Institution: Heriot-Watt University

Unit of Assessment: Earth Systems and Environmental Sciences (B7)

a. Overview

Heriot-Watt University's (HWU) environmental sciences research covers the marine and terrestrial realms, focussing focusing on biodiversity, ecosystem processes and environmental protection and management. The industrial interface with the fossil fuel and renewable energy sectors is a unique and especially strong feature of our portfolio. This research encompasses work in the **Environment Department** (ED; led by **Fernandes**) in the School of Life Sciences (SLS; headed by **Hopkins**) in Edinburgh and the **International Centre for Island Technology** (ICIT; led by **Side)** on HWU's Orkney campus. In the ED, the **Centre for Marine Biodiversity & Biotechnology** (CMBB), led by **Roberts**, provides a focus for marine and offshore research and was at the core of the RAE2008 submission. CMBB is leading the environmental sciences contribution to a £17M joint venture between HWU, the British Geological Survey (BGS) and the Scottish Funding Council (SFC) to develop the **Sir Charles Lyell Centre** (SCLC) announced in 2013. HWU's role in the SFC's **Marine Alliance for Science & Technology in Scotland** (MASTS) has further strengthened co-operation between the ED and ICIT, placing HWU in a pivotal position amongst HEIs for marine research. Since 2008, there has been significant staff recruitment and turnover leading to 12.5 FTE new researchers on the HWU academic staff, 3.5 FTE of whom are early career researchers (ECRs) and 4.0 FTE of whom are professors. This recruitment has simultaneously strengthened leadership, increased capacity and improved succession planning. It has also led to substantial strengthening of our marine and coastal science research; allowed the establishment of a new research theme in terrestrial environmental research; and supported alignment with the marine renewable energy industry.

b. Research strategy

i. Vision and strategic plans

Our vision is to place HWU's Environmental Sciences research at the forefront of the fields of marine and aquatic biology, with a particular focus on conservation and contamination research, terrestrial ecosystem science, and environmental management, especially applied to the energy industries. Our research vision aligns us with the strategic national and international priorities in environmental protection and management, and in sustainable energy production.

- For marine and coastal science, the emphases are research that advances fundamental understanding of marine ecology, in an environment subject to the pressures of global climate change and ocean acidification, and the challenges of increased and new forms of contaminants, understanding of which underpins environmental protection and sustainable use.
- For research allied to the energy sector, the goal is to contribute to the emergence of marine renewable energy and to understand the socio-economic and environmental context and challenges facing this sector, thereby exploiting the unrivalled capacity and facilities at Orkney.
- For terrestrial environmental research, the emphases are on understanding and predicting the effects of change in degraded, marginal and extreme environments, both managed and unmanaged, and advancing understanding of biogeochemistry. We aim to position ourselves at the forefront of earth systems science by integrating terrestrial, freshwater and marine research.

Our capacity will be increased to 35-40 research-led academic staff, 20-25 postdoctoral staff, and 50-60 PGR students within five years. This will be complemented by the associated 160 BGS scientists in the **SCLC** from 2014 supported with £17M investment from HWU, BGS and the SFC in new buildings on HWU's Edinburgh campus. This expansion will be achieved by further research investment and intensification, supported by competitively awarded research grants and contracts. This growth is consistent with the current trajectory of HWU's research strategy.

ii. Heriot-Watt University research strategy

HWU has launched major initiatives to realise its strategic objectives of increased inter-disciplinarity and research intensification, leading to an expansion in research academic. These objectives form the cornerstone of the 2013-18 HWU Strategy (http://www.hw.ac.uk/documents/strategic-plan.pdf) and its implementation includes the following:

- The **Global Search for Research Leaders** is the main route for new academic recruitment leading to the appointment of seven new researchers since 2011 (**Aspray**, **Fernandes**, **Gutierrez**, **Henry**, **Johnson, Wookey** & **Woolf**) and will be used for further expansion.
- Focussing research activities into a set of cross-disciplinary themes is leading to new activities. Two of the themes, **Environment & Climate Change** (ECC) and the **Life Sciences-Physical**

Sciences Interface (LSPI), feed directly into environmental sciences research. The ECC theme led to the appointments of senior researchers working in environments sensitive to change: **Roberts** brought deep-sea ecology expertise and **Porter** strengthened coastal marine research and added a biotechnological dimension; **Hopkins** founded terrestrial environmental research at HWU, and **Wookey** brings new expertise in biogeochemistry and ecosystem science. **Brown** strengthens physiological research capacity in marine organisms as part of the LSPI theme.

- The boost to research from MASTS includes **Sanderson's** (ECR) appointment, strengthening expertise in coastal and marine policy and management. Membership of MASTS also led to increased PGR student recruitment and ensures that HWU strongly influences the marine research agenda because HWU researchers have influential roles in MASTS leadership, its Graduate School, training and its specialist groups.
- HWU launched the annual **James Watt PhD Scholarships** competition in 2012 to provide three-year PGR studentships, seven of which were awarded in the environmental sciences.
- The establishment of the **SCLC** is a tangible example of HWU fulfilling its strategic objective to develop collaborations through national and international alliances, and will promote research in geoscience, marine ecology, mathematics, computing and engineering. This will also benefit from the recently-awarded **NERC Centre for Doctoral Training in Oil & Gas** at HWU.

iii. Environmental sciences plans

We will position ourselves at the forefront of environmental science research by:

- Developing joint research with the BGS including the following themes: Marine Biodiversity & Environment, Marine & Terrestrial Geosciences, Water Resources and Energy in the **SCLC**.
- Enhancing research collaboration within HWU, including the Institute of Petroleum Engineering and the Ocean Systems Laboratory in HWU's School of Engineering & Physical Sciences.
- Launching a Centre of Research Excellence in Ecotoxicology which will also link to human health research through the research of Stone (returned in UoA B6).
- Expanding ICIT to exploit its unique position at the centre of national and international partnerships linking the government, academic and industrial sectors to deliver research that addresses the global energy challenge.
- Developing our terrestrial environmental research by aligning our soil science capacity with the interests of the BGS, building on existing links with the polar science communities, and collaboration with UK and international agricultural and environmental sciences institutes.

iv. Developments since RAE2008

Environmental Sciences research at HWU has developed rapidly since RAE2008 and significant progress in three areas plus the foundation of a new theme can be reported:

Marine conservation research

The intensity of marine conservation research has increased significantly with **Roberts'** appointment (2009). He leads an international team (USA, Germany, Denmark, Spain) examining the effects of ocean acidification and warming on cold-water corals, supported by £550k from NERC and EU FP7. This has provided insights into the functional ecology of coral habitats and their vulnerability to climate change. The research has built on knowledge of hydrographic regime and food supply [output 4] leading to discoveries of unexpected natural pH variability around deep coral reefs [output 1], insights into temporal and spatial change in biodiversity [output 2], and has used geochemical approaches to reconstruct ecosystem history [output 3]. **Hennige** and **Roberts** led the UN Convention on Biological Diversity report on the effects of ocean acidification on marine ecosystems presented at UN headquarters in June 2013. Coral and algal research was boosted in 2013 by the award of a NERC Independent Research Fellowship (£500k) to **Hennige** (ECR). **Hennige** has previously demonstrated how photosynthetic characteristics underlie bleaching susceptibility in tropical corals and the unique acclimation mechanisms of coral symbiotic microalgae. The NERC Fellowship will enable **Hennige** to be the first to develop experimental coral tissue cultures to assess climate change impacts on corals [output 1].

The appointment of **Porter** in 2009 has enhanced biotechnological and biodiversity aspects of marine research. She has developed new collaborations with the Natural History Museum and internationally (e.g. University of Waikato, NZ). With grant support (NERC, EU INTERREG, EU FP7 held at her previous institution), she has developed molecular and biochemical techniques to investigate phylogeny and ecology of marine Bryozoa and related invertebrates [outputs 1-4]. Underpinned by this research, she launched a spin-out company, BryoActives Ltd, in 2011 to discover and develop novel anti-microbial compounds from marine sources for use as antibiotics.

Sanderson (ECR) specialises in applied benthic research supporting sustainable marine management, including Marine Protected Areas (MPAs). With £350k of support and collaboration from Defra, Marine Scotland Science (MSS), Scottish Natural Heritage, the Joint Nature Conservation Committee and Natural Resources Wales. He has developed novel pressure models to support the assessment of Good Environmental Status, the management of European MPAs, and monitoring rare habitats in protected areas when conventional designs fail [output 1].

The international dimension of marine conservation research work has developed through **Mair's** enduring collaborations in South and Central America (including the Smithsonian Tropical Research Institute), supported with research and capacity-building grants from Defra's Darwin Initiative and the British Council. This has resulted in designations of the Seaflower UN Biosphere Reserve in the Caribbean and the Las Perlas Special Management Zone in the Gulf of Panama [outputs 1, 2 & 4]. **Mair**'s research is applied to restoration of Caribbean coral reefs [output 3], and offshore oil and gas exploration in the Caribbean and Pacific. This theme is being developed in SE Asia with support from Royal Society of Edinburgh and is complemented by **Porter**, **Sanderson** (ECR) and **Lyndon's** work on ecology of temperate biogenic reefs [**Lyndon** output 1].

Lyndon's research on control of diseases in aquaculture was reported in a UoA 6 in RAE2008, but with the strengthening of marine sciences he is included in this UoA. His research underpins the sustainability of marine aquaculture and aims to minimise its environmental impact. He is developing probiotics and feed additives to control ectoparasite and skin infections of fish [outputs 2, 3 & 4]. Through a definitive industry-funded project (MSD Animal Health [formerly Schering Plough]) he is assessing the efficacy of novel vaccines against emerging pathogens [outputs 2 & 3]. This work facilitates the implementation of research discoveries into tangible industrial outcomes and has led to novel vaccine for diseases in farmed fish (patent number PE955013GB).

Marine contaminants and ecotoxicology research

Ecotoxicology research has been substantially intensified by the appointments of **Fernandes, Gutierrez** & **Henry**. The complementary expertise of this group now allows toxicological assessments to cover microorganisms, invertebrates and vertebrates, linked through to human health (through Stone's work returned in UoA A6). **Fernandes'** research specialises in assessment and management of eutrophication and pollution, assessment of effects and management of aquaculture, the development of sustainable estuarine and coastal zone fisheries [output 2]), and the assessment of effects and management of a range of contaminants, including nanomaterials in the environment [outputs 3 & 4]. Through her work she has set the research agenda for the ecotoxicology of nanomaterials in the environment [output 1; 550+ citations since 2008]. Her work is supported by substantial EU and NERC funding (£1.5M). Her expertise in environmental impact assessment and management has led to on-going funding from MSS to provide scientific evidence for the implementation of the Water and Marine Framework Directives [output 2].

Henry addresses the effects of toxicants in fish and has demonstrated the relative safety of nanoparticles [outputs 1], the importance of co-contaminants associated with nanoparticles [outputs 1 & 3], and the potential for natural cyanobacteria blooms to disrupt fish endocrine systems [outputs 4]. He investigates gene expression profiles linked to higher order responses to enhance understanding of DNA damage and repair, reproductive system physiology and fish responses to various environmental toxicants including pharmaceutical substances and endocrine disruptors [outputs 2, 3 & 4], cyanobacterial and algal toxins [output 4], toxic metals [output 1].

Gutierrez's research has uncovered novel taxa (including one new family) of 'specialist' oil-degrading bacteria in the ocean [output 2], including hitherto the most detailed analysis of the microbial response to the Deepwater Horizon oil spill [output 1 & 4]. This research is being developed (e.g. by whole-genome sequencing) to understand microbial responses to major maritime oil spills and to inform the development of effective response tools to mitigate environmental damage [outputs 2 & 3].

Research on the ecological effects of oil-spills and the fate of wastes and contaminants from oilfield operations continues through the work of **Hartl**. He has developed, and adapted from biomedical applications, novel bioassay systems for ecotoxicology [outputs 1, 2 & 3]. His research has revealed hitherto unknown toxicological interactions between nanomaterials and metals [output 4]. **Hartl** has established collaborations with the regulatory sector (SEPA) and international partnerships (Consejo Superior de Investigaciones Científicas [the Spanish Research Council]), and has attracted funding from EU (FP7), the Scottish and Saudi Arabian governments.

Brown has integrated traditional, genomic and physiological approaches to describe marine

invertebrate behaviour and nervous system function, especially tunicate evolution and behaviour for the first time, leading to a marine biological model for environmental and biomedical research [outputs 1, 2, 3 & 4]. With FP7 funding (€340K) held at his previous institution he used the biophysics of marine animals to describe the environmental impact of metal nanoparticles in the marine environment; this is now being developed with ecotoxicologists at HWU.

Research to support marine renewable energy (MRE) development

MRE research and its integration with other sea users is a major focus of ICIT [**Side** output 1]. Located in Orkney (with the highest concentration of MRE R&D in the world) ICIT is uniquely positioned to develop this theme. Led by **Side**, the MRE programme was highlighted in RAE2008 and has since drawn together numerous researchers and attracted several high profile awards. A SFC Strategic Research Development Grant (£1M with the University of Highland & Islands) and participation in MASTS have facilitated strong collaborative links. Industry/government support has resulted in two multi-institutional EPSRC Grand Challenge projects (**Side** as PI; TERAWATT [£1M] and ECOWATT2050 [£1M]). Earlier research that developed insights into floating tidal turbine design [outputs 2 & 4] and environmental assessment and monitoring techniques for renewables [output 3] have been widely commercialised leading to the extensive range of spin-out companies from ICIT (e.g. ScottRenewables and Aquatera, which employ 119 in total and contribute £8.8m pa GVA to the Orkney economy [HWU Economic Impact Study 2012]). Research collaborations continue with, for example, mammal/turbine collision detection equipment (from EPSRC Supergen Marine II) now installed on the Scotrenewables' tidal turbine, and noise monitoring approaches being developed with pioneering companies in the marine renewable energy sector (e.g. Scotrenewables, Voith, Wello and Pelamis). Research at ICIT combines physical and ecological modelling to meet the needs of industry and regulators and creates a preferential environment for research (e.g. SNH and Pelamis are now funding unique noise measurement and noise modelling approaches for the installed Pelamis arrays). Partnerships such as these, and with MSS, ensure results contribute directly to the governance of the marine resource.

Kerr and **Johnson** (ECR) have further developed the governance theme through EUFP7 research (Monitoring & Evaluation of Spatially Managed Areas; MESMA; £6.5m) exploring the implementation of ecosystem-based management in the context of EU marine spatial planning. This has led to a well-supported approach for the scientific and regulatory evaluation of spatially managed marine areas [**Johnson** output 1; **Kerr** outputs 1 & 4). **Kerr** established and now co-ordinates an international network (http://www.issmer-network.org; Universities of Ghent, Nantes & Washington, and Acadia University Canada, IT University Denmark, University College Cork) to explore socio-economic impacts of environmental change from MRE. Further work, on socio-economic impacts of technology-induced environmental change critically evaluates the sustainability of UN Clean Development Mechanism projects [**Kerr** outputs 2 & 3]. Again linking environmental science with governance, **Johnson** is working with MSS to install novel high frequency radar technologies for wave/tide remote sensing (£50k first phase funded by an industry-government consortium), adding value to ECOWATT2050 and TERAWATT.

Woolf has strengthened the remote sensing capability and added specific expertise in MRE resources, including an understanding of tidal characteristics and dynamics [output 3], and the relationship of tidal and wave characteristics to resource accessibility and environmental effects of extraction. He also brings a broad knowledge of ocean waves, including wave climate and impacts, and marine Earth Observation, especially radar remote sensing. **Woolf** was supported by NERC through the National Centre for Earth Observation (2008-2013; £250k) to develop novel algorithms for air-sea exchange [outputs 1, 2 & 3] and these insights are currently been applied with further support from European Space Agency (OceanFlux GHG, €350k).

Terrestrial biogeochemistry research

This new theme has been established through new appointments since 2011. **Hopkins** has substantial field experience in polar regions (including ten summer programmes in Antarctica), attracted NERC grants during the International Polar Year (2007-2009; £700k held at previous HEI), and has enduring collaborations with major Antarctic research programmes (British Antarctic Survey logistics and £200k in-kind support from Antarctica NZ). His work has focussed on element cycling in polar environments [outputs 2 & 3] and the application of modern metagenomics to the polar soil virome [output 1]. **Hopkins** extended his research from polar deserts to tropical and hot desert ecosystems and now leads a Royal Society/DFID Capacity Building Network with partners in Mozambique, Zimbabwe and South Africa. His research in agricultural systems has focussed on

quantifying and predicting effects of environmental and management change on soil carbon [output 4], and with plant biotechnologists at Dundee University he has pioneered research on the fate of residues from lignin modified (GM) plants in soils and implications for carbon cycling processes.

Wookey joined in 2013 and brings significant complementary expertise and experience in ecosystem ecology, particularly in arctic and alpine environments. His research focuses on how ecosystems both respond to the environment (and change) [output 4; see also **Wookey** et al. 2009 Global Change Biol. 15, 1153-72 (c. 100 citations) and Post et al. (including **Wookey**) Science 325, 1355-8 9 (200+ citations)] and how they influence the carbon cycle and climate system [output 1, 2 & 3]. His research is supported by NERC (successive Arctic Programme grants and access grants to the Radiocarbon Facility), and the International Arctic Science Committee. Both **Hopkins** and **Wookey**, with NERC support, work closely with collaborators in Exeter and Aberdeen Universities and Rothamsted Research on temperature regulation [**Wookey** output 2] and feedback processes in biogeochemical cycling [**Wookey** output 1].

Aspray has research expertise and extensive professional experience in brownfield site investigation and remediation, developing novel assays supporting treatability testing, remediation endpoint evaluation, and understanding of biodegradation processes [output 1]. He has secured research funding from Scottish Crucible, industry and consultancy (~£90k value since 2012). **Aspray's** and **Hopkins'** work builds on a history of applied and environmental microbiology at HWU complemented by **Gutierrez's** and **Porter's** expertise in molecular ecology and biodiversity.

c. People

i. Staffing strategy and staff development

HWU's research intensification strategy has been underpinned by a recruitment strategy that has included the **Global Search for Research Leaders**, the development of cross-disciplinary themes (e.g. **Environmental & Climate Change**, and the **Life Science-Physical Sciences Interface**), and the establishment of the **James Watt Scholarship** scheme (see also [bii]). This has enabled recruitment at all levels including injection of new leadership (**Fernandes, Hopkins, Roberts** & **Wookey**), complemented by mid-career expertise (**Brown**, **Gutierrez**, **Henry**, **Porter** & **Woolf**) and rejuvenation by the appointment of ECRs (**Aspray, Hennige, Johnson** & **Sanderson**). Overall this has led to expansion of the submission in REF2014 compared to RAE2008:

- The academic staff submitted has increased from 10.5 FTE to 17.5 FTE (67% increase).
- The PDRA population has increased from 3.55 FTE to 8.2 FTE (131% increase) to date, representing an increase from 0.33 to 0.47 PDRA FTE per academic FTE since RAE2008. This excludes 1.0 FTE PDRA in BryoActives Ltd and 5.0 FTE PDRAs starting between November 2013 and January 2014 with Wookey and Fernandes (NERC, EU FP7 and commercial support), which will take the ratio to 0.81 PDRA FTE per academic FTE.
- The PGRS population has expanded from 14 to 25 (79% increase).

The strategy is to recruit academic staff on the basis of research achievement or potential in the case of early career researchers. Our development since RAE2008 has led to a team with new vitality (3.5/17.5 FTE ECRs), expanded expertise and experience (12.5/17.5 FTE new appointments) and increased leadership capacity (6.0/17.5 FTE professors). We have also achieved a well-balanced team in terms of subject expertise (8.0 FTE marine scientists, 3.0 FTE terrestrial environmental scientists, 4.0 FTE specialist ecotoxicologists and 2.5 FTE environmental management and policy specialists). ECRs are allocated limited teaching and administration roles during the first 2 years when they are mentored intensively and supported to facilitate research and academic development. Potential candidates for prestigious fellowships (e.g. NERC Independent Fellowships – see **Hennige**) are supported by an internal review and interview process operated by HWU's "Fellowship College" during the preparation of and application for fellowships. Since 2011, the research development has been facilitated by a programme of curriculum reform that embeds research-led teaching where appropriate and facilitates research intensification.

HWU has a robust framework to support equality and diversity and has recently been awarded the Athena SWAN Institutional Bronze Status. An HWU-wide Equal Opportunities Committee oversees and advises on operational and legal compliance, and ensures effective linkages across the HWU governance structures. The positive actions that HWU has taken to support the career development of all researchers and the measures in place to implement its declared principles have been recognized externally. In 2010, it was amongst the first ten HEIs in the UK to receive the HR Excellence in Research award from the European Commission (and renewed in 2013).

ECRs are supported by the HWU **Centre for Academic Leadership & Development**(CALD)

offering the **Postgraduate Certificate in Academic Practice** that includes developing key research skills. CALD operates the **HW Crucible** and HWU's Research and Enterprise Services operates the **Converge Challenge** (See REF3a) which support staff (particularly ECRs) developing interdisciplinary and commercially-focussed research, respectively. These have been successful with **Porter** winning business development support in 2011 from the Converge Challenge to set up a spin-out company, BryoActives Ltd, and **Aspray** (ECR), **Hartl** and **Hennige** (ECR) all winning seed-corn grants in the HW Crucible.

The ED and ICIT have devolved budgets some of which are used to support initiatives by ECRs and to co-fund research studentships targeted on recently-appointed staff (e.g. with MSS, The Esmée Fairbairn Foundation, Scottish Natural Heritage). PDRAs in the ED are members of the department committee and are represented through elected representatives on the SLS Management Committee. At ICIT, PDRAs and PGRSs participate fully in the running of the Campus, attending the regular research and management meetings. All PDRAs and PGRs are encouraged and supported financially to attend and present at conferences and participate in outreach events (2 PDRAs and 3 PGRSs won the Principal's Prize for Public Engagement).

ii. Research students

Our growing PGRS population is an integral part of the dynamic, scholarly community and they contribute to increased activity in terms of both outputs and securing additional resources. They are supported by robust supervisory, monitoring and support mechanisms as well as practical and financial assistance. Each PGRS is supervised by a primary supervisor with specific and relevant expertise. A second supervisor is also allocated to provide additional support and provide cover. Where there is an additional supervisor from an industrial partner, the supervisor's credentials are confirmed by a nomination operated by HWU's Post Graduate Studies Committee. Where appropriate, projects are reviewed and approved in advance by the SLS Research Ethics committee. At the start of their postgraduate studies, PGRSs attend an induction session with the PGR coordinator (**Porter**) and with student PGRS representatives, involving introduction to the HWU PGRS Code of Practice, with emphasis on the mutual responsibilities of the PGRS and supervisors for regular meetings, progress reporting and monitoring. This takes full account the RCUK Concordat. PGRSs are provided with an induction checklist that they work through with their supervisors and PGRS representatives offer guidance on aspects of the PGRS experience.

PGRSs are provided with a tiered approach to training and development. Training and support programmes are offered in Edinburgh and Orkney. Students conduct diverse types of research, so training is often required in fieldwork, laboratory work, mathematical modelling, molecular biology, biochemical assays or imaging techniques. Some training is provided in-house and through specialist external courses (e.g. diving safety), where relevant supplemented by the MASTS Graduate School. Responsibility for progress monitoring is coordinated by the Director of Postgraduate Research Studies (**Porter**) and supported by the School's Director of Research. PGRSs participate in a tailored programme of workshops that cover scientific writing, the peer review process, presentations at scientific meetings, and a guest seminar programme. All PGRSs have access to the relevant HWU facilities, a dedicated desk and a networked PC in shared offices, all of which have been upgraded since 2011. HWU's £9M Postgraduate Centre (opened in 2010 with RCUK-SRIF and industrial support) provides an innovative approach to PGRS development and houses an auditorium, seminar, study and social spaces, and video-conferencing facilities for PGRSs.

PGRSs are encouraged to seek independent research opportunities to complement their studies. Examples include one PGRS undertaking marine research in Antarctica, based at Rothera Station for 4 months, supported by the NERC/British Antarctic Survey Collaborative Gearing Scheme, two PGRSs accessing the NERC Facility for Environmental Nanoscience Analysis & Characterisation and a further student accessing the NERC Isotope Facility.

The PGRSs (and ECRs) are also encouraged to develop research skills through the Research Futures Programme provided by the HWU CALD that complements SLS provision, and which includes organisation skills, literature survey, report writing, IT, team and project management, presentation skills, career development, ethics, business awareness and intellectual property.

PGR students are encouraged to disseminate their work through publication and conference presentation. Depending on the subject area, by the time they graduate, students can have both a substantial number of published outputs (the current maximum is nine [Osalusi]), high profile presentations (e.g. SET for Britain Awards at the Houses of Parliament in 2013 [Loxton]), or

awards for presentations at conferences, of which there have been six since the start of 2012.

Our PhD progression and completion rates reflect good practice across the research community and a several recent PhD graduates maintain enduring collaborations with HWU as they move into professional roles, such as science policy advisor with the Ecuadorian Government, leading Metocean activities for Shell Nigeria, and scientific advisor in the Ministry of Education of Thailand.

d. Income, infrastructure and facilities

i. Income

Since the end of the RAE2008 period, there has been a 6-fold increase in research income (expenditure), rising from £199k in the 2007/08 FY to £1.24M in 2012/13 FY (excluding income-in-kind). This increase is driven largely by greater success from competitive RCUK and EU sources, and reflects the effectiveness of our recruitment and research intensification strategies. In addition, during the REF2014 period there has been an estimated £600k of in-kind support for the research of **Hopkins** and **Wookey** for work in remote field locations and an estimated further £1.5M of research grant support was held at the former institutions of new recruits (principally **Fernandes**, **Hopkins**, **Roberts** and **Wookey**), neither of which are captured in REF4b.

ii. Infrastructure and facilities

The ED has extensive aquaria for cold-water corals, marine and freshwater invertebrate, and quarantine aquaria for fish health and disease research, which will be upgraded in the new **SCLC**. Associated with new recruitment, laboratory facilities have been developed for toxicology, molecular microbiology, soil biogeochemistry, and membrane biophysics. The total investment in these facilities since RAE2008 has been £650k. The new facilities complement the experimental and analytical laboratories refitted when the CMBB was established. 2013 is HWU's Scientific Dive Unit (http://www.cmbb.hw.ac.uk/facilities/seagoing-research/scientific-divers.html) 50th anniversary. The Dive Unit has operated around all parts of the Scottish coastline and four researchers (**Lyndon**, **Mair, Porter** & **Sanderson** [ECR]) are HSE Part IV qualified divers to Nitrox level and three have Trimix qualifications with collectively 100+ years' scientific diving experience. Originally established to undertake environmental impact assessments for the oil and gas industries, the Dive Unit underpins marine indicator and conservation projects, as well as supporting PGRS research. The ED also operates an 8 m inshore research vessel (http://www.cmbb.hw.ac.uk/facilities/seagoing-research/rv-serpula.htm) to support coastal research. At ICIT, the facilities also include a wet area to support diving operations and laboratory facilities to support biological fieldwork, and specialist equipment dedicated to underwater survey (e.g. remotely operate vehicles, drop camera, underwater video equipment) and hydrographic research (e.g. drifters, hydrophones, tide gauges). These facilities are complemented by access to the equipment and infrastructure of spin-out companies and partner organisations, including diver support, hyperbaric facilities, wave tide/tank and a wide range of ocean survey equipment. ICIT is also developing high performance computing capability in support of the TeraWatt and Ecowatt 2050 projects. Over £450M has been invested in renewable energy in Orkney over the last decade including the European Marine Energy Centre facilities which include experimental test beds for tidal energy in the Pentland Firth.

The ED has 4.0 FTE research technicians (one of whom is HWU's Nominated Animal Care & Welfare Officer and Aquarium Manager), a dedicated Diving Supervisor and is supported by a retained in-shore skipper. The ED also has access to a staffed (1.0 FTE) Life Sciences workshop, Stores (1.5 FTE) and IT technician (1.0 FTE), while ICIT has 1.0 FTE IT technician for the Orkney Campus. Administration support is provided at the SLS level with this UoA's share equating to 2.5 FTE, including dedicated Research Administrators (1.4 FTE), and a Business Development Executive (1.0 FTE) shared across two cognate UoAs (A7 & B6). HWU's Research & Enterprises Services provides professional support on all aspects of bid development and commercialization of research, including the creation of new companies and engagement with existing companies.

iii. Policy and Practise for Research Governance

Our research complies with HWU's Code of Good Practice in Research and is co-ordinated by the School Research Committee which reports to HWU's Research and Knowledge Exchange Board chaired by the Pro-Vice-Chancellor (Research & Knowledge Exchange). Research is overseen by an Ethics Committee and is fully compliant with the Home Office Animal Procedures Act. Health and Safety (H & S) issues are overseen by School-level H&S, Biological Safety and Genetic Manipulation Safety Committees which report to HWU's H & S Committee (chaired by **Hopkins**).

e. Collaboration or contribution to the discipline or research base

Expert advice and service to the policy, academic and commercial sectors are well represented in

our portfolio. The examples below emphasise leadership (except for ECRs). Similarly, the Environmental Sciences researchers make multiple contributions to their disciplines and the research base, and many have enduring international and national collaborations.

Expert advice: **Aspray** (ECR) - Lead advisor Waste Resource Action Programme; **Brown** - Steering Committee European Marine Biological Research Infrastructure project (FP7), Expert evaluation Future and Emerging Technologies (FP7); **Fernandes** – Service on panels for French, Canadian and EU Research panels, Scientific Committee on Health and Environmental Risks, EC Environmental Risk assessor; **Hartl** - Swedish Research Council Environment, Agricultural Sciences & Spatial Planning; **Hopkins** - Defra Advisory Committee on Releases into the Environment (GMOs), Chair UK National Committee on Antarctic Research (Royal Society auspices), NERC Peer Review College & panel member; **Kerr** - Royal Society of Edinburgh Commission on Hill & Island Areas, UNESCO Workshop on Culture, Management and Development of Small Islands; **Porter** - NERC Peer Review College & panel member; **Roberts** - Contributing author IPCC 5th Assessment Report; Convention on Biological Diversity's Expert Group on ocean acidification, Expert Panel United Nations Regular Process for Global Reporting & Assessment of the State of the Marine Environment; **Sanderson** (ECR) - Defra UK Healthy and Biologically Diverse Seas Group, Benthic Expert Group of Oslo- Paris Convention; **Side** - Expert member of the Crown Estate Panel for Pentland Firth & Orkney Waters Operators Agreement, Lead author of 2012-13 Marine Climate Change Impacts Partnership Report on Coastal Offshore Structures; **Wookey** - Scientific Advisory Board for Nordic Centre of Excellence; NERC Peer Review College & panel member; International Arctic Science Committee Terrestrial Working Group; Trans-National Access Board of the EU FP7 Programme International Network for Terrestrial Research in the Arctic. **Woolf** - NERC Peer Review College and panel member.

Service & leadership (editorial roles): Brown - *Invertebrate Neuroscience*; **Fernandes** – *Journal of Nanoparticle Research;* **Hartl** - *Journal of Fisheries Science*; **Hopkins** - *Soil Biology & Biochemistry*, *Plant & Soil*, *Biology & Fertility of Soils;* **Lyndon** - *Freshwater Reviews*; **Porter -** *Biodiversity and Systematics*, Taxonomy Editor for World Register of Marine Species; **Roberts** - *PLoS One, Nature Scientific Reports;* **Side -** *Ocean and Coastal Management;* **Wookey** – *Global Change Biology*, *Arctic, Antarctic & Alpine Research*. **Woolf** - *Atmospheric Science Letters*.

Service & leadership (learned societies): Aspray - Committee of the Institute of Professional Soil Scientists; **Fernandes** – Council of Estuarine and Coastal Science Association; **Hartl** - President of Physiology Section of American Fisheries Society; **Hopkins** - President of British Society of Soil Science; **Lyndon** - Council of Fisheries Society of British Isles; **Porter** - Council of Linnean Society of London, Council of International Bryozoology Association; **Woolf** – Chair of Royal Meteorological Society special interest group on Satellite Meteorology & Oceanography.

Service & leadership (conference/session organiser): Aspray – Int. Conference on Mercury as a Global Pollutant (Edinburgh 2013), **Fernandes** – Chair of Society of Environmental Toxicology and Chemistry (SETAC) Europe conference (Glasgow 2013); **Hartl** – Int.Congress Biology of Fish (Portland 2008; Barcelona 2010; Madison 2012). **Henry** – Society of Environmental Toxicology and Chemistry (Glasgow 2013); **Kerr** - Environmental Impact Marine Renewables conference (Kirkwall 2012); **Side** – Int. Council for Exploration of Seas Annual Conference (Gdansk 2011).

Esteem and recognition: Fernandes – Elected Fellow of the Society of Biology; **Hopkins -** Elected Fellow of Society of Biology, Adjunct Professor (Antarctic Studies) University of Canterbury NZ; **Side** - Elected Fellow of the Royal Institution of Chartered Surveyors. **Roberts** - Principal Scientist RRS *James Cook* 073 'Changing Oceans Expedition 2012', first review of cold-water coral research (*Science* **312**: 543, 2006) selected by Thomson Reuters as a "Fast Moving Front" paper in 2010. **Wookey** - President & Steering Group of International Tundra Experiment.

Enduring International Collaborations: Fernandes – South Carolina and Rice Universities (USA), Spanish National Institute for Agriculture and Food Research and Technology; **Gutierrez -** Universities of N Carolina at Chapel Hill and Georgia (USA); **Henry** – Universities of Campinas (Brazil) and Tennessee Knoxville (£700K since 2006); **Hopkins -** NZ Antarctic programme, Agriculture & Agri-Food Canada; **Mair** – Smithsonian Tropical research Institute, Panama; **Roberts** - University College Cork, Smithsonian Institution (USA) and Senckenberg am Mer (Germany) that led to first textbook on Cold-water Corals (CUP 2009). **Wookey** – International Arctic Science Council, the US NSF and UN Environment Programme in-kind support for International Tundra Experiment and the NERC Arctic Programme.