference attendance) and for diverse external seminar speakers (e.g. 40% female 2016-2019 in SNS). We have achieved a marked increase in prominence of Bangor female staff and PGRs in online material and events, including a notably enhanced profile of International Women's Day.

3. Income, infrastructure and facilities

3.1 Research funding and strategies for generating research income

UoA7 research income averaged GBP10,600,000 per annum during 2013-2019 (GBP74,000,000 total) compared with GBP8,000,000 per annum for RAE2014, an increase of 33% (income is quoted throughout section 3 as the amount awarded by the funder to Bangor).

Our strategy remains to target prestigious UKRI funding in addition to other government, EU, charity and industry/private sources to ensure research vitality and sustainability. **Total research income from UKRI was GBP16,900,000**, including GBP10,600,000 from NERC, GBP4,500,000 from BBSRC, GBP1,200,000 from EPSRC, and GBP330,000 from ESRC. Active mentoring has resulted in over half of academic appointees since 2014 (majority were ECRs) securing UKRI funding. Funding from both **EU (GBP36,000,000)** and **Welsh and UK governments (GBP12,900,000)** has been significant, and targeted predominantly at enhancing research infrastructure and capacity-building (expanded on in section 3.2), while **trusts, charities and foundations** have contributed **GBP3,400,000**.

The diverse sources of research income cover the breadth of our environmental science programme, across staff at all career stages, but focused in particular on our 6 priority research areas: Marine Resources, Aquatic Pollution, Biotechnology, Molecular Ecology, Conservation, Animal Physiology and Behaviour.

Our focus on **Marine Resources** has led to notable UKRI success, supporting fundamental science. The physical oceanography group continue to achieve significant funding to provide the physical context to biological processes (e.g. NERC, PEANUTS, **Lenn**, 2018-2021, GBP216,000: establishing the role of escalating nutrient fluxes in driving productivity in the Arctic Ocean) and to improve predictive models of weather and climate through advances in understanding mixing in shelf seas (e.g. NERC, P cynMix, **Rippeth**, 2014-2017, GBP222,000). Understanding the physical basis of ecosystem-scale change feeds through to research at

national and global scales in fisheries (e.g. NERC, IMMERSE, **Hiddink**, 2014-2018, GBP622,000). Fundamental research into tides including their role in global change (NERC, MATCH, **Green**, 2019-2022, GBP593,000) also underpins more applied projects including our focus on tidal energy such as that led by **Austin** (EPSRC, 2017-2019, GBP145,000) on developing hydrodynamic metrics for parameterisation of turbulent flow in tidal races.

We have built on UKRI-funded research in **Marine Resources** by using EU funds to develop capacity and impact. Key examples are large Ireland-Wales INTERREG consortium projects on resilient blue growth in fisheries and aquaculture (Bluefish, **Malham**, 2014-2020, GBP1,100,000) and climate adaptation through ecologically sensitive coastal infrastructure (ECOSTRUCTURE, **Jenkins** 2017-2022, GBP729,000). Competitive European Regional Development Fund (ERDF) funding was secured to extend our strategic focus on marine renewable energy through establishment of the Smart Efficient Energy Centre (SEEC) linking UoA12 and UoA7 (Col's **Ormondroyd, Healey**, 2019-2022, **GBP4,600,000**) and the SEACAMS 2 project (**Le Vay, King**, 2015-2022, **GBP9,800,000**) (expanded in section 3.2). This development of a leading centre in marine renewable energy is strategically linked to energy research in other areas including the use of integrated, smart and low-carbon energy for distributing water resources (Dŵr Uisce, **Williams-A**, 2016-2021, GBP872,000) and development of eco-building materials that address poor air quality, while also radically improving energy efficiency (ECO-SEE, **Ormondroyd**, 2013-2019, GBP610,000).

In other priority research areas including **Aquatic Pollution, Molecular Ecology, Biotechnology** and **Conservation** we have taken advantage of UKRI's increasing focus on funding impactful science to support research that extends from fundamental discovery science through to applied projects with real-world environmental impact.

This approach is demonstrated in our recent strategic focus on **Aquatic Pollution** where we have built the interdisciplinary expertise and research infrastructure to develop this global priority research area over coming years. UKRI funding has enabled us to study the origin and fate of human pathogenic viruses in the freshwater-marine continuum (NERC, VIRAQUA, **Jones-D**, 2015-2018, GBP361,000) leading to significant development of COVID-19 incidence monitoring methods from wastewater both nationally (NERC Urgency, VIRAQUA II, N-WESP, **Jones-D**, 2020-2021, GBP300,000) and in Africa (EPSRC GCRF, Co-surveillance of Waste-water, **Malham**, 2020-2022, GBP324,000). Fundamental advances in understanding the survival, persistence and ecology of microbial communities in the 'Plastisphere' (NERC Highlight Topic, **Golyshin**, 2019-2023, GBP489,000) underpin practical actions including **Jones-D's** recent success in the NERC GCRF Programme on Reducing the Impacts of Plastic Waste in Developing Countries (Agricultural microplastics-food security, 2021-2025, GBP2,490,000) with collaborators in Asia and Africa, and Bangor's lead on the NERC/NRF (Singapore) SE Asia Plastics project (Col's **Robins, Hiddink, Skov**, Reduction, control and mitigation of marine plastic pollution, 2020-2023, GBP708,000).

In **Biotechnology** the practical applications of different fundamental processes have been primarily funded through BBSRC including developing novel metagenomic biocatalyst collections for industrial use (BBSRC, MetaCat, **Golyshin**, 2015-2018, GBP335,000) and economic technology to support novel herbicide production (BBSRC, BAW, **Tverezovskiy**, 2014-2020, GBP240,000). EU funding has been used to build capacity to develop innovative screening methods for industrial application of marine enzymes (INMARE, **Golyshin**, 2015-2021, GBP543,000), obtain novel functional proteins from crops (Pro-Enrich, **Charlton**, 2018-2021, GBP401,000) and extract metals from deep ore deposits (BioMOre, **Johnson**, 2015-2018, GBP302,000).

UKRI and the Leverhulme Trust support leading international research in **Molecular Ecology**. Research into eDNA over this REF period has progressed from basic research into the mechanistic basis of the technique, through to the development of applied tools. This is exemplified by **Creer's** work on the ecology of airborne pollen diversity and implications for human health (NERC, PollerGEN, **Creer**, 2016-2019, GBP405,000) plus the ecological

relevance of eDNA in freshwater lotic ecosystems (NERC Highlight Topic, LOFRESH, **Creer**, 2015-2020, GBP532,000). Other successful use of cutting-edge molecular tools supported by UKRI includes forecasting potential biodiversity losses from ecological and evolutionary patterns and processes (NERC, **Papadopulos**, 2018-2021, GBP298,000) and engineering tree microbiomes for disease suppression (BBSRC, FutureOak, **McDonald-J**, 2020-2023, GBP931,000). Complementary Leverhulme Trust support for **Molecular Ecology** has been important in funding ambitious and innovative research on the evolution of new sympatric species (**Turner-G**, 2014-2018, GBP204,000) and mapping of novel model species' genomes (**Mulley**, 2016-2019, GBP182,000).

In natural resources and **Conservation** we have utilised UKRI funding to develop tools for science end-users, e.g. for soil nitrogen status (BBSRC, **Jones-D**, 2017-2020, GBP317,000), N₂O emissions (NERC, Upland-N₂O, **Chadwick**, 2015-2019, GBP458,000) and ecosystem services via mobile phones (ESRC, MobilES, **Willcock**, 2018-2021, GBP219,000). Our global strength in **Conservation** is also supported through private trusts. The Bertarelli Foundation have supported **Turner-J's** research in the Chagos archipelago (2018-2022, GBP999,000) to determine whether marine protected areas increase ecosystem resilience to climate change. The Leverhulme Trust funded interdisciplinary social/natural science research led by **Jones-J** to determine if payments for ecosystem services can deliver both environmental and livelihood benefits (2015-2019, GBP249,000). This builds on her NERC/ESRC-funded research (including two 2014-2017 Ecosystem Services for Poverty Alleviation Fellowships) that led to the impact case study on the Social impacts of different models of conservation as experienced by local communities. In applied natural resources research, **Chadwick** has gained EU funding to strengthen capacity to identify emission hot-spots in dairy pastures (Target-N₂O, 2018-2021, GBP210,000) and develop new bio-based fertilisers from organic waste upcycling (FertiCycle, 2020-2023, GBP217,000).

Looking ahead, to develop our priority research areas a central strategy is to promote and support high-achieving Early Career Researchers. This includes an **ERC Starter Grant** to **St.John** to resolve the links between poverty and rule-breaking in conservation (WILDPOV, 2018-2023, GBP1,100,000) and 10 Marie Skłodowska-Curie postdoctoral research fellowships, including research on the natural and human drivers of tropical reef fish communities (FISHSCALE, **Richardson**, 2019-2021, GBP167,000) and characterisation of microbial communities inhabiting subterranean acidic mine environments (PARMIN, PI- **Johnson**, GBP167,000). This funding for ECRs has been complemented by Welsh Government support through the COFUND-EU Marie Skłodowska-Curie scheme (e.g., **Foote** and **Markestijn** in SNS, and **Heenan** and **Richardson** in SOS).

3.2 Infrastructure supporting research and impact

Our strategic investment in core organisational, specialist, operational and scholarly infrastructure and facilities is the basis for increasing research vitality and sustainability across our research themes and priority areas. Since 2014, we invested heavily in improving this infrastructure through funding of five major research centres (GPB25,400,000) – detailed below.

New infrastructure developed using ERDF funding has enhanced capability in **Biotechnology** through the new Centre for Environmental Biotechnology (CEB) (**Golyshin**, 2017-2022, **GBP5,000,000**), including research into mining the biosphere for novel enzymes and biomolecules of industrial biotechnological relevance, and promoting green growth through the innovative use of natural resources. Other notable investment includes the new Smart Efficient Energy Centre (SEEC) that links UoA12 and UoA7 (Col's **Ormondroyd**, **Healey**, 2019-2022, **GBP4,600,000**) and the Biorefining Centre of Excellence (BEACON+ and East) (**Charlton**, 2015-2022, **GBP3,200,000**). SEEC is a major strategic investment for the University in interdisciplinary research spanning environmental science and engineering. It links three low-carbon energy sectors (ocean, nuclear and energy-efficient structures) to its big-data cyber-

infrastructure hub. Importantly, SEEC is targeting long-term capture of new research funding by transforming capacity to model decadal data sets across the marine energy sector. These methods will then be applied to sensor networks in either building structures or nuclear facilities to establish a major strategic contribution to energy sustainability.

ERDF funds have also advanced research within Research Theme 4, in particular in **Marine Resources** through the creation of the Shellfish Centre (**Le Vay**, 2018-2021, **GBP2,800,000**) and SEACAMS 2 (**Le Vay**, 2015-2022 **GBP9,800,000**). The Shellfish Centre has facilitated new partnerships with businesses across the UK shellfish sector, for example Fowey Shellfish, Deepdock Ltd and Tethys Oysters Ltd, to develop existing and new/underexploited shellfisheries, aquaculture and related supply chains. SEACAMS2 is a partnership project between Bangor and Swansea Universities to develop economic opportunities in Low Carbon, Energy and Environment in Wales through commercial application of research and innovation in marine renewable energy, climate change resilience and resource efficiency. SEACAMS2 supported research has resulted in two ICS's across disciplines: Marine renewable energy (UoA12, Neill) and Sustainable fisheries (UoA7, **Hiddink**).

Success of investments in new infrastructure has benefited from **continued investment in existing core infrastructure**. For example, on our Menai Bridge site, the Marine Centre Wales (MCW), which houses the Centre for Applied Marine Sciences (CAMS), has been an integral part of the new SEEC, Shellfish Centre and SEACAMS2. MCW is a national resource designed to integrate research, innovation, commerce and policy in the marine sector. MCW houses ~50 research staff and academics across Research Theme 1 (Earth Systems) and Theme 4 (Natural Resources) providing them with conference facilities, well-equipped laboratories and aquaria. Since its opening, MCW has provided hot-desking and workshops/conferences to support over 100 companies/external organisations, including industry (BAE Systems, Horizon Nuclear Power, Global Aquaculture Alliance, Milford Haven Port Authority), government (Natural Resources Wales, Irish Embassy) and regulators (Food Standards Agency, Public Health Wales). This innovative approach to partner co-working has stimulated over 60 collaborative research projects (value >**GBP20,000,000**).

Complimenting MCW, on the SNS site, is Environment Centre Wales (ECW), a partnership between Bangor and UKCEH. This facility has benefitted from continued investment through this REF period and provides a unique and sustainable research environment for over 100 scientists ranging from Professors to MSc students. Shared spaces foster interactions with key research partners and end users including Natural Resources Wales and Forest Research (whose Welsh base we have recruited to ECW since 2014 through our strategy to develop Bangor as a hub for forestry research). Co-location of CoESE scientists from environmental and genomic fields with UKCEH scientists and stakeholders, complemented by open-science knowledge exchange, has resulted in ongoing inter-institutional collaboration since 2014 on flagship and impactful UKRI-funded research, including NERC Highlight Topics (e.g. LOFRESH, **Creer**, 2015-2020, GBP532,000), NERC Large Grants (e.g. DOMAINE), STARS CDT and Covid-19 national monitoring, as well as the internationally-pioneering **GBP3,600,000** Environment & Rural Affairs Monitoring and Modelling Programme (ERAMMP), which is transforming the evidence-base for Welsh Government environmental policy making.

Defra grants (PI-**Chadwick**; total GBP317,000) supported two phases of the Sustainable Intensification Platform and other infrastructure developments at the Henfaes Research Centre, further enhanced through two BBSRC/Newton-funded Centres for Agricultural Nitrogen (GBP784,000) and Welsh Government capital funding. This has substantially increased capacity for research on sustainable food production. Henfaes is a 252-ha resource providing unrivalled capacity to research diverse environments, land use and GHG fluxes across an altitudinal cline, from sea-level to mountain, a major focus for PhD projects. It hosts the University's Centre for Hill and Upland Management whose commercial sheep unit supports research into environmental impacts of management regimes, e.g. Uplands-N₂O (PI-**Chadwick**, NERC; GBP458,000). Together these key infrastructures enable our research that informs the farming industry's drive for climate-smart management linked to key policy changes, notably UK Net-

Zero Carbon and Clean Air Strategies. Through this investment Henfaes has gained designation as a Global Farm Platform Network site and Linking-Environment-And-Farming Innovation Centre. Henfaes also hosts the bequest-funded Sir William Roberts Centre for sustainable land use, a new collaboration amongst CoESE staff, students and partners to foster interdisciplinary sustainability research.

Several of our priority research areas have benefited from investment in **specialist infrastructure and facilities**. For example, within CEB the **Biotechnology** research group gained a GBP2,600,000 state-of-art equipment investment, including liquid handling robotics for high-throughput cloning and expression of proteins, microscale bioreactors and specialist mass spectrometers (ion mobility spectrometry and triple quadrupole LC-MS for targeted metabolomics). Together they provide world-leading capability in enzyme and biomolecular discovery, whilst also enabling rapid advance in our new strategic focus on **Aquatic Pollution** through cutting-edge microbiological research. Additionally, establishment of the Shellfish Centre has generated complementary investment (GBP110,000) in two new Category II microbiology laboratories within MCW that enabled the research underpinning the Viral pathogens ICS (**Malham, Jones-D**). Finally, capabilities for cross-cutting work in geospatial analysis have been transformed through the purchase of a Terrestrial Laser Scanner (TLS), Differential Global Positioning System (DGPS), and Mavic 2 Pro Drone, enabling us to map the spatiotemporal dynamics of terrestrial and coastal ecosystems over broad geographic areas.

We are the best equipped University in the UK for research on shelf seas, supported by the RV Prince Madog. This 35-m, 390-tonne vessel hosts 10 scientists continuously at sea for up to 10 days and was instrumental in research underpinning the Sustainable fisheries ICS (**Hiddink**). RV Prince Madog is a NERC-recognised facility, owned through a joint venture between Bangor and P&O Maritime Services. To support novel **Marine Resources** research utilising the vessel, key investment has been made in three new Coastal Observatories (GBP450,000), floating multi-sensor arrays that feed real-time data to iMarDis (the data management and information portal developed through SEACAMS2) and a new multibeam seabed mapping system in 2020 (GBP180,000). Together they significantly enhance the resolution and scale of our mapping capabilities.

Our research and impact are supported by key **operational and scholarly infrastructure**. Two chief technicians coordinate 29 core-funded technicians across SOS, SNS and the research centres, and provide operational expertise in specialist equipment and facilities. These include essential laboratory, fieldwork and computing expertise, like the running and maintenance of world-class fresh- and sea-water aquaria (with Home Office-license) that support priority research areas **Animal Physiology and Behaviour** and **Marine Resources**. These were recently upgraded to include a tropical fish laboratory for the Sustainable Aquariums Project (ERDF, SNAP, **King**, GBP385,000), which is enhancing fish-breeding capabilities to reduce pressures on tropical ecosystems from aquarium-trade wild harvesting, and quarantine facilities for work through ECOSTRUCTURE on non-native biosecurity. Our technicians also provide key analytical support in proteomics, genomics, and metabolomics and the systems manager ensures 'big data' researchers have the necessary training and technical support to benefit from high-performance computing through partnership with Supercomputing Wales. Several research themes benefit from the University's 18-ha Treborth Botanic Garden (an increasingly rare resource in UK academia) comprising a diversity of woodland and rare grassland habitats, orchards, and specialist plant collections, glasshouses and below-ground rhizotron. Treborth also hosts the migratory bird facility, key research infrastructure for **Holland** and **Bishop's** work on bird migration. The garden provides vibrant citizen-science engagement with the local community through The Friends of Treborth Botanic Garden, an aesthetically inspiring filming backdrop for research outreach and impact, including a recent BBC 'One Show', and a key well-being resource for research staff, students and the public.

We promote **collaborative use** of our diverse research infrastructure. RV Prince Madog facilitates collaboration with numerous UK government partners and research institutions. For example, since 2014 she has provided core research support in sustainable management of

Marine Resources to the Welsh and Isle of Man Governments (continuing through **Jenkins**, 2020-2025 GBP896,000 Fisheries science advice to the Isle of Man; **McCarthy**, European Maritime and Fisheries Fund/Welsh Government 2019-2023, GBP960,000) providing an integrated assessment of Irish Sea fisheries and underpinning marine ecology. Collaborations with Aberystwyth, Swansea, University College Cork, the Marine Institute and Bord Iascaigh Mhara have been realised through the BLUEFISH project; simultaneous cruises with the Celtic Voyager have allowed characterisation of microbial communities around oceanographic features as part of underpinning research toward climate change policy. In **Biotechnology**, BC supports the commercial use of its pilot-scale production and testing instruments, facilitating both research collaborations and science up-take with end-user industry partners. The radio isotope facilities in ECW enable joint-funded projects with other HEIs including Bristol, Lancaster, Lincoln (New Zealand) and Western Australia. The infrastructure at Henfaes is used by collaborative partners, including Nottingham, Southampton, Sheffield, Warwick and Rothamsted Research for pot-, plot-, field- and landscape-scale research, and two BBSRC/NERC-SARIC-funded projects (both **Jones-D**, total GBP545,000) in partnership with industry (e.g. Yara, NRM Laboratories). We collaborate with UKCEH in using their ozone enrichment experimental facility also located at Henfaes.

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

4.1 Facilitating research collaborations and partnerships

UoA7 staff collaborate widely with academics, partners in industry, NGOs and governments across the world, evidenced through the wide reach of our research impact. For example, the six ICS's alone include direct impact in 47 countries across 5 continents.

The staff support outlined in section 2, plus specific funding mechanisms and outward-facing seminar series, facilitate the development and maintenance of partnerships and collaboration. SOS awards Kirby-Laing Fellowships to support sabbatical visits by international scientists (e.g. Turra, Universidade de São Paulo, Brazil and UNESCO Chair for Ocean Sustainability; Timmermans, Yale University, USA; MacKinnon, SCRIPPS Oceanographic Institution, USA). We regularly host visiting self-funding senior academics (e.g. Tripathi, Mizoram University, India, funded by a DBT-CREST Fellowship), early-career researchers (e.g. Llopis funded by Swiss Science Foundation) and numerous visiting PhD students. We support regular multidisciplinary research seminar series covering: Life and Environment, and Ocean and Geosciences; and more focused, group seminars including: Molecular Ecology, Behaviour and Physiology, Biogeochemistry, Environmental Biotechnology, Forestry, Conservation, and Marine Renewable Energy. During the COVID-19 lockdown we have been instrumental in setting up several international, virtual seminar series. These include the Sed-Online initiative and Virtual European Physical-Oceanography Shelf-Seas seminar series (co-led by **Lenn** and **Rippeth**).

Examples of major Bangor-led national and international collaborations:

- **Turner-J** leads the GBP2,100,000 Bertarelli Programme in Marine Science “Coral Reef condition in the Chagos Archipelago” Monitoring Programme with partners including UCL, Oxford, Woods Hole Oceanographic Institution and local stakeholders.
- **Green** developed an international collaborative network (NASA, Harvard, Washington, Oregon, Purdue, Lisbon, Stockholm, Upsala and Oxford Universities) including leadership of the NERC MATCHES program, which is unravelling the key role of ocean tides in the evolution of climate, and potentially life on earth and on exoplanets.
- **Smith** co-founded the joint research centre between Bangor University and Central-South University of Forestry and Technology (CSUFT) in Changsha, Hunan, China (first joint publication **Smith, McDonald-M, Patil**. 2019 *Proceedings National Academy Sciences USA*).

- **Chadwick** established academic-industry collaborations to address sustainable dairy production in Costa Rica and across South America through leadership of the GCRF *Sus-CoRiDa* project (GBP425,000), partnering with the Tropical Agricultural Research and Higher Education Center (CATIE), processors, farming cooperatives and the Ministry of Agriculture.
- **McDonald-J** pioneered work into the microbiome analysis of complex host-microbiota interactions leading to Acute and Chronic Oak decline with multiple collaborators, notably Forest Research, which has led to two recent awards from BBSRC with a total value of GBP3,400,000. **McDonald-J** also leads research into the use of synthetic landfill microbial communities for enhanced biomass conversion to biogas (SYNBIOGAS; BBSRC; GBP462,000), with Leipzig and Marseille partners.

Major long-term collaborations demonstrate the sustainability of our research and have led to important impact. Many individual staff have long-term productive links around the globe (e.g. **Jenkins, McCarthy**–Brazil 12 years; **Healey, McDonald-M**–Jamaica 35 and 30 years respectively; **Sinclair**–Kenya 25 years; **Jones-J**–Madagascar 20 years; **Skov**–Kenya 15 years; **St.John**–Tanzania 8 years). At the institutional level we have maintained collaborations through significant grant income. For example:

- Longstanding partnership with UKCEH through Environment Centre Wales (ECW) has resulted in new collaborative research including: the NERC consortium of 20 organisations led by **Creer** on understanding the ecological relevance of eDNA in freshwater lotic ecosystems (total GBP1,100,000); the multi-institution NERC large grant on dissolved organic matter in freshwater ecosystems (**Jones-D**, total GBP2,000,000); the **Jones-D**-led (with **Chadwick**) NERC/BBSRC/Defra Soil Security Programme award: Securing long-term ecosystem function in lowland organic soils (SEFLOS); and partnership in three Bangor-led NRN-LCEE research clusters (Multi-Land, Climate-smart Grass and Resilcoast). ECW is the hub of the pan-Wales UKCEH-led ERAMMP, partnered by Bangor (see section 3.2). A joint monthly ECW seminar series includes speakers from UKCEH and the University, acting as a platform to disseminate research and foster new collaboration.
- The physical oceanography and sediments groups have historically strong links with the National Oceanography Centre (NOC), British Antarctic Survey, Scottish Association for Marine Science (SAMS), Met Office and BGS (e.g. 7 joint PhD students since 2014, and through membership/leadership of the recent NERC PcynMix, COHBED, OSMOSIS, FASTNET, TEA-COSI, CandyFlos and BRITICE-CHRONO consortia) adding significant weight to our **Marine Resources** focus. Research in Arctic oceanic mixing includes collaborations with Alfred Wegener Institute Germany, Universities of Fairbanks, Yale, CNRS-Ifremer, Bergen, Institute of Ocean Sciences Canada, Norwegian Polar Institute and Lomonosov Moscow.
- We have long-established, strong links with Rothamsted Research, particularly through **Chadwick** and **Jones-D's** BBSRC-, NERC- and Defra-funded research on improving nitrogen-use efficiencies in cropping and livestock systems, and understanding the environmental and management factors that control agricultural N₂O emissions.
- **Sinclair** has 25 years of continuous research collaboration with World Agroforestry (ICRAF) – a UN CGIAR Centre), which led to a novel framework for agroecological development to be adopted internationally by the UN Committee on World Food Security, described in the Agro-ecology ICS.

4.2 Engagement with end-users to enhance impact

We have a long track record of end-user engagement and run regular impact training events to share good practice. Bangor has hosted external workshops specifically aimed at promoting end-user engagement with research-active staff, supported through NRN-LCEE. The Collaboration for Environmental Evidence, led by **Pullin** as Chief Executive, is a major international initiative spanning 7 countries (UK, Australia, Canada, France, South Africa, Sweden, USA) to engage stakeholders and systematically assess the effectiveness of natural-environment management and policy interventions. Bangor is one of 24 UK universities to receive ESRC Impact-Acceleration-Account funding, which supported **Bishop, Jones-J, Malhotra, Pullin, Rippeth, Turner-J** and **Willcock** to enhance delivery of economic and social research impact.

We support two outward-facing centres undertaking research activity based on engagement with end user partners. CAMS links academic research to real-world applications in marine sciences, as outlined in section 3. BC's industry-facing approach is demonstrated through collaborative projects with large national and multinational companies (e.g. Mitsubishi Chemicals; Huntsman Chemicals; Kronospan; Unilever; BSW; Croda, Mars, PPG, Tate and Lyle) through to SME's and start-ups (e.g. Silverlining Furniture; Lignia Wood Company; Penotec). Its work has made a substantial contribution to UK government policy on climate-mitigation strategies through promoting the role of biomass utilization in meeting UK 2050 emission targets. **Spear** and **Ormondroyd's** analyses of wood in construction for carbon-emissions abatement informed the Committee on Climate Change's 2018 report: Biomass in a low-carbon economy.

Our commitment to external partnerships and investment in impact-relevant infrastructure, has ensured that since 2014 our economic and societal contributions extend well beyond those detailed in the 6 ICS's, e.g.

- **Williams-G's** international research generating high-resolution climate projections for coral reefs is used in training workshops (e.g. NOAA, TNC) and as evidence in documents produced by the United Nations Environment Programme, Department of Environment and Energy (Australia) and UK Houses of Parliament.
- **Austin's** collaboration with the Royal National Lifeboat Institution through a NERC Partnership grant led to a change in beach risk assessment for rip-current hazards. This also led to significant outreach via various news channels including BBC TV World.
- Our PhD training is generating impact (section 2). For example, an Envision DTP PhD student supervised by **Van Landeghem**, with CASE partners NOC and Llanelli Sand Dredging, has guided sustainable sand-dredging practice (**VanLandeghem, Baas. 2019 Marine Geology**).
- **Steele's** Innovate-UK project (GBP432,000) with LGC Biosearch Technologies and South-Asian rice breeders generated novel genomic assays that are replacing 1990's markers in national programme rice improvement, while EU tomato breeders have benefitted from the new assay designs.
- **Charlton** has established the Biorefining Technology Transfer Centre and, through BEACON+, in 2014 was awarded the European Commission's Regio-Stars award for good practice in regional development.
- **Smith** and **Healey** collaborate closely with the Woodland Trust (WT) who have co-funded several PhD studentships and research projects. Agroforestry research outputs generated by their MULTILAND NRN-LCEE research cluster featured in the WT's formal proposal to Welsh Government for a new agroforestry component to the Welsh farm support scheme (2020).
- The collaboration of **Williams-A** with the water industry on the Hydro-BPT and Dŵr Uisce projects has enabled Welsh Water to prioritise potential hydropower schemes for investment to build their renewable energy portfolio in order to reduce carbon emissions and ultimately reduce water bills for consumers.

4.3 Engagement with diverse communities

As the centre for higher education for a large region, we are heavily involved in outreach. Through active dissemination at major annual cultural events, including the Royal Welsh Show (average annual attendance 250,000) and the National Eisteddfod (160,000), we promote STEM and agriculture/food stakeholder engagement. We also led the Bangor Science festival (1000 per day) until 2019 when it merged with the Anglesey Food and Boat shows to become the Festival of Discovery (1500 per day). We provide STEM activities across the region, interacting with over 70 schools during 2018-19 alone, as well as participating in the Welsh Government-funded SEREN network. In particular, **Lenn's** contribution to STEM development was recognised by reaching the national finals of the 2018 Womenspire-Chwarae Teg Awards.

Through partnership in the Time4Geography initiative **Baas** received the 2020 Silver Publishers' Award of the Geographical Association for educational videos on tsunamis. **Willcock** played a leading role in a National Geographic documentary "The Lost Forest", which has had over 1 million views since its release in May 2020. **Lenn** and **Green** produced a popular science book "30 Second Ocean" (Ivy Press) translated into 4 languages. **Skov** developed an app to estimate carbon sequestration in salt marshes (NRN-LCEE Resilcoast), now widely used by A-level students.

The novelty of our environmental research reaches beyond academia as evidenced by coverage of individual research outputs (Figure 1).

Output	Altimetric score	News outlets
Willcock.2020 Nature Communications	1920	253
Bishop.2016 Science	776	82
Shannon.2014 PNAS	703	44
Williams-G.2016 Scientific Reports	637	62
Williams.2019 PNAS	486	38
Bishop.2015, Science	399	29
Hiddink.2019 Nature Climate Change	279	17
Green.2020 Proc Roy Soc A	192	15

Figure 1: Examples of altimetric scores and news coverage of Bangor research outputs.

A notable example of the use of our environmental research in the media is **Freeman's** collaborative work with Friends of the Earth (FoE), the first to highlight the widespread contamination of inland waters by plastics (**Freeman.2019 Journal Limnology**). Widely reported (>500 media outlets globally including SKY, BBC, ITN), this is being used as evidence in the development of the "Plastics Pollution Bill" in collaboration with FoE, Women's Institute, Marine Conservation Society and Soil Association, and was a finalist in the UK's first national 'Plastic Free' award in 2019.

Other recent research-based interactions with mainstream media include: **Jones-J's** participation in the BBC's 2020 landmark (Attenborough) documentary *Extinction: The Facts*; *National TV News* (**Jones-J, Jones-D, Lenn**); *Countryfile* (PhD student supervised by **Smith**); *Gardeners' World* (**Jones-D** and another PhD student supervised by **Smith**); *One Show* (**Austin, Creer, Webster**); *In Our Time* (**Holland**); *Newsweek* (**Green, Rippeth**); *World Service Newday* (**Rippeth, Willcock**), *Farming Today* (**Healey**); *Discovery Channel* (PhD student supervised by **Smith**); *The Guardian* (**Jones-J**) and *The Observer* (**Healey**).

Bangor was an early adopter of *The Conversation* and has strongly encouraged engagement since its inception in 2010. Since 2014, >75 articles have been published by UoA7 staff and student researchers, attracting a global readership >2.5 million (1st Jan 2021), including 424,776 for **Austin's** 2016 article on rip-currents as coastal hazards.

4.4 Indicators of wider influence

The influence of our staff is indicated through prizes awarded since 2014: **Freeman** (Society of Wetland Scientists, International Fellows Award), **Austin** (British Society for Geomorphology, Gordon Warwick Medal), **Carvalho** (Fisheries Society of British Isles, Beverton Medal), **Rippeth** (Royal Meteorological Society, Vaisala Prize), **Jones-J** (British Ecological Society, Founders' Prize), **Thomas** (Learned Society of Wales, elected Fellowship). Our PhD students have also been recognised: one supervised by **Baas** was the first PhD student to be awarded the biannual International Association of Sedimentologists' Faas Research Prize. **Turner-G** had a fish (*Placidochromis turneri*) named after him in recognition of his work on Lake Malawi cichlids and The UK Antarctic Place-names Committee named an Antarctic Glacier after **Thomas**.

The **influence of our staff** stretches from regional to global scales and from academia through to government and industry via membership and chairing of numerous bodies, as illustrated by examples across a range of career stages:

UKRI panels/ committees:

- Most staff peer review for UKRI, with >15 participating in UKRI national panels since 2014.
- **Thomas** is a member of the NERC Science Committee (2017-) and has chaired numerous panels including the NERC Task-and-Finish panel for Centres for Doctoral Training (2019) and the UKRI Future Leaders Fellowship panel (2019-2020). He initiated and is Chair of the major NERC Changing Arctic Ocean programme (GBP20,000,000) 2017-present.
- **Van Landeghem** was a member of the NERC Training Advisory Board (2016-19) and Training Advisory Network (2019-).
- **Creer** is a member of the NERC Biomolecular Analysis Facility Committee

Membership of other national and international academic committees:

- **Chadwick**: National Academy of Agricultural Green Development, International Advisory Committee (2019-)
- **Patil**: American Geophysical Union, Catchment Hydrology Technical Committee (2020-)
- **Lenn**: Chair, International Scientific Committee on Oceanic Research, working group on oceanic mixing (2020-).
- **Green**: Challenger Society for Marine Sciences, Council (2014-2018), Honorary Secretary (2018-).
- **McDonald-M**: Commonwealth Scholarship Commissioner (2020-).
- **Thomas**: Chair, NOC, Association of Marine National Capability Beneficiaries Steering Board (2019-)
- **Hiddink**: Deputy Chair, British Ecological Society, Grants Committee.

Membership of government bodies:

- **Jones-D**: DEFRA Climate Change Committee
- **Williams-A**: Chair, Agricultural Industry Climate Change Forum; Welsh Government, Strategic Framework for Agriculture Group (Amaeth Cymru); Farming Connect programme (GBP45,000,000), Board
- **Jones-J**: Darwin Expert Committee, reviewer DEFRA forest/biodiversity strategy
- **Carvalho**: Natural Resources Wales, Evidence Advisory Committee.
- **Waggitt**: Joint Nature Conservation Committee (JNCC), Joint Cetacean Protocol Steering Group
- **Turner-J**: Foreign and Commonwealth Office British Indian Ocean Territory, Advisor.

Commercial/ Industry bodies:

- **Ormondroyd:** Chair, Wood Technology Society (2018-2022), Strategic Advisor, Institute of Materials, Minerals and Mining
- **Webster:** Founding Member, UK Shrimp Hub, collaborating with the first commercial shrimp grow-out facility in UK (Flo Gro)
- **Sinclair:** Leader, Consultative Group for International Agricultural Research (CGIAR), Smallholder Production and Markets research programme
- **Healey:** Chair, Institute of Chartered Foresters, Professional and Educational Standards Committee (2014-2017).
- **Williams-A:** National Farmers Union, Net Zero Science Advisory Panel.

We recognise the importance of editorship of major international journals. Within this REF period 47% of our staff have been heavily involved with editorial duties, including **Carvalho** (Editor, *Proceedings Royal Society B*, *Fish and Fisheries*, *Conservation Genetics* and *Molecular Ecology*), **Pullin** (Editor-in-Chief, *Environmental Evidence*), **Healey** (Speciality Chief Editor, *Frontiers in Forests and Global Change*), **Jones-D** (Editor, *Frontiers in Agronomy*), **Chadwick** (Editor, *Frontiers of Agricultural Sciences and Engineering*), **Golyshina** (Editor, *Scientific Reports* and Associate Editor, *Frontiers in Microbiology*), **Lenn** (Editor, *Journal of Physical Oceanography*), **Georgiev** (Editor, *American Journal of Primatology*), **Hill** (Editor, *Rhizosphere*), **Ormondroyd** (Editor, *International Wood Products*). A further 27 of our staff act as Associate Editors and/or Editorial Advisory Board Members.

All staff share their work through attendance at international conferences, with many invited to give plenary lectures and keynotes. Recent examples include: **Carvalho**, keynote speaker, *International Council for the Exploration of the Sea (ICES) Annual Science Conference* (Denmark, 2015) and the *World Fisheries Congress* (Korea, 2016); **Golyshina**, keynote presenter, *Gordon Research Conference on Archaea* (Switzerland, 2019) and *12th International Congress on Extremophiles* (Italy, 2018); **Williams-G**, invitee, International Symposium: 'Rethinking the Future for Coral Reefs', convened by the Earl of Wessex, Patron, Central Caribbean Marine Institute; **Pullin**, invitee of King Carl XVI Gustav of Sweden, Royal Colloquium 'Environmental reality: Rethinking the options'; **Green** and **Lenn**, amongst the 24 invited speakers, inaugural *Gordon Research Conference on Ocean Mixing* (USA, 2018).