Institution: University of Sheffield

Unit of Assessment: 7 - Earth Systems and Environmental Sciences

a. Context

The staff in this UoA provide research leadership in key areas of strategic importance for policymakers and society that have enabled them to develop extensive collaborations beyond HE. Beneficiaries since 2008 include international and UK ambassadors, government ministers, departments/agencies, climate negotiators, royalty, local authorities, NGOs such as conservation charities, industry, Arctic indigenous societies and the general public (see details below). We have communicated key findings of our research to these beneficiaries through meetings, commissioned reports, and co-authorship of papers with non-academic partners. We have actively engaged in industry partnerships ranging from large international agro-chemical companies to SMEs in the developing green economy, to achieve economic impacts, and contributed to public understanding of science through outreach activities, non-academic publications, and the national and international media. As a result, our research has achieved important impacts including influencing policies for protection of the environment and biodiversity in the following areas: global climate change impacts - especially in the Arctic and oceans; ecotoxicology; biodiversity and conservation; urban ecology; crop resistance and defence to parasites and diseases in Europe and Sub-Saharan Africa; marine fisheries and ocean ecosystem sustainability (see details below).

b. Approach to impact

Impact has been central to our culture of research innovation and application that stems from longstanding end-user engagement and policy-advisory roles undertaken by staff in this UoA. In RAE2008 we defined the agenda for impact in our mission statement "*to conduct high quality interdisciplinary research that advances understanding of ecosystem functioning and informs the development and implementation of science-based policy for sustainable environments*". Our commitment to this vision, and resulting track record in delivering tangible impacts and benefits for society from our research, is built on 3 key approaches:

1. Facilitation of **world-leading science** addressing strategically important questions, published in high-visibility journals. This makes our **internationally/nationally leading expertise** globally visible, and enables immediate impacts from our research findings e.g. via press releases.
2. Commitment to **follow-on** government and end-user **research commissions**, and **expert advisory / report writing** roles that proceed from our international/national research standing.
3. Active encouragement of new and ongoing **collaborations** with end-users outside the HE sector and engagement in knowledge exchange (KE), from project development, to reporting findings.

These three approaches have been pivotal in establishing relationships with policymakers and beneficiaries and delivering impacts of the greatest reach and significance. Examples include:

(**i**) World-leading long-term experimental studies of climate change impacts in the Arctic published by ***Callaghan*** (Case Study 1), led to his major role in international expert synthesis reports (ACIA 2005), and chapter lead author for the 4th International Panel on Climate Change report (IPCC 2007), which resulted in his shared award of a Nobel Prize. These have been the main internationally agreed policy-focussed documents on Arctic and Global climate change until 2011 and 2013 respectively. Building on this track record, ***Callaghan & Phoenix*** have made substantial invited contributions to SWIPA (2011), The Arctic Council's Project on Climate Change and the Arctic Cryosphere, which contributed to the 5th IPCC report released in Sept. 2013. ***Callaghan*** accepted invitations to Royal Colloquia on Arctic climate change and, in advance of the 2009 UN Convention on Climate Change, to brief 27 Ministers of the Environment, 50 ambassadors and climate negotiators. (**ii**) ***Quegan's*** unique skill in combining developments in ecosystem modelling, polarimetry, signal processing, ionospheric correction and system calibration provided the scientific underpinning of the technology that will be used in the €470M European Space Agency's BIOMASS mission to provide the first accurate global maps of forest biomass from space. This required ***Quegan*** to undertake pan-European networking and stakeholder engagement to explain the benefits of the technology he proposed. (**iii**) ***Maltby***'s expertise in ecotoxicology led to her serving as President of both the European and Global Society of Environmental Toxicology and Chemistry and the European Food Safety Authority, and serve on EU and UK toxicity and pesticide safety advisory committees. ***Maltby***'s resulting track record in ecotoxicology research, translational activities and policy advice, led to research commissioned by the Highways Agency to investigate the toxicity of road run-off. This provided the basis of the risk assessment procedure incorporated

into the Agency's 2009 Design Manual for Roads and Bridges (Case Study 2). (**iv**) On the strength of our ecosystems ecology expertise, MAFF/Defra commissioned, from 1989, studies on impacts of pollutant N on species-rich grasslands in Derbyshire (***Leake, Phoenix***). The key findings of this work were communicated by ***Phoenix*** in the 2012 *Review of Transboundary Air Pollution* report, which provides the latest synthesis and policy advice on N pollution thresholds and impacts on UK ecosystems. (**v**) Paradigm-shifting work by ***Warren*** revealed the importance of gardens for biodiversity and wildlife for the first time, receiving wide publicity. This led to a national scale follow-on study commissioned by regional conservation agencies that has had major impacts on policymakers in national and local government, NGOs, and gardeners (Case Study 3). (**vi**) ***Buck's*** paper on Bayesian-based radiocarbon calibration led to her invitation to join the group that publishes the international standard calibration. ***Buck*** improved the reliability and date range over which carbon dating is feasible, resulting in the 2009 universal standard. This is used throughout the world in ^{14}C dating including by government agencies, consultants, and commercial labs, working in the areas of palaeoenvironments, archaeology, antiquities, and building heritage. (**vii**) ***Scholes***'s expertise on *Striga* has led to work on rice and sunflower resistance to the parasite funded by *Syngenta Foundation For Sustainable Agriculture* and a *BBSRC-DFID* project with partners in Senegal, and ICRISAT India/Africa and NIAB, UK. In collaboration with Rothamsted Research, ***Scholes*** studied suppression of *Striga* by a forage legume, providing evidence underpinning promotion of intercropping by agricultural extension workers in Africa to improve economic and food security of subsistence farmers. (**viii**) ***Leegood's*** expertise in photosynthesis led to his involvement as a PI in the *C4 Rice Consortium*, a $20M project supported by the *International Rice Research Institute* and *Bill and Melinda Gates Foundation*. In its first phase, the consortium has introduced 10 of the 13 genes needed for C4 photosynthesis with the goal of improving the photosynthetic and water-use efficiency of rice to increase yields and farm incomes. (**ix**) ***Rolfe***'s expertise on microbial degradation of organic pollutants led *Shell* to fund a studentship on biodegradation of biofuels- a major concern for fuel substitution in the aviation industry.

We have employed a number of mechanisms that have fostered a pro-active and agile approach to seeking non-academic research partners, achieve knowledge exchange, and respond to funding opportunities that require or benefit from such partners. Examples include:

(**i**) ***Holt***, our **NERC-KE fellow** established a database of the research contacts and expertise within the UoA, enabling us to build on our existing network of collaborators, and identify strategically important gaps in these networks. (**ii**) ***Holt*** organised two **KE workshops** (Multifunctional Landscapes- 2009; Sustainable Agriculture- 2013) to showcase our work to invited potential end-users. This led directly to new relationships with *Heineken* and *Tata Steel* (***Cameron, Evans***) and the Water Friendly Farming Project (***Maltby***) which brings together charities (*Pond Conservation*, *Game & Wildlife Trust*) industry (*Syngenta* and *Anglian Water*), government/regulators (*Environment Agency, Chemicals Regulation Directorate*) and two other universities. (**iii**) Personal recommendation led to new collaboration with *RAGT Seeds* (a leading European crop breeder) in a BBSRC-TSB-funded project (***Cameron, Leake***) that has identified wheat phenotypes with contrasting abilities to form mycorrhiza, now being used in field trials of new commercial cultivars bred from these lines. (**iv**) Within the UoA, a policy of preferential allocation of RCUK PhD studentships to **CASE partnerships** has encouraged a greater proportion of our research to be supported by external sponsorship, and deliver impacts. For example, ***Beckerman***'s two NERC-CASE studentships studying factors limiting endangered parrot populations in the Caribbean with the *World Parrot Trust*, led to a full-time conservation programme to protect the population being established by one student on completion of his doctorate. (**v**) the University's EPSRC Knowledge Transfer Account (one of only 8 such awards in the UK) and its EPSRC Cross-disciplinary Feasibility Account, helped support research (***Cameron, Phoenix***) that led to the commercial development by industry-partner Boningale Nurseries of 'GreenSky' - the first green roof substrates optimised for different climate regions. The IP licence grants The University 10% royalty on GreenSky profits. (**vi**) The University of Sheffield's commitment to invest in world-leading facilities to deliver world-leading science is reflected in our £4.5M environment research centre, opened in 2009, which has enabled industry collaborations funded by *Syngenta* (***Scholes***) and *Heineken* (***Evans***). (**vii**) Staff are encouraged to take on policy-advisory roles that benefit from their expertise and engage policy-makers. For example, ***Blanchard*** and ***Webb*** serve on international advisory panels on ocean ecosystem sustainability. ***Blanchard's*** recent work on marine fisheries indicators has been used in the Marine Strategy Framework Directive and in predictions of climate-change

impacts on marine fisheries led by international teams at NOAA. (**viii**) Esteem indicators are important in staff promotions, with industry-linked projects, and policy-advisory roles being highly valued. (**ix**) Public engagement has been facilitated by results being reported in the media, by popular science books such as '*No nettles required*', (>18,000 copies sold) from the urban biodiversity studies co-led by ***Warren,*** and websites aimed at a general audience. We have engaged the public in research, for example, ***Callaghan*** has involved indigenous Sami people in knowledge-exchange on climate-change driven alterations of vegetation snow and ice interactions, to which these nomadic reindeer herders need to adapt. Over the past 5 years we have developed a very popular outreach programme based on our aquatic food web research. We provided 37 visit days for 2546 children from 20% of Sheffield schools, including some Special Needs schools, in 2012-13. Our families' Researcher's Night, and the Faculty's Discovery Night during Science week in 2012 were attended by about 2300 children.

c. Strategy and plans

Our strategy is to continue to publish world-leading science, and enthusiastically engage in knowledge-exchange to inform policies, and enable industries, to deliver more sustainable management and protection of the environment. The overall success of our established strategy and culture of commitment to impact is evidenced by the growth in reach and significance of our end-user engagement through the review period. Of the 450 ISI listed publications (2008-2013) by the staff in this UoA, 38% include co-authors from outside the HE sector, 28% being with an international partner outside HE (e.g. *World Wildlife Fund*, *BirdLife*, *The International Institute for Applied Systems Analysis*, *NOAA*, *NASA*, *Sabah Forestry Dept*., *Nature Seychelles*, etc.). In addition, we have more than doubled the numbers of industrial partners since RAE2008 with new partners *Shell, Microsoft Research, Bayer CropScience, Oxford Advanced Surfaces, Heineken, etc.)* more than doubling cash income from industry sources. We have increased both the range of research commissions and collaborations to include 10 government departments or agencies (e.g. *DFID, DEFRA, FERA, CEFAS, The Environment Agency, Natural England, English Heritage, Scottish Natural Heritage),* and expanded our portfolio of international policy-political contacts.

We seek to build on these successes, develop our existing relationships and further enhance our vibrant culture of research innovation, application and knowledge exchange. Central to achieving these aims is our strategic appointment and mentoring of new staff who combine research excellence in priority areas with enthusiastic engagement in impact. This is exemplified by the 7 new lecturers/fellows appointed since 2011 (***Ton***, ***Smith***, ***Casson, Blanchard***, ***Edwards, Evans, Zona***). They further strengthen our science base in sustainable agriculture and marine fisheries, tropical forest conservation, urban ecology, and Arctic biogeochemistry and climate change. These appointments have enhanced our representation on policy-focussed advisory panels, and our potential for impact on national and international policymakers, agri-food industry and society.

To support the further development of existing research partnerships, and help establish strategic new partnerships with industry and other end-users, the University has launched a £1.2M 'Science Gateway' that is employing Impact Fellows, attached to departments. They will assist in embedding extensive end-user engagement in multidisciplinary consortium projects of the kinds in which we have a strong track record of success (e.g. EU-FP7, Marie-Curie, NERC-Urban BESS, EPSRC-SECURE). The NERC Doctoral Training Partnership *Adapting to the Challenges of a Changing Environment* we lead (with York, Liverpool and CEH- total £9M) will fund 110 studentships 2014-19 and has 20 CASE partner agreements. Our goal is to increase to 40% CASE Studentships.

Our popular outreach work to schools and the general public will be developed to showcase the importance of science in society through examples of our research impacts on policy and industry.

d. Relationship to case studies

The impacts of our 3 case studies (*Arctic ecosystems and climate change, Managing risks to aquatic habitats from road runoff* and *Biodiversity in Urban Gardens)* arose from sustained research excellence, and our scientists being established as leading experts. This resulted in invitations to follow-on research, contribute to international authoritative policy-focussed reports, participate in high-level policy briefings, and assist in developing risk-management tools (by the Highways Agency), that are now used internationally. In the *Arctic* and *Urban* cases staff took active steps to directly engage the public (Arctic indigenous societies, and UK gardeners respectively). Our case studies exemplify how important impacts follow from outstanding scientists combining excellence in research with personal leadership qualities and motivation to engage with a wide diversity beneficiaries in order to help protect the environment and benefit society.