

environmental SCIENTIST



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A vibrant pop art graphic featuring a large, jagged, yellow and red impact shape in the center. The background is filled with halftone patterns of green and red dots, and radiating lines of yellow and red. The text 'THE IMPACT OF ENVIRONMENTAL SCIENCE RESEARCH' is overlaid on the graphic in a bold, stylized font.

THE
IMPACT
OF ENVIRONMENTAL
SCIENCE RESEARCH

Is knowledge translated to impact?



The 2014 Research Excellence Framework (REF) assessed the impact of research undertaken by UK universities for the first time. Universities submitted case studies to demonstrate their research impacts on “the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia”. The Committee of Heads of Environmental Sciences (CHES) is the arm of the Institution of Environmental Sciences (IES) dealing with higher education, and thus has a keen interest in how the discipline informs society as a whole. Here, we showcase the impact of environmental science research from UK universities, and explore how researchers develop and demonstrate impact, ensuring that interdisciplinary work is appropriately represented in analyses of societal effects. Although many academics were initially unsupportive of impact assessment, impact is of particular relevance to environmental scientists, many of whom engage in mission-oriented research and are individually motivated to ‘make a difference’. Here, we examine which areas of environmental science research have shown impact. Vicky Jones begins by examining why impact was included in REF 2014 and discusses the processes designed to assess impact.

development case studies directly impacted on industry best practice, and Mark Everard reports a lack of business involvement in ecosystem services. Pete Shaw and Ian Williams identify that few case studies covered a range of waste management principles, whilst Ben Williams reports low coverage of behavioural change for air quality management. Finally, Christian Devenish and Ruth Bowyer find gaps between climate change impacts and biodiversity and marine research respectively.

The environmental sciences are highly impactful across a range of sectors and in collaboration with a diversity of partner organisations. Non-university organisations are particularly important as participants in research, including through funding. Ben Williams identifies a range of international governmental, NGOs and charities where impactful research has contributed to policy-making. Following this, Robert Ashcroft interviews two users of university research to discuss some of the ways in which impact can be driven and assessed. The articles published here clearly show how environmental science impacts society within health, economic and cultural agendas, often informing public policy at the highest levels.

This issue takes six major sectors of environmental science, drawn from IES members’ interests; they demonstrate the breadth of the environmental sciences. We have looked at the range of impacts, areas where impact is obviously missing, and what we can learn from the process. The issue also examines an apparent disconnect between high-quality research and institutional practice on sustainability, with Carolyn Roberts and Robert Ashcroft exploring connections between the environmental science REF results and the “greenness” of the institution concerned.

One conclusion of a recent report on REF 2014 research impact² is that multiple fields of research are often a feature of societal impact, making it hard to map the research to particular units of assessment (UoAs) used within REF 2014. Environmental sciences are multi- and interdisciplinary, spanning many UoAs. Indeed, of 220 case studies directly identified as “environmental science”, 134 are listed as interdisciplinary and come from 20 UoAs³.

Interestingly, despite the diversity of case studies, several authors found a lack of engagement with key sectors. For example, Ben Williams finds that few sustainable

We hope that this volume is both an interesting introduction to the variety of impacts that environmental science research has in the UK, and a useful resource for researchers seeking to further develop the impact of their own work.

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REFERENCES

1. Watermaeyer R. (2014) Impact in the REF: issues and obstacles. *Studies in Higher Education*, DOI: 10.1080/03075079.2014.915303
2. HEFCE, REF2014 Impact Case Studies, RSA: Environmental Sciences <http://impact.ref.ac.uk/CaseStudies/Results.aspx?Type=S&Tag=764> [Accessed 23 November]
3. King’s College London and Digital Science (2015) *The nature, scale and beneficiaries of research impact: an initial analysis of Research Excellence Framework (REF) 2014 impact case studies*. Bristol, UK: HEFCE.

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Adding impact

Vicky Jones explains why the impact of the research carried out in UK universities was included in the assessment of its quality.

About £2 billion per year is given to UK universities by the UK's four higher education funding bodies. The money aims to support a dynamic and internationally competitive UK research sector that makes a major contribution to economic prosperity, national wellbeing and the expansion and dissemination of knowledge.

So as to distribute funds selectively on the basis of quality, provide accountability for public funding of research and demonstrate the benefits of the investment the funding bodies assess universities' research through a periodic exercise. This was known as the Research Assessment Exercise (RAE), but was replaced by the Research Excellence Framework (REF) REF 2014¹. Over that year, 1,157 expert panel members assessed the research of 154 UK universities. This included 191,150 research outputs submitted by 52,061 academic staff and 6,975 case studies demonstrating the impact of UK research. Each submission was assessed on the

originality, significance and rigour of its research outputs and the vitality and sustainability of its research environment.

ADDING IMPACT TO EXCELLENCE

For the purposes of REF 2014, impact was defined as "an effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia"².

“research undertaken in UK universities has made a contribution to every country in the world”

In REF 2014, for the first time, the impact of research beyond academia was assessed along with the academic excellence of research. Universities submitted four-page case studies of impacts from 2008 to 2013. One case study was submitted for every 10 members of staff included in a university's submission. Therefore the REF assessment of impact was not a comprehensive audit of all the impacts that occurred during the period, but did provide a wealth of evidence of the wide-ranging and significant impact resulting from UK research.

WHAT DID WE LEARN ABOUT IMPACT IN UNIVERSITIES?

We drew on the expertise of academic peers and non-academic users of research from across industry and other sectors to assess the case studies in terms of their reach and significance. They reported impressive, high-quality impacts, covering diverse scales of activity and influence involving all research disciplines – from the life sciences to arts and humanities – and from many diverse UK universities with submission of all sizes. On average across all submissions, 44 per cent of impacts were judged outstanding, with a further 40 per cent judged to demonstrate very considerable impact.

Alongside the REF assessment process, Digital Science (working in conjunction with Nature Publishing Group and the policy institute at King's College London) were commissioned by the UK higher education funding bodies, Research Councils UK (RCUK) and the Wellcome Trust, to analyse the impact case studies³. The key findings of the report included:

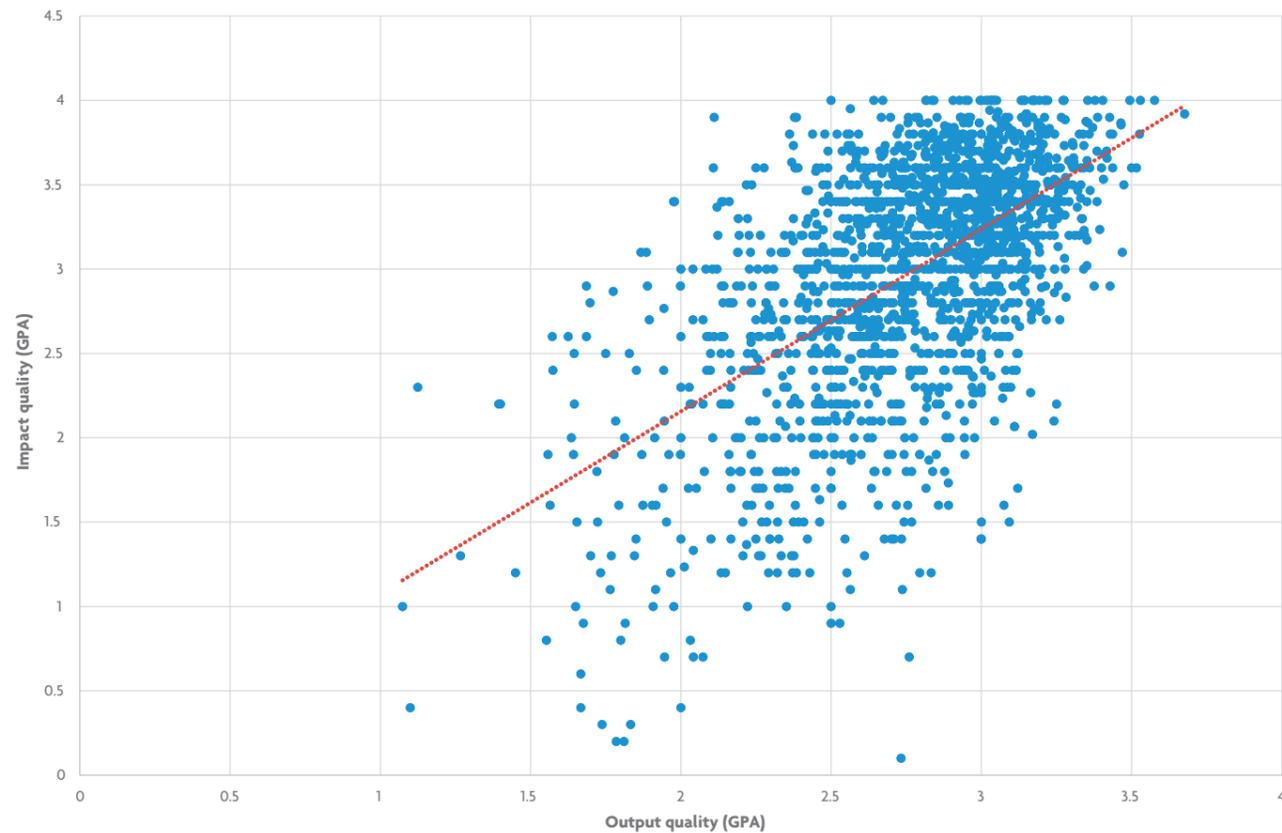
- Over 80 per cent of REF 2014 impact case studies included underpinning research that was multidisciplinary;
- The impact case studies were diverse and wide ranging, with over 60 unique impact topics identified;
- Over 3,700 unique pathways from research to impact were identified; and
- Research undertaken in UK universities has made a contribution to every country in the world.

THE EFFECTS OF IMPACT ASSESSMENT

Once REF 2014 was complete, the UK funding bodies undertook a wide-ranging review of the REF process itself, focusing particularly on impact using the following:

- Feedback from universities;
- Feedback from panel members; and
- An externally commissioned evaluation by RAND Europe⁴.





▲ **Figure 1. Graph showing the relationship between scores received for output quality and impact quality for individual submissions to the REF. Source: Stephen Hill⁷.**

We found evidence that assessment of impact, along with other policies such as RCUK's Pathways to Impact⁵, has led to cultural change within universities. For example, there is evidence that some universities are now including impact as a criterion for promotion, building a plan for impact into projects, and implementing systems to store evidence of impact.

Overall the assessment of impact worked well, but there are areas for improvement. By a large majority, panellists felt the process enabled them to assess impact in a fair, reliable and robust way. However, there were some particular areas that were a challenge. For example, the guidelines for eligible impact required case studies to provide a clear link from the underpinning research to the claimed impact. This was particularly challenging where a body of research had led to the reputation of

a researcher enabling them to work with and advise public bodies and policy-makers. Similarly, how much impact could an individual with a high media profile claim when much of the work they disseminate is not their primary research?

Although there may be areas for improvement it is clear that the systematic collection of impact data has generated an important national asset, and provided new insight into the relationship between research and impact. The evaluation has given us plenty of food for thought and we always welcome further input from the community as we develop plans for a future exercise.

WHAT DOES RESEARCH EXCELLENCE LOOK LIKE?

Something else that the introduction of impact

allowed us to consider is what we mean by high-quality research. A recent blog post by Steven Hill, head of research policy at the Higher Education Funding Council for England (HEFCE), explored this in more detail⁷.

The introduction of the impact element of REF 2014 has allowed us to assess quality against two broad criteria: – the research outputs from an academic perspective and the broader societal impact of research. The data from REF 2014 allows us to consider, for the first time, how far these two dimensions of research quality are related to each other.

“the most positive aspect of preparing for REF 2014 was to illuminate the vast array of research impact which [the university] may not otherwise have realised it had”⁶

Analysis of the scores a submission received for impact with the scores that submission received for outputs showed that the two elements were related but not perfectly aligned (see **Figure 1**). This tells us that high-quality research and high-quality impact generally occur in the same place, but not necessarily that it is the same research or undertaken by the same people. The challenge for research assessment is recognising these different dimensions of research quality and valuing and rewarding them all.

IMPACT CASE STUDIES AS A RESOURCE

REF 2014 has provided a wealth of information (over 6,500 documents), showcasing the value of research for wider society, with outstanding impacts on the economy, society, culture, public policy and services, health, the environment and quality of life – within the UK and internationally. The case studies reflect universities' productive and fruitful engagements directly with the public and with a very wide range of public, private and third-sector organisations.

The REF 2014 impact case studies database⁸ is freely available, to enable anyone to carry out their own analysis and undertake deeper exploration. It is a searchable online tool offering a wide range of automated text mining functionality, including: free text word searches of the case studies, searches by research subject areas and geographical locations referred to within the documents, and filtered searches for research funders.

The database has maintained high levels of interest across the higher education sector, in government and industry, with approximately 10,000 visits to the website each month. Users are investigating impacts under different thematic headings, for instance exploring how public engagement is described, used and evidenced. Universities are able to compile suitable lists of case studies to help them understand what quality looks like and how research has been harnessed for impact delivery. The tool has also proved helpful in finding case studies and research relevant to particular professions and industries.

ENVIRONMENTAL IMPACT

Each case study in the database has been assigned to one of eight impact types, including environmental impact. This reveals 459 impact case studies tagged as having an environmental impact, submitted by over 100 UK universities in 28 of the 36 subject-based units of assessment. And this is just a snapshot of the environmental impact of research carried out in UK universities. We encourage you to take a look at the database and find out more. **ES**

Vicky Jones has worked at HEFCE for seven years and is a Senior Policy Adviser in the Research Policy team, with particular involvement in the programme of activities to evaluate REF 2014 and the development of a future exercise. Prior to this Vicky was Deputy Manager in the REF delivery team. Before joining HEFCE, Vicky spent six years at the Engineering and Physical Sciences Research Council, following a PhD in Analytical Chemistry.

REFERENCES

1. REF 2014, www.ref.ac.uk.
2. HEFCE (2011) Assessment framework and guidance on submissions, REF 02.2011. Available at: www.ref.ac.uk/pubs/2011-02/ [Accessed 30 October 2015].
3. King's College London and Digital Science (2015) The nature, scale and beneficiaries of research impact: An initial analysis of Research Excellence Framework (REF) 2014 impact case studies. www.hefce.ac.uk/pubs/rereports/Year/2015/analysisREFimpact.
4. Manville, C., Morgan Jones, M., Frearson, M., Castle-Clarke, S., Henham, M.-L., Gunashekar, S., and Grant, J. (2015) Preparing impact submissions for REF 2014: An evaluation. Rand Europe, Cambridge. www.hefce.ac.uk/pubs/rereports/Year/2015/REFimpacteval/Title,103726,en.html.
5. Research Councils UK. Pathways to Impact. www.rcuk.ac.uk/innovation/impacts/ [Accessed 19 October 2015].
6. Institutional feedback submitted by the London School of Economics. All feedback submitted is available at: <http://www.hefce.ac.uk/rsrch/REFreview/feedback>.
7. Hill, S. (2015) Dimensions of quality research. HEFCE blog, 27 July. blog.hefce.ac.uk/2015/07/27/dimensions-of-quality-research/ [Accessed 19 October 2015].
8. REF 2014. Search REF Impact Case Studies. impact.ref.ac.uk/casestudies [Accessed 19 October 2015].



Sustainable development: the impacts of UK university research

Ben Williams analyses the sustainable development case studies that focus on environmental impact.

Sustainable development by its very definition is an approach that aims to balance competing needs within social, economic and environmental boundaries for both current and future generations. Without practising sustainable development on all fronts, we risk exacerbating climate change, which, through sea level rise, is threatening the existence of low-lying nations at present and is likely to be keenly felt closer to home over the coming years. If the loss of entire nations to the seas is not enough, climate change is expected to have a significant impact on global biodiversity, and unsustainable uses of finite resources could have significant political consequences globally.

Relevant impact case studies were found by first performing a search for “sustainable development” using the Higher Education Funding Council for England (HEFCE) online database¹. The search was then refined by impact type: environmental, legal, health, cultural, societal and economic. This returned 164 that were considered relevant to sustainable development, of which 48 were considered to broadly address environmental impact. This review focuses on these 48 case studies.

The research undertaken beneath the umbrella of sustainable development is wide and varied; key topics include: resource management, the impact of climate change on society and policy-making, and biodiversity maintenance and its management. The research typically focuses on a number of areas:

- Informing policy development and adaptation at national and international levels;
- Informing companies at the forefront of natural resource acquisition such as mining, forestry and food production; and
- Those organisations that use these resources.

As shown, the impact from this area of research can be both wide-ranging and significant.

IMPACT ON POLICY

The impact on policy is wide and varied, and has not only contributed to policy change in the UK, but also in nations around the world, with a particular focus on developing nations. UK researchers have contributed to evidence-based policy-making within a variety of both governmental and non-governmental organisations (NGOs) including

various local and national governments globally, the EC, the UN (UNESCO, UNFAO, and REDD among others), the OECD, the European Space Agency, NASA, the World Bank, Oxfam, Save the Children, and the WWF, to name a few.

Typically, the impact on policy is the result of evidence-gathering exercises and the development of methodological tools and models to help policy-makers interpret data, set targets, predict environmental change, and mitigate risk. The impact of the research in this field is often realised by way of close collaboration or working relationships with policy-makers, established through targeted funding mechanisms, dissemination through publication, and membership of relevant high-level forums and committees. The policy impact established by many of these case studies is demonstrable and powerful, showing how evidence-based policy-making can generate real-world change, from implementing flood risk management schemes to protect communities in the UK, to helping the international community set global carbon emissions targets, and encouraging organic farming in China.

BOX 1: DEVELOPING EVIDENCE-BASED POLICY²

Developing Evidence-Based Policies for Tropical Forest Management and Carbon Emission Reductions

Since 2008, researchers at Exeter University have been conducting research focused on quantifying the impacts of environmental change on fire risk and carbon dynamics in Amazonian forests. Their case study, submitted under the Geography and Environmental Studies Unit of Assessment which demonstrates several main impact streams arising from this work.

Their research into drought frequency and intensity and fire occurrence has directly informed the design and implementation of a ‘zero fire’ policy in the State of Acre in Brazil.

Furthermore, the research has also led to the development of new monitoring tools to assist policy-makers in understanding the interactions between climate, ecosystems, and human health in Amazonia. This team, research into carbon emissions has also influenced methodological development within the United National REDD (Reducing Emissions from Deforestation and Forest Degradation) programme in Colombia.

Finally, the case study highlights the attention this work has received from Brazilian and international media, which they argue has increased awareness of drought and fire issues in Amazonia amongst policy-makers and the general public. This includes interviews and features with several major newspapers and the BBC.

INFORMING CONSERVATION MEASURES

Several case studies demonstrate a direct impact on conservation measures. Areas of research have included engaging with remote community groups in several locations globally to help maintain a balance between conservation and social practices. Other research with impact includes the development of

satellite technology to enhance knowledge about wildfires, which can then be used to better inform the conservation of flora and fauna. Understanding of the palaeoenvironment was also used for developing forward-looking policies on land management and biodiversity conservation.

BOX 2: SCIENTIFIC ADVICE³

Scientific advisory services for climate adaptation and development planning

This case study gives examples of how research at Loughborough University since 1993 on regional climate modelling, risk assessment and adaption planning has delivered impact through services to national and international agencies, NGOs and commercial partners. These organisations are developing strategies to manage exposure of their portfolios to climate risks. By developing climate risk assessment frameworks and adaption planning approaches for long-lived water and energy infrastructure, this research has assisted these organisations in these tasks and delivered impact.

The research was primarily translated into beneficial services in the form of public domain software, practitioner training, and technical advice to policy makers. In this way, this research and associated engagements with partner organisation has helped to “build technical capacities in climate risk management and adaption options appraisal”, particularly in vulnerable areas of Asia and the Middle East.

SUSTAINABLE ENERGY USE

Particular case studies focus on the impact of developing more efficient techniques for reducing energy consumption, such as reducing energy use in waste processing and improving the energy efficiency of buildings. Other case studies explain the impact of their research on helping governments, businesses and individuals to adopt practices for sustainable energy use as well as forging the way ahead with research into systems that will make sustainable energy production a shared reality in the future.

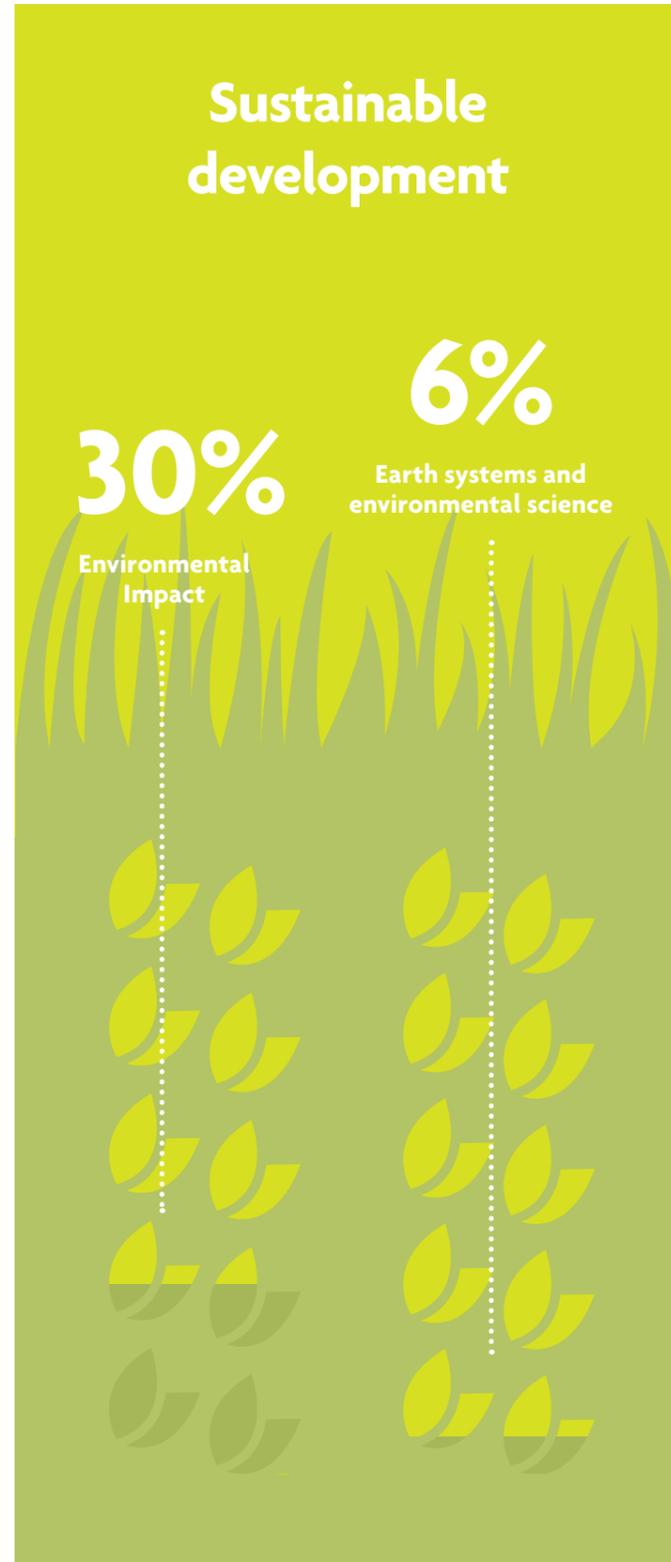
IMPROVING PUBLIC HEALTH

Some case studies demonstrate impact in the protection of human health. Examples include:

- Predicting the likelihood of droughts using satellite data in sub-Saharan African nations;
- The detection of harmful algal blooms and toxins in shellfish;
- Establishing frameworks for sustainable global food production; and
- Improved access to water for marginalised communities in Kenya.

INDUSTRIAL BEST PRACTICE

While impacts on government policy at a national and international level are likely to contribute to changes in industry, only a few case studies demonstrate direct



▲ Figure 1. The percentages of case studies assigned the Summary Impact Type 'environmental', and which were submitted under the Earth systems and environmental science UoA. (Source: REF2014 impact case study database; search term: "sustainable development").

influence on industry best practice. One case study describes a contribution to the improved competitiveness of the European aquaculture industry; another body of work led to changes to the regulatory system at European Commission level.

WHAT CAN WE LEARN?

The United Nations Division for Sustainable Development has 17 goals², all of which aim to address the balance between social, economic and environmental boundaries. As a collection, the submissions to REF 2014 touch upon each one in some form, which by itself shows the strong international presence UK institutions have in this important area. This is also seen in the spread of submissions within this field across many of REF 2014's units of assessment (UoAs) (see Table 1). The submissions focusing on the environment accounted for approximately 34 per cent of all those provided under the sustainable development heading.

These environment-focused, sustainable development impact case studies demonstrate that the UK is at the forefront of research into how to minimise global contributions to climate change and develop systems for reducing its impact on the biosphere as a whole.

BOX 3: LESSONS FROM THE PAST⁶

Peru - Aridification and Landscape Modification: Lessons from the Past

Research from the University of Cambridge combining paleoenvironmental research with study of sedimentary and archaeological data in Ethiopia, New Mexico and Peru indicates a long-term climatic trend “from a damper and well-vegetated environment to the currently prevailing semi-arid, almost desert-like, conditions”. This case study explores the impact of this work on education and conservation in the Ica Valley, on Peru’s southern coast.

In this region, research is revealing how agriculture and climate change have acted to trigger major social upheaval in the past. The historical insights offered by this research are now informing education programmes and policy development in the present, in the hope of sustaining sympathetic land use for the future. One specific project, in collaboration with the Royal Botanic Gardens at Kew has highlighted the threats to livelihoods and biodiversity associated with felling vital tree species, and this is being translated into education policy. This research has also contributed to the implementation of Peruvian decrees regarding education and forest conservation, and has been an informing factor in the establishment of forest-management agreements with major landowners.

WHAT IMPACT IS NOT CAPTURED BY REF 2014?

When evaluating whether REF 2014 reflects the true impact of environmental research on sustainable development, one must consider that this is the first time research impact has been assessed at this level and therefore clear methods for measuring and gathering evidence of impact may not have yet been fully

Table 1. REF 2014's units of assessment covering sustainable development and the environment

REF unit of assessment	Number of case studies
A5 Biological Sciences	5
A6 Agricultural , Veterinary and Food Sciences	3
B7 Earth Systems and Environmental Sciences	6
B12 Aeronautical, Mechanical, Chemical and Manufacturing Engineering	1
B14 Civil and Construction Engineering	1
B15 General Engineering	1
C16 Architecture, Built Environment and Planning	2
C17 Geography, Environmental Studies and Archaeology	16
C19 Business and Management Studies	5
C21 Politics and International Studies	2
C23 Sociology	1
C24 Anthropology and Development Studies	1
C26 Sport and Exercise Sciences, Leisure and Tourism	1
D29 English Language and Literature	1
D 32 Philosophy	1
Unknown	1



▲ **Figure 2. Wildfire burning on savannah in Kenya, January 2013. One case study⁵ explained how researchers have developed methods for estimating albedo and thus classifying a 'burned area' from Earth Observation data, which is being used for fire management by various government agencies. © Byelikova | Dreamstime**

developed by institutions and their researchers. The impact of our research in general could be improved by providing institutions with very clear guidelines on what constitutes impact at each standard of excellence.

Many researchers both within and outside this field have found impact difficult to quantify. The research can be original, robust and powerful, yet influencing meaningful policy change can be an uphill struggle. For example, an incumbent government may be receptive to new research and willing to enact policy changes, yet political differences mean an incoming government is not interested, resulting in the impact of the research being degraded or lost.

References to impact on policy decisions at the government level abound, both because it is easy to substantiate and because the measure of impact in other important areas (such as influencing business decisions, social interactions and behaviours) is not as well defined. These case studies therefore focus on high-level impact because researchers need to provide evidence in order to reach the higher star ratings, but in doing so we may be missing the more subtle influences that research has on society as a whole. Engendering behavioural change on a local and individual level is increasingly important when it comes to environmental issues, so evaluating the successful impact of new policies or regulations. Methods for defining and assessing these different kinds of impact will be the challenge for researchers and institutions to overcome in future rounds of assessment.

CONCLUSIONS

There are case studies presented here that provide a fantastic insight into the impact that UK researchers can have on a global scale. However, policy may take a while

to percolate through regulatory systems and thus impact generated through policy, particularly in this field, may not necessarily have a significant effect immediately (although some within these submissions most certainly have). Impact at industry level, from the development of new products and technologies to the reduction in energy consumption could contribute to immediate impact but may not be felt as widely.

The challenge for researchers and institutions across the UK is to combine rigorous academic research with lasting, real-world impacts. The current crop of impact case studies in sustainable development demonstrate just this; that UK researchers have an influence globally, helping combat the causes and consequences of climate change, habitat loss and resource depletion. Essentially, what makes good research in this field is what always has – research that aims to make a positive difference to the world, its inhabitants, and future generations.^{ES}

Dr Ben Williams is a Research Associate at the Air Quality Management Resource Centre at the University of the West of England. His current research interests include the modelling of bioaerosol emissions from composting facilities, the modelling of pollutant emissions from domestic solid fuel burning within the UK and understanding the importance of strategic decision-making in the development of healthy urban environments. Prior to this he worked as an environmental consultant, developing and undertaking source apportionment investigations for industry and regulatory authorities.

REFERENCES

1. REF 2014. Search REF Impact Case Studies. impact.ref.ac.uk/casestudies [Accessed 19 October 2015].
2. University of Exeter, Developing Evidence-Based Policies for Tropical Forest Management and Carbon Emission Reductions, REF2014 impact case studies, <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=36399> [Accessed 30 October 2015].
3. Loughborough University, Scientific advisory services for climate adaptation and development planning, REF2014 impact case studies, <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=12402> [Accessed 30 October 2015].
4. Royal Holloway, University of London, Sustainability, Biodiversity Conservation and Indigenous Peoples: Community-Owned Solutions to Future Challenges in the Guiana Shield, South America, REF2014 impact case studies, <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=30230> [Accessed 30 October 2015].
5. University College London, Development of models permitting the use of Earth Observation data to monitor global climate change and land management, REF2014 impact case studies, <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=34490> [Accessed 30 October 2015].
6. University of Cambridge, Peru - Aridification and Landscape Modification: Lessons from the Past, REF2014 impact case studies, <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=17892> [Accessed 30 October 2015].

Biodiversity conservation: the impacts of UK university research

Christian Devenish shows that the most common impacts of research are on biodiversity management, planning and policy.

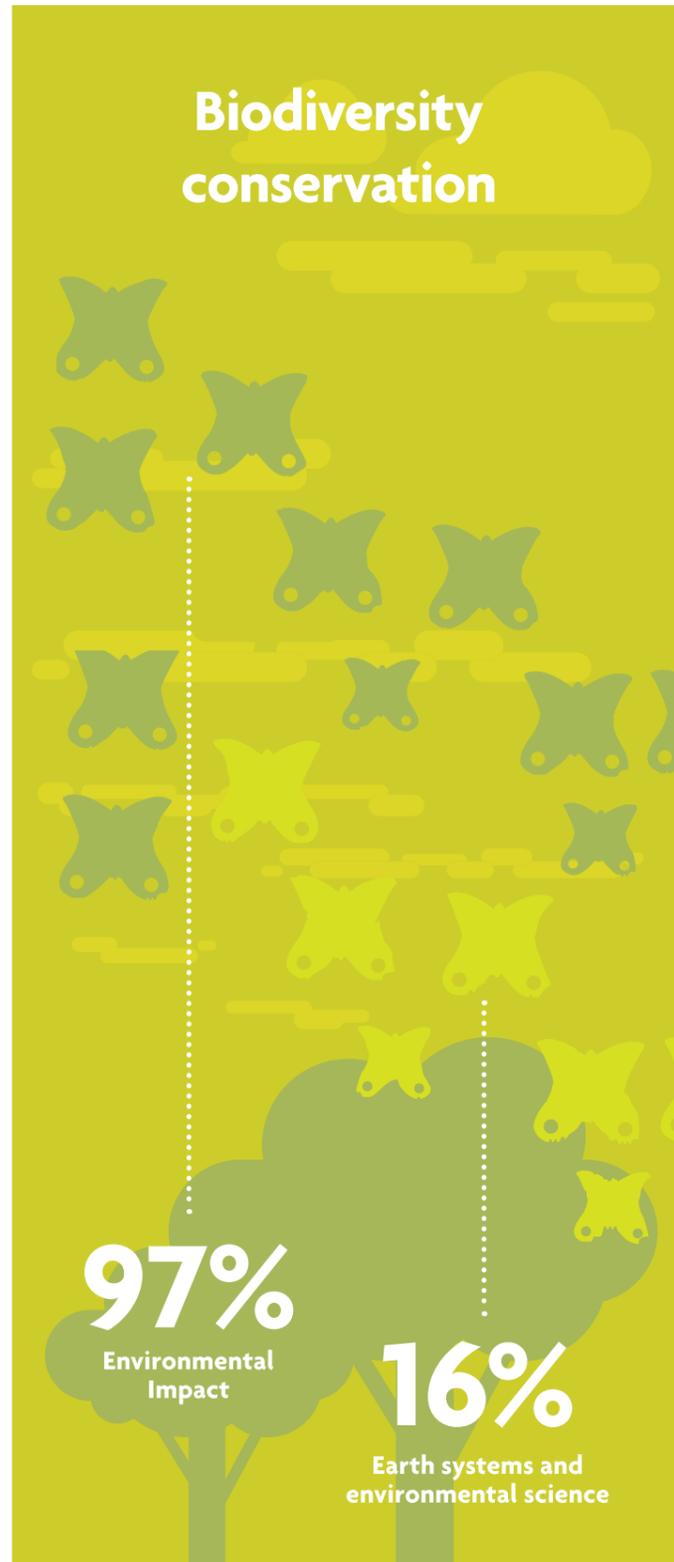


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This article aims to review the impact of research carried out in UK higher education institutions on biodiversity conservation worldwide. I begin by describing areas where most impact has been documented, its geographical scope and beneficiaries. Then I look at how research topics map to impact areas and some characteristics of the research generating this impact. Finally, I suggest areas where impact is not sufficiently represented and put forward recommendations for improving impact in biodiversity conservation.

To characterise types of impact in the field of biodiversity conservation, I performed a search of case studies with the keywords, "biodiversity conservation" OR "nature conservation" OR "wildlife conservation". The search

returned 86 case studies, produced by 56 institutions, with a third presenting more than one case study. I recognise that this is not a definitive group of case studies related to biodiversity conservation; different arrangements and choices of keywords may bring up more results, but also include a greater number of case studies further removed from this impact area. An automated topic analysis by Kings College London¹, allowing each case study to be tagged by up to three topic areas, found 147 case studies under the impact area of nature and conservation, although the group selected for this review is not wholly included in that number. To conduct this review I performed an ad hoc classification of the case studies in terms of major impact themes and research areas.



▲ **Figure 1. The percentages of case studies assigned the Summary Impact Type 'environmental', and which were submitted under the Earth systems and environmental science UoA. (Source: REF2014 impact case study database; search term: "Biodiversity conservation").**

KEY IMPACT THEMES

Case studies have multiple areas of impact but mainly lie within two or three broad groups (see **Figure 2**) – biodiversity management and planning (cited in 85 per cent of case studies), policy (75 per cent) and knowledge exchange (35 per cent). The least-cited areas of impact are social, cultural or economic, including public health, gender issues, public services and livelihood improvements. Case studies often coincide in groupings of impact areas that may reveal impact pathways, for instance, through policy to action, as illustrated by a species action plan leading to habitat management, although the data format does not facilitate such an analysis.

Case studies come from 11 different units of assessment (UoAs; see **Figure 3**), yet over 70 per cent are within just three:

1. Biological Sciences;
2. Geography, Environmental Studies and Archaeology;
3. Earth Systems and Environmental Sciences.

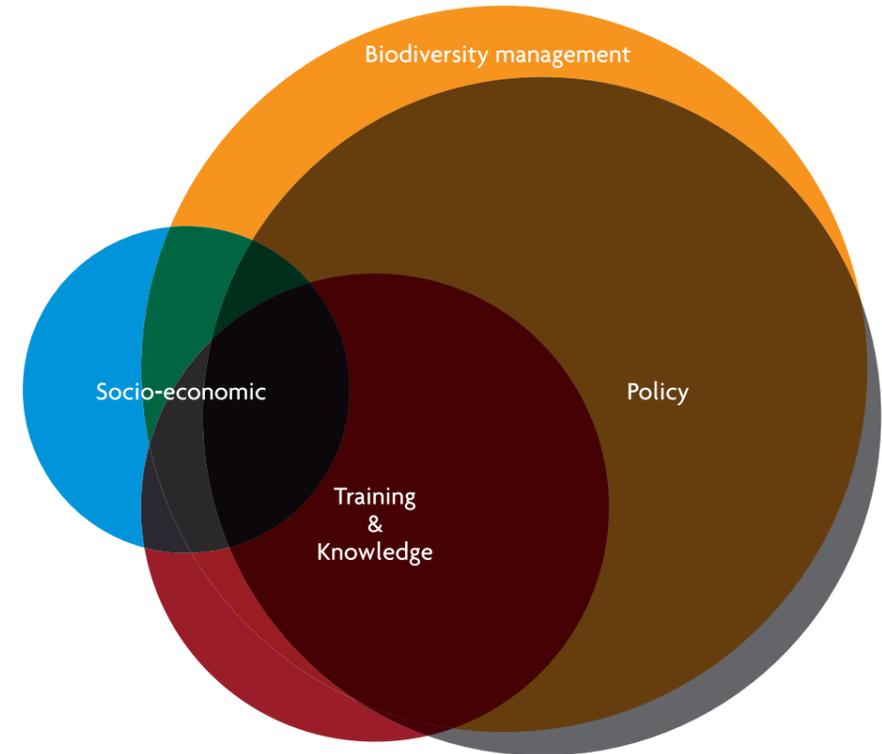
Although REF guidance states that the area of Ecology and Conservation is expected under Earth Systems and Environmental Sciences², the variety of UoAs may be an indication of the multidisciplinary nature of some research, but also the fact that research in different areas has an impact on biodiversity conservation, albeit in a small number of cases. Some examples of these kinds of impacts are given below (e.g. **Box 1**).

ON BIODIVERSITY MANAGEMENT AND PLANNING

The most widely cited impacts in this category were in the two non-exclusive areas of wildlife and ecosystem management (75 per cent of case studies), followed by conservation planning (20 per cent of case studies). Less-cited impacts included those related to natural history museums, animal health, research techniques and urban infrastructure.

Typical impacts in wildlife and ecosystem management include:

- Species- or taxa-specific conservation projects (e.g. saiga antelope, stag beetle, turtles);
- Ecosystem-specific impacts (e.g. peatlands, coral reefs);
- Restoration, threat or disturbance reduction, human-wildlife conflicts (e.g. human-elephant conflict); and
- Harvesting wildlife (e.g. bushmeat management).



▲ **Figure 2. Proportion of case studies classified under broad, non-exclusive impact types. Most case studies show multiple types of impact.**

BOX 1: BOUNDARY-MAKING AND RESOLUTION⁴³

Boundary-making and resolving disputed territorial claims

This case study concerns research conducted by the International Boundaries Research Unit (IBRU) at the University of Durham and was submitted under the Geography, Environmental Studies and Archaeology UoA. This research, since the 1990s, has improved understanding of boundaries and developed a range of resources including databases and digital maps. Processes developed by the IBRU have supported peaceful dispute avoidance and resolution, with direct impact in a range of geopolitical conflicts and disputes, particularly in Africa.

One such example concerns work conducted for UNEP to help resolve a dispute between the government of Sierra Leone and the mining company Cluff Golf over conservation policy and resource management. The company held a mining licence was defined as extending to the eastern boundary of the Kangari Hills Forest reserve, a closed canopy forest region that is very important for biodiversity. However, the boundary of the park was uncertain and disputed, so the IBRU conducted archival and field studies to establish the true alignment of the reserve boundary. This resulted in the reserve extending much further than the mining company had claimed, thereby helping to promote fact-led conservation in the region.

As well as impacts in conservation projects, impacts in ecosystem management were also cited for diverse industry users, such as:

- Fisheries (e.g. reducing bycatch of marine mammals³);
- Water services (e.g. managing peatlands⁴);
- Farming (e.g. management of field margins within the UK Government's agri-environment scheme⁵); and
- Logging (e.g. management of tropical forest⁶).

Impacts in conservation planning included establishing indicators of threat (e.g. IUCN red list⁷) and population trends (e.g. Living Planet Index⁸), priority setting and reserve selection. Conservation areas featured in at least 15 case studies, with research feeding into management strategies for protected areas⁹ or leading to the creation of new reserves¹⁰.

Research into assessment of ecosystem services led to impacts in both management and planning, for example valuing ecosystem services in urban planning processes¹¹ and as tools for communities to use resources more sustainably¹².

IMPACTS ON POLICY

The most widely cited impact in this broad area relates to influencing policy within a wide range of themes, such as climate change, fisheries, invasive species, protected area management, species conservation and urban habitats. Smaller numbers of case studies cite specific policy change or creation as a direct result of the research. In part, this small number no doubt reflects the difficulty in establishing direct links between research and, especially given the relatively short impact window compared to the research period. REF guidelines state that impacts should have occurred between 2008 and mid-2013, resulting from the direct contribution of research implemented between 1993 and 2013¹³.

“the most widely cited impact in this broad area relates to influencing policy within a wide range of themes”

Case studies citing specific policy change or creation include those changing legislation, for example, research results showing the value of riparian habitat were able to refute proposed changes to a Brazilian forestry bill to reduce the width of obligate riparian forest buffers¹⁴. Further and more numerous examples of policy creation include research contributing to strategy documents such as biodiversity or species action plans¹⁵ or to industry decision-making.

Although not exclusively related to policy, impacts in climate change are included here. In fact, climate change adaptation or mitigation is not widely cited amongst the impacts. This may be partly due to impacts in these areas encompassing wider areas than biodiversity conservation and therefore not labelled specifically as such in impact statements. In the classification by Kings College¹, fewer than 20 per cent of those case studies labelled under climate change were also labelled as nature and conservation. However, examples of impacts related to climate change policy include work for REDD+ preparation (such as carbon sequestration estimates and strategic planning¹⁶), local adaptation strategies, and several contributions to IPCC reports (such as extensive research on the effects of climate change on terrestrial biodiversity¹⁷).

With regard to implementing policy, fewer case studies

cite impacts in this area. While several provide research results to aid meeting targets of EU directives or reporting obligations of multilateral environmental instruments³, fewer use research to actually implement legislation. However, one example of this impact comes from a case study on bringing the EU Habitats Directive to control fisheries in marine Natura 2000 sites¹⁸, effectively setting a precedent for Europe (see **Box 2**).

IMPACTS ON KNOWLEDGE EXCHANGE

Impacts documented in this category are grouped almost equally into awareness raising and capacity building, with a smaller number also citing formal education. Awareness raising was cited as an impact in 20 case studies. This was often incorporated in research projects as outreach work, especially those of a more applied, conservation-based nature, but also featured as an integral part of research actually measuring its effect on reducing threats to biodiversity¹⁹. In other case studies, awareness was created by communicating research results, such as through non-specialist publications^{20,21}.

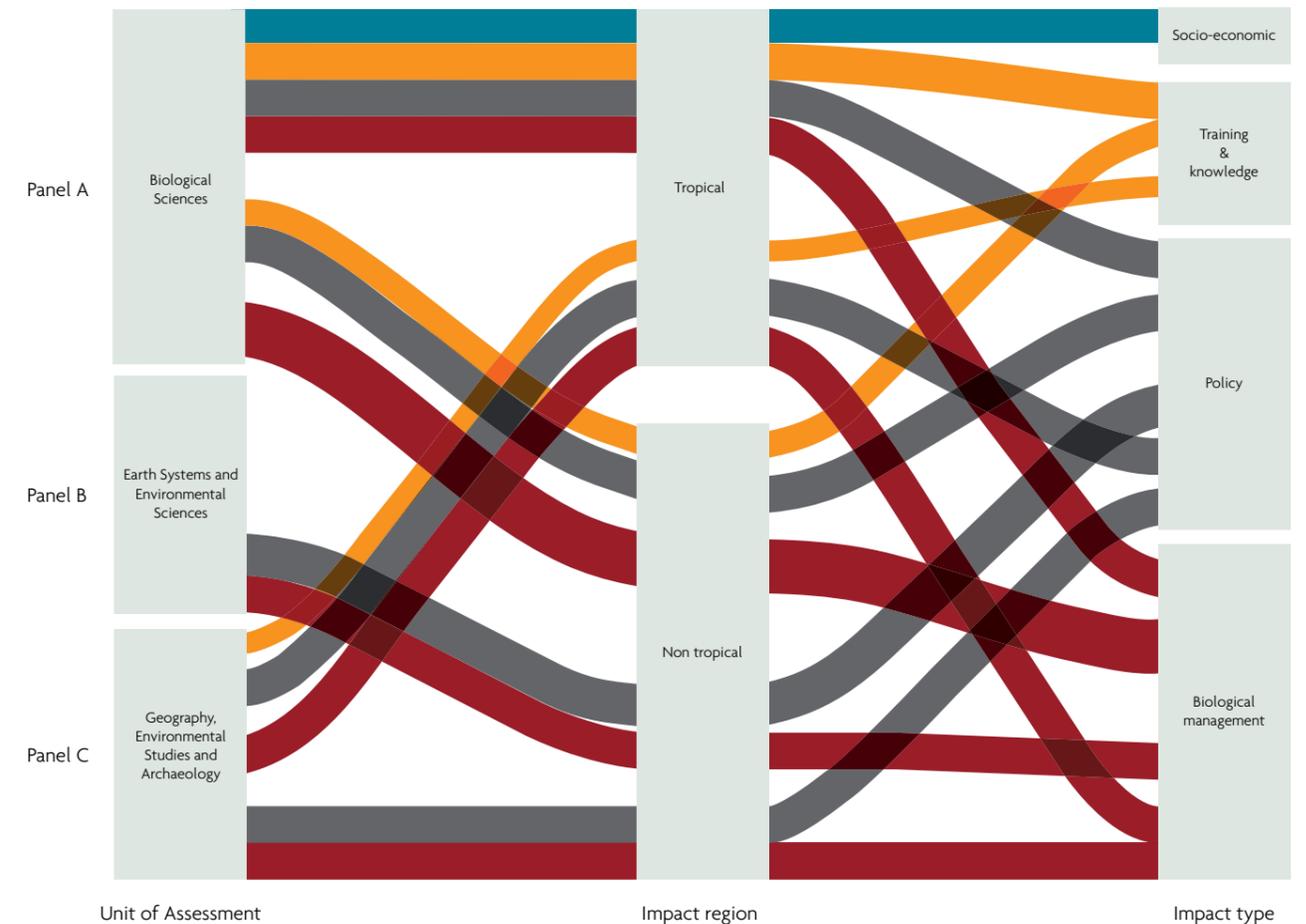
Capacity building impacts were cited in more than 15 cases studies. These include training for non-governmental organisation (NGO) or government agency staff, often in technical areas such as GIS and monitoring methods²², but also for non-specialists to play a part in scientific

BOX 2: A EUROPEAN PRECEDENT⁴⁴

Reducing overfishing in the UK and its overseas territories and supporting marine communities through the use of established terrestrial property management practices

This piece of research from the University of the West of England, applied established terrestrial management practice to the marine environment to investigate the problem of overfishing. Through direct engagement with external organisations, this work has led to a range of impacts, including the establishment of the first community-led marine reserve in the UK, the Isle of Arran no-take zone, and the creation of the Chagos marine reserve in the British Ocean Territories. Through further engagement, this research has also contributed to the preservation of public ownership of UK fishing rights and promotion of the fair allocation of quota to sustainable fishermen, and changes in the management regime of the Crown's marine estate to include more emphasis on coastal communities.

This work also applied the EU Habitats Directive to UK fisheries, noting that the commercial fishing sector has no legal exclusions. Natura 2000 sites cover 17 per cent of EU waters, and are given specific protection under the Directive. In collaboration with the Marine Conservation Society, Client Earth and a leading environmental QC, led to a change in government approach whereby a risk-based approach to fishing in UK Natura 2000 sites has now been adopted. Technically, environmental impact assessments should be undertaken and damaging activities should only be allowed in the public interest and with compensatory measures in place. This is considered a leading approach in the EU, and should set a precedent for better protection in the waters of other member states.



▲ **Figure 3. Principal relationships between major unit of assessment, geographical region of impact and type of impact. Social and capacity building impacts are concentrated in tropical countries, whereas policy is concentrated in non-tropical countries.**

BOX 3: A SPECIFIC IMPACT-LED PROJECT⁴⁵

Reintroduction of the great bustard to the UK

The great bustard is a globally endangered bird formerly extinct in the UK (see **Figure 4**). The project to reintroduce it is a flagship conservation project. Research from the University of Bath underpins the project and contributes directly to the implementation of the reintroduction.

The project has successfully established a new breeding population in the region of Salisbury Plain, enhanced the survival rates of released birds and led to other benefits (“ecological enrichment”) in the release area. The project has recruited volunteers and supporters from across society and is the focus of a public engagement programme on conservation.

This is an example of an applied research project commenced with specific impact goals from the outset, a model for impact delivery.

studies, as citizen scientists²³ or parabiologists in local communities²⁴. Impact through capacity building also encouraged more sustainable use of natural resources among communities through diverse methods such as improving organisational capacity²⁵ and acquiring skills for adaptive management²⁶.

Although education and capacity building was cited as an impact of much research, it was the specific focus of relatively few case studies. One such example set out to improve education strategies at zoos and aquaria with impact on visitor experience and wider awareness of issues such as extinction and threatened species²⁷.

Impacts cited in formal education are at both schools and higher level albeit in surprisingly few case studies, given the interest of UK higher education institutions in contributing to the national curriculum. Just one case study describes direct input

BOX 4: CLIMATE CHANGE AND BIODIVERSITY⁴⁶**Recognition that global climate change is a major driver of biodiversity change and its implications for policy**

Research at the University of York has provided strong empirical evidence that species are responding rapidly to recent anthropogenic climate change, and illustrates that climate change presents an extinction threat to many species. In this case study, the researchers demonstrate how this research has impact on national and international policy.

By transforming international understanding of the magnitude of the threats to biodiversity posed by climate change through the International Panel on Climate Change (IPCC), the researchers assert that this research has steered major policy decisions that have affected many sectors of society from 2008 to 2013. The impact in this case has largely been delivered through inclusion of the research in various high-level international reports, and as such the case study demonstrates impact on policy at a range of levels, including UK and EU. They also explain how this work has impacted on the policies and activities of many conservation organisations, in which they include government and state departments and agencies, as well as NGOs across the world.

to the national curriculum in the UK, while two case studies related to single-species conservation impacted directly on teaching content and practice. Postgraduate study in conservation-related subjects is supported in connection with research projects abroad with a view to improving in-country capacity for conservation science.

Finally, one impact type in this broad area concerns the selection of research topics themselves with the specific goal of increasing impact. A research method to define priority research areas by establishing current policy priorities has been applied to biodiversity research in the UK and abroad^{28,29}.

SOCIOECONOMIC IMPACTS

Socioeconomic impacts were mainly recorded in livelihood improvements resulting from biodiversity conservation. These may take the form of employment through conservation projects – several case studies cite NGOs providing paid work for local communities, for example in controlling rabies in Ethiopian wolf and elephant conservation in Malaysia. Impacts are also documented through direct strategies to reduce pressure on certain natural resources by providing alternative incomes (for example honey production as part of a project to conserve Sichuan partridges) or changing behaviours (for instance with regards to hunting). Often approaches are combined.

WHO USED THE RESEARCH AND WHERE?

Impact was recorded worldwide, typically in multiple countries per case study. A similar proportion of case studies documented impact in the UK as abroad (70 per cent of case studies), with an emphasis on biodiverse

countries. At UK level, impact was registered in all regions of the UK, with institutions based in England having substantial impact in Wales and Scotland. Outside the UK, impact was reported for 36 countries, of which 24 were in the tropics (dominated by Africa and Asia). This indicates that the same research is being translated into impacts both in UK biodiversity conservation as well as in more biodiverse regions. Furthermore, impact is reported for 13 of the 17 most biodiverse nations on Earth³⁰. Impact in the USA was notably absent from UK research, with just eight case studies citing impact in this country specifically.

Of impacts outside the UK, no distinction was found between Russell Group universities and the remainder in terms of geographic scope. This may indicate that higher education institutions are prioritising high-biodiversity areas despite budgetary considerations when planning research, or are effective in reaching out to these areas with a view to applying research.

Research users were classified in five main groups, with national and local government cited the highest number of times (>80 per cent of case studies), followed by NGOs (45 per cent), the public (35 per cent; including local communities), industry (25 per cent) and international organisations (25 per cent). Impact types were evenly spread between beneficiaries following the patterns above; of note are the similar number of relationships between impacts in biodiversity management and industry and international organisations, and that more relationships were found between impacts in training and knowledge and government than with NGOs.

RESEARCH-TO-IMPACT PATHWAYS

Different routes between research and impact are evident from the case studies. More applied research projects may be formulated with specific impacts as goals from the outset (e.g. **Box 3**). Examples include conservation projects where a specific issue is researched and resolved through the project. Many of these have the same partners as collaborators at the research stage and as beneficiaries or research users. For example, American minks in Scotland were controlled through a research project supported and implemented through a large local partnership³¹.

Other research is less orientated towards specific impacts at the outset. These tend to include longer-term research programmes rather than specific, short-term projects (e.g. **Box 4**). Research often includes work on methods and has multiple impacts with a wider range of users. Examples include work on estimating animal abundance over different taxa³² and establishing indicators of extinction risk⁷. It may be more difficult to establish concrete links between these types of research programmes and impacts³³, given the broader application and less-specific applied focus at the



▲ **Figure 4. Two released great bustard, photographed in Wiltshire in 2015. This reintroduction project has been underpinned by research at the University of Bath © Mikelane45 | Dreamstime**

outset. Nevertheless, a range of research-to-impact routes of this kind are presented and appear to be the dominant type within the case studies reviewed.

WHAT IMPACT IS NOT CAPTURED BY REF 2014?

It is difficult to gauge whether the impact reported in the REF 2014 case studies is representative of the impact achieved in biodiversity conservation worldwide as a result of UK research, given the lack of a baseline or comprehensive assessment of research impact in this area. However, we can evaluate whether research presented in case studies is similar to that published over the same time period.

“applied research projects may be formulated with specific impacts as goals from the outset”

A search on SCOPUS for articles published between 1993 and 2013 by authors based in the UK, using the same keywords as above, produced 2,200 results. Tabulating the indexed keywords returned from this search provides an approximate picture of UK biodiversity research themes. In terms of similarities, areas such as conservation management, planning, endangered species and ecosystem services are well represented on both this list and in the case studies. Discrepancies, which could be interpreted as poor

representation of impact in the case studies, result in areas such as conservation genetics, climate change, remote sensing, urban biodiversity, reserve selection and agrobiodiversity.

In terms of geographic scope, research in approximately 40 per cent of articles returned by the SCOPUS search was based in the UK, indicating that a high proportion of biodiversity research is implemented abroad. Although this ties in with the geographic patterns shown by the case studies, in that much impact is reported outside the UK, it would also seem to indicate that more impact is shown for the UK in the case studies than would be expected from the locations of UK biodiversity research.

MORE IMPACTS FROM DIVERSE AREAS OF RESEARCH

The case studies emphatically show that most impacts in biodiversity conservation come from research in conservation biology. Although this may sound obvious, conservation biology, as a crisis-orientated discipline, should have a multidisciplinary structure, encompassing a broad range of fields outside biology³⁴. This implies that impacts in this field should also be coming from research in economics, social sciences and ethics, among others. This is clearly lacking (but see **Box 1**).

More multidisciplinary research is required, for instance, on how biodiversity can be included in measures of wellbeing, or on the relationship between governance and biodiversity loss³⁵.

RESEARCH LED BY SOCIETAL NEEDS

One way of improving the impact of research beyond academia is to focus research where it is needed. Sutherland

*et al.*²⁸ led an exercise to establish 100 priority questions in relation to policy development in areas of environmental concern in the UK. The questions were grouped around 14 topics, of which at least four are poorly represented among impacts cited by the case studies: agriculture, energy generation, rivers and flooding, and urban development. All of these are highly relevant to biodiversity conservation. To focus research, similar exercises might be implemented for other areas in addition to policy, most likely at smaller scales, for example to solve biodiversity management problems or to maximise biodiversity benefits from development projects.

RESEARCH ON BEST PRACTICES

The volume of biodiversity research is growing, yet biodiversity loss persists³⁶, implying missing links between research and impact. Of course, other factors conspire to increase the complexity of bridging this gap, not least the fact that conservation research often lacks industry sponsorship and marketable products, and it is not always aligned with economic growth or development³⁷.

Nevertheless, a good case exists for improving impact by researching how impact in this field is actually created and expressed, for instance, in compiling best practices, examples of successful translations of research into impact and in better communication³⁸. In a similar vein, Brechin *et al.*³⁹ call for further evaluation of decision-making processes, organisational performance and systematisation of case studies to improve the availability of conservation research for impact.

DIVERSIFY IMPACT IN DIFFERENT GEOGRAPHICAL REGIONS

Analysis of case studies implies that certain types of impact are unevenly distributed between high- and low-biodiversity countries (see **Figure 3**). First, policy impacts are less common in tropical countries. For less-developed countries, policy innovation is especially important in improving administrative structure and capacity to implement and enforce legislation^{40,41}, implying further scope for impact opportunities. Conversely, socioeconomic impacts, such as livelihood improvements, are almost absent from impacts in Europe and the UK. Although needs are different, social impacts in biodiversity conservation are still relevant⁴² and this may also present novel research and impact opportunities.

ES

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REFERENCES

- King's College London and Digital Science (2015) The nature, scale and beneficiaries of research impact: An initial analysis of Research Excellence Framework (REF) 2014 impact case studies. HEFCE: Bristol, United Kingdom.
- REF (2012) Panel criteria and working methods. HEFCE and partners, Bristol, UK. www.ref.ac.uk/pubs/2012-01/ [Accessed 28 September 2015].
- Hammond, P.S. et al. (2013) Cetacean abundance and distribution in European Atlantic shelf waters to inform conservation and management. *Biological Conservation*, 164, pp.107–122.
- Grand-Clement, E., Anderson, K., Smith, D., Luscombe, D., Gatis, N., Ross, M., and Brazier, R.E. (2013) Evaluating ecosystem goods and services after restoration of marginal upland peatlands in South-West England. *Journal of Applied Ecology*, 50(2), pp.324–334.
- Woodcock, B.A., Potts, S.G., Pilgrim, E., Ramsay, A. J., Tscheulin, T., Parkinson, A., Smith, R.E.N., Gundrey, A.L., Brown, V. K., and Tallwin, J. R. (2007) The potential of grass field margin management for enhancing beetle diversity in intensive livestock farms. *Journal of Applied Ecology*, 44(1), pp.60–69.
- Hawthorne, W.D. (1996) Holes and the sums of parts in Ghanaian forest: regeneration, scale and sustainable use. *Proceedings of the Royal Society of Edinburgh Section B: Biological Sciences*, 104, pp.75–176.
- Mace, G.M., Collar, N.J., Gaston, K.J., Hilton-Taylor, C., Akçakaya, H.R., Leader-Williams, N., Milner-Gulland, E.J., and Stuart S.N. (2008) Quantification of Extinction Risk: IUCN's System for Classifying Threatened Species. *Conservation Biology*, 22(6), pp.1424–1442.
- Collen, B., Loh, J., Whitmee, S., McRae, L., Amin, R., and Baillie, J.E.M. (2009) Monitoring Change in Vertebrate Abundance: the Living Planet Index. *Conservation Biology*, 23(2), pp.317–327.
- Bo, D., Dowell, S.D., Garson, P.J., and Fen-Qi, H. (2009) Habitat utilisation by the threatened Sichuan Partridge *Arborophila rufipectus*: consequences for managing newly protected areas in southern China. *Bird Conservation International*, 19(02), p.187.
- Reynolds, G., Payne, J., Sinun, W., Mosigil, G., and Walsh, R.P.D. (2011) Changes in forest land use and management in Sabah, Malaysian Borneo, 1990–2010, with a focus on the Danum Valley region. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 366(1582), pp.3168–3176.
- Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Ka mierzczak, A., Niemela, J., James, P. (2007) Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and Urban Planning*, 81(3), pp.167–178.
- Peh, K.S.-H. et al., 2013. TESSA: A toolkit for rapid assessment of ecosystem services at sites of biodiversity conservation importance. *Ecosystem Services*, 5, pp.51–57.
- REF (2011) Assessment framework and guidance on submissions. HEFCE and partners, Bristol. www.ref.ac.uk/pubs/2011-02/ [Accessed 28 September 2015].
- Lees, A.C., and Peres, C.A. (2008) Conservation value of remnant riparian forest corridors of varying quality for Amazonian birds and mammals. *Conservation Biology*, 22(2), pp.439–449.
- Harvey, D.J., Hawes, C.J., Gange, A.C., Finch, P., Chesmore, D., and Farr, I. (2011) Development of non-invasive monitoring methods for larvae and adults of the stag beetle, *Lucanus cervus*. *Insect Conservation and Diversity*, 4(1), pp.4–14.
- Gardner, T.A. et al., 2012. A framework for integrating biodiversity concerns into national REDD+ programmes. *Biological Conservation*, 154, pp.61–71.
- Thomas, C.D. et al. (2004) Extinction risk from climate change. *Nature*, 427(6970), pp.145–148.

REFERENCES

- Appleby, T., and Solandt, J.-L. (2011) The habitats directive and fisheries administration: An immovable object meets and irresistible force? In: *World Conference on Marine Biodiversity*. Aberdeen, Scotland (UK). www.marine-biodiversity.org/ [Accessed 1 October 2015].
- Howe, C., Obgenova, O., and Milner-Gulland, E.J. (2012) Evaluating the effectiveness of a public awareness campaign as a conservation intervention: the saiga antelope *Saiga tatarica* in Kalmykia, Russia. *Oryx*, 46(02), pp.269–277.
- Gaston, K.J. (2004) Gardens and wildlife: the BUGS project. *British Wildlife*, 16, pp.1–9.
- Thompson, K. (2006) No Nettles Required: the truth about wildlife gardening, Eden Project Books.
- Coyne, M., and Godley, B. (2005) Satellite Tracking and Analysis Tool (STAT): an integrated system for archiving, analyzing and mapping animal tracking data. *Marine Ecology Progress Series*, 301, pp.1–7.
- Gardiner, M.M., Allee, L.L., Brown, P.M.J., Losey, J.E., Roy, H.E., and Rice Smyth, R. (2012) Lessons from lady beetles: accuracy of monitoring data from US and UK citizen-science programs. *Frontiers in Ecology and the Environment*, 10(9), pp.471–476.
- Basset, Y., Novotny, V., Miller, S.E., Weiblen, G.D., Missa, O., and Stewart, A.J.A. (2004) Conservation and biological monitoring of tropical forests: the role of parataxonomists. *Journal of Applied Ecology*, 41(1), pp.163–174.
- Upton, C. (2008) Social Capital, Collective Action and Group Formation: Developmental Trajectories in Post-socialist Mongolia. *Human Ecology*, 36(2), pp.175–188.
- Mistry, J., Berardi, A., Roopsind, I., Davis, O., Haynes, L., Davis, O., and Simpson, M. (2011) Capacity building for adaptive management: a problem-based learning approach. *Development in Practice*, 21(2), pp.190–204.
- Wagoner, B., and Jensen, E. (2010) Science Learning at the Zoo: Evaluating Children's Developing Understanding of Animals and their Habitats. *Psychology & Society*, 3(1), pp.65–76.
- Sutherland, W.J. et al. (2006) The identification of 100 ecological questions of high policy relevance in the UK. *Journal of Applied Ecology*, 43(4), pp.617–627.
- Sutherland, W.J., Fleishman, E., Mascia, M.B., Pretty, J., and Rudd, M. (2011) Methods for collaboratively identifying research priorities and emerging issues in science and policy. *Methods in Ecology and Evolution*, 2(3), pp.238–247.
- Mittermeier, R.A., Robles Gil, P., and Mittermeier, C.G. (1997) Megadiversity: Earth's Biologically Wealthiest Nations. CEMEX, Mexico City.
- Bryce, R., Oliver, M.K., Davies, L., Gray, H., Urquhart, J., and Lambin, X. (2011) Turning back the tide of American mink invasion at an unprecedented scale through community participation and adaptive management. *Biological Conservation*, 144(1), pp.575–583.
- Thomas, L., Buckland, S.T., Rexstad, E.A., Laake, J.L., Strindberg, S., Hedley, S.L., Bishop, J.R.B., Marques, T.A., and Burnham, K.P. (2010) Distance software: design and analysis of distance sampling surveys for estimating population size. *Journal of Applied Ecology*, 47(1), pp.5–14.
- Bell, S., Shaw, B., and Boaz, A. (2011) Real-world approaches to assessing the impact of environmental research on policy. *Research Evaluation*, 20(3), pp.227–237.
- Soulé, M.E. (1985) What Is Conservation Biology? *BioScience*, 1(1), pp.727–734.
- Rands, M.R.W., Adams, W.M., Bennun, L., Butchart, S.H.M., Clements, A., Coomes, D., Entwistle, A., Hodge, I., Kapos, V., Scharlemann, J.P.W., Sutherland, W.J., and Vira, B. (2010) Biodiversity Conservation: Challenges Beyond 2010. *Science*, 329(5997), pp.1298–1303.
- Butchart, S.H.M. et al., 2010. Global Biodiversity: Indicators of Recent Declines. *Science*, 328(5982), pp.1164–1168.
- Czech, B. (2008) Prospects for Reconciling the Conflict between Economic Growth and Biodiversity Conservation with Technological Progress. *Conservation Biology*, 22(6), pp.1389–1398.
- Young, J.C., et al. (2014) Improving the science-policy dialogue to meet the challenges of biodiversity conservation: having conversations rather than talking at one-another. *Biodiversity and Conservation*, 23(2), pp.387–404.
- Brechin, S.R., Wilshusen, P.R., Fortwangler, C.L., and West, P.C. (2002) Beyond the Square Wheel: Toward a More Comprehensive Understanding of Biodiversity Conservation as Social and Political Process. *Society & Natural Resources*, 15(1), pp.41–64.
- Mayda, J. (1984) Environmental Legislation in Developing Countries: Some Parameters and Constraints. *Ecology Law Quarterly*, 12, p.997.
- Andreen, W.L. (2000) Environmental Law and International Assistance: The Challenge of Strengthening Environmental Law in the Developing World. *Columbia Journal of Environmental Law*, 25, p.17.
- Pretty, J., and Smith, D. (2004) Social Capital in Biodiversity Conservation and Management. *Conservation Biology*, 18(3), pp.631–638.
- University of Durham, Boundary making and resolving disputed territorial claims, REF2014 impact case studies, <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?id=11842> [Accessed 30 October 2015].
- University of the West of England, Reducing overfishing in the UK and its overseas territories and supporting marine communities through the use of established terrestrial property management practices, <http://impact.ref.ac.uk/CaseStudies/Results.aspx?val=boundary+divisions> [Accessed 30 October 2015].
- University of Bath, Reintroduction of the Great Bustard to the UK, <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?id=43208> [Accessed 30 October 2015].
- University of York, Recognition that global climate change is a major driver of biodiversity change and its implications for policy, <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?id=43422> [Accessed 30 October 2015].



It cannot be denied that there is need for effective and sustainable management of the materials that people consider to be 'waste'. In the UK alone, about 200 million tonnes of waste are produced annually¹; on average over 500 kg of waste is produced for every individual in the UK².

Given the resultant need for effective waste management and the need for an evidence base to guide and underpin strategy, policy and practice, there is considerable scope for research to have a positive impact in this realm.

This review therefore presents a profile of impact case studies (ICSs) submitted as part of the Research Excellence Framework (REF) assessment undertaken in 2014³. To explore how impact in waste management was reported and within which unit of assessment (UoA), we carried out qualitative and semi-quantitative assessments of the ICS statements submitted in 2014. An initial search of the REF 2014 ICS database³ using the search term "waste management" revealed 44 ICS statements that included, in various terms, reference to impacts on waste management. When considered in terms of the type of impact stated in these ICSs (see **Table 1**), there was a bias towards the environmental and technological, with over 70 per cent of ICSs detailing impacts in these two terms. Fewer impacts were reported in political, societal and economic areas.

THE WASTE HIERARCHY

Further scrutiny of the ICS statements revealed that many were explicitly within the realm of waste management. Other ICSs, however, focused primarily on other themes or issues, and statements relating to waste management were peripheral or tangential to the primary impact as stated. We subsequently focused on a subset of ICSs orientated primarily and explicitly towards aspects of

Waste management: the impacts of UK university research

Peter Shaw and **Ian Williams** explore the reach and significance of UK university research in the waste management sector.

Table 1. Numbers and proportions of impact types for impact case studies broadly related to waste management³

Impact type	Number of ICS statements
Environmental	17 (39 per cent)
Political	5 (11 per cent)
Technological	14 (32 per cent)
Societal	5 (11 per cent)
Economic	3 (7 per cent)



▲ Figure 1. The waste hierarchy, as outlined in the EU Waste Framework Directive (2008/98/EC). Adapted from Defra⁷.

waste management. We selected only ICSs that were aligned with the key principles of the waste hierarchy (see Figure 1), facets of sustainable waste management^{4,5} or the circular economy⁶. Only 19 out of the 44 ICSs broadly related to waste management met these criteria.

For these 19 ICSs in the subsample, there was not a common or frequent destination for the ICS statements with regard to the Unit of Assessment to which they were submitted. ICSs for waste management were submitted to 10 different units of assessment across all four REF 2014 Main Panels (see Table 2). For example, eight ICSs addressing impacts in the disposal, storage and containment of radioactive waste were submitted in four different units of assessment, albeit all within REF Main panel B.

“the principles of the waste hierarchy are firmly established and commonly employed to guide and assess migration of waste management towards best practice”

To explore in more detail the impacts set out in these ICS statements, we evaluated each in relation to key principles and concepts in waste management. First we considered each statement in relation to the waste hierarchy (see Figure 1); the principles of the waste hierarchy are firmly established and commonly employed⁸ to guide and assess migration of waste management towards best practice⁹. Secondly, we considered the ICS statements in relation to the principles of sustainable waste and resource management^{4,10}, and with reference to the concept of the

Table 2. The REF 2014 main panels and units of assessment in which waste management ICSs were submitted³.

REF 2014 Main Panel (A, B, C or D) and unit of assessment	Number of waste management ICSs
A3 Allied Health Professions, Dentistry, Nursing and Pharmacy	1
B7 Earth Systems and Environmental Sciences	3
B8 Chemistry	3
B12 Aeronautical, Mechanical, Chemical and Manufacturing Engineering	2
B13 Electrical and Electronic Engineering, Metallurgy and Materials	2
B14 Civil and Construction Engineering	2
B15 General Engineering	2
C16 Architecture, Built Environment and Planning	1
C17 Geography, Environmental Studies and Archaeology	1
D34 Art and Design: History, Practice and Theory	1

circular economy, in which the value of waste materials in the production of new goods is foregrounded⁶).

Our assessment (see Table 3) showed that there only were two of these 19 ICSs for which impacts aligned with a wide range of waste management principles and concepts. This is an exploratory assessment: distinctions are not absolute in that the principles of the waste hierarchy overlap with notions of sustainable waste management which, in turn, are associated with the needs and methods for a circular economy. Nonetheless, our assessment shows that the focus of many of the waste management ICSs is quite specific and often aligned with one or two elements of the waste hierarchy that are of lower preference.

All ICSs in the area of nuclear waste treatment and/or storage were primarily concerned with disposal, albeit with occasional or minor references to recovery of (nuclear) fuel from radioactive waste streams. Only one ICS focused primarily on prevention, which is the most preferred element of the waste hierarchy. There were only two examples of upcycling (aggregates produced from waste materials). Although upcycling could be considered a form of recycling, there is an emerging and growing recognition of the potential of upcycling to make positive contributions to waste management. More broadly, activity in the area of upcycling is increasing in profile, although largely at local or individual scale¹¹ as opposed to in industrial processes.

With regard to the two ICSs for which impacts were aligned with a broad range of waste management principles and concepts, differences in the research leading to and underpinning the impacts illustrated different mechanisms leading to impacts.

POSITIVE IMPACTS

The sustainable waste management ICS (see Table 3) showed an approach in which impact arises from a purposefully holistic approach that encompasses all facets of the waste hierarchy and aligns with the principles of sustainability and the circular economy. Notable impacts as stated include contributions to the UK's increased diversion of waste from landfill and increased recycling rates, plus development of value recovery from waste using anaerobic digestion. In this particular ICS, inter- and multi-disciplinary research is clearly evident, including elements of social and economic research in addition to scientific, engineering and technological work. We also noted that much of the underpinning research in this particular case was conducted in collaboration with industry partners,



▲ Figure 1. The percentages of case studies assigned the Summary Impact Type 'environmental', and which were submitted under the Earth systems and environmental science UoA. (Source: REF2014 impact case study database; search term: "waste management")

▼ **Table 3. Focus of REF 2014 impact case studies in relation to the waste hierarchy, and aligned with principles of sustainable waste management (SWM) and the circular economy (CE).**

Primary focus	Aligned with:						
	Prevent	Reuse	Recycle	Recover	Dispose	SWM	CE
Sustainable waste management	✓	✓	✓	✓	✓	✓	✓
Lifecycle modelling	✓	✓	✓	✓	✓	✓	✓
Waste prevention planning	✓					✓	
Biodegradation of municipal waste			✓ ^a	✓		✓	
Sustainable design			✓ ^{2a}			✓	
Waste treatment with CO ₂ to produce aggregates ^{3c}			✓			✓	
Waste into energy				✓			
Organic waste ^{4d}			✓				
Nuclear waste treatment/storage ^{5e}					✓		

✓ indicates ICS alignment; ✓ indicates primary or strong alignment;

^a Focus on composting and anaerobic digestion;

^b Focus on composting;

^c Two ICSs with a highly similar focus;

^d Two ICSs that focus on bioaerosol emissions from organic waste during composting;

^e Eight ICSs with primary focus on nuclear/radioactive waste; all had the same primary focus.

regulators and professional bodies. Such connections have clearly contributed to the communication of research findings to users and decision-makers (see **Box 1**), a means by which direct applications of research outputs can be facilitated.

In contrast, the lifecycle modelling ICS (see **Table 3**) engages in waste management via research that addresses the assessment and management of supply chains. As for the sustainable waste management ICS considered above, the research leading to and underpinning the impacts of lifecycle modelling adopts an holistic approach. There is emphasis on the role of the research and associated outputs in terms of decision support and management; the work has clear applications in industrial contexts and for local authorities and waste management authorities. Again there is evidence that connections with the user

community serve as a means of communicating and facilitating the application of the research findings.

We noted that the two ICSs statements most broadly aligned with the waste hierarchy – sustainable waste management and the circular economy – were both returned under unit of assessment B15: General Engineering.

KEY OBSERVATIONS

In reviewing the ICSs submitted for REF 2014 in the field of waste management, there are several key observations. First, not all those ICS statements that alluded to waste management could be considered to focus on waste management as a primary impact. Secondly, there is no common destination for waste management ICSs in terms of the unit of assessment to which they were submitted. This situation may be due to two factors that are not mutually exclusive:

BOX 1: WASTE REDUCTION¹³

Driving the waste reduction agenda: facilitated uptake by Local Authorities of knowledge, ideas and techniques for developing waste prevention plans

This case study from the Centre for Sustainable Wastes Management (CSWM) at the University of Northampton describes the impacts of its collaboration in a training programme for Local Authorities. Reflecting a shift in emphasis in the early 2000s from waste management to waste prevention, the Waste and Resources Action Programme (WRAP financed a major Local Authority training programme which involved the CSWM based on its research expertise in the area of waste prevention.

An independent evaluation of the training programme showed that over 90% of the 204 delegates (who between them represented 33% of Local Authorities) developed a deeper understanding of waste prevention and 41% consequently upgraded their own plans. This programme led to the embedding of sustainable practice in their organisations and reduced waste arisings. As such, the ultimate impact of this research has been to save money for Local Authorities and reduce the total amount of waste going to landfill.

1. There is no single unit of assessment that aligns naturally with waste management impacts. Given the wide range of research themes and researchers (engineering, technology, management, economics and social), it would be difficult to envisage a "one-size-fits-all" unit of assessment unless there was one that was explicitly designated as relating to waste management.
2. Institutions making REF 2014 submissions make decisions regarding units of assessment in the contexts of other areas of concern in the REF 2014 process and in the context of institutional strategy. The placement of an ICS in a specific unit of assessment may not therefore reflect a simple match of an ICS to one of the available units of assessment.

Which regard to the focus of ICSs and their alignment with key concepts and principles (see **Table 3**), we suggest that the variation observed is an overall strength of waste management research as witnessed in the ICS submissions. There is obvious appeal to research adopting holistic, multi- and inter-disciplinary approaches and a resulting impact that, in combining elements of the waste hierarchy, leads towards systems and methods aligned with sustainability and the circular economy. At the same time, more specific focus on discrete elements of waste management is observed to lead to narrower and deeper impact. It is arguable these two modes of research and their respective pathways to impacts are complementary. The REF guidelines for assessment of the impact subprofile¹², however, purport to determine "... the extent to which the unit's approach described in the template was conducive to achieving impacts of 'reach and significance'." How ICS statements will be focused and aligned to optimise their reach and

significance in order to achieve high grading in future REF assessments will no doubt lead to and require considerable and strategic evaluation. **ES**

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Ian D. Williams is Professor of Applied Environmental Science at the University of Southampton. Ian's research interests in waste management are aligned with the aims and principles of the circular economy. His work focuses on a wide range of waste materials from different sectors, including management of household waste and critical raw materials found in electronic and electrical wastes. (idw@soton.ac.uk)

REFERENCES

1. Department for Environment, Food and Rural Affairs (Defra; 2015) UK statistics on waste. www.gov.uk/government/statistics/uk-waste-data [Accessed 30 September 2015].
2. Chartered Institution of Waste Management (CIWM) (2013) UK stagnates on EU recycling league table. www.ciwm.co.uk/CIWM/Publications/LatestNews/UKStagnatesOnEUR Recycling-LeagueTable.aspx [Accessed 13 February 2014].
3. Research Excellence Framework (REF) (2014a). Search REF impact case studies. impact.ref.ac.uk/CaseStudies [Accessed 1 October 2015].
4. Lisney, R., Riley, K., and Banks, C.J. (2003) From waste to resource management: part 2. *Management Services*, 48, pp.6–12.
5. Communities and Local Government (CLG) (2011) Planning policy statement 10: planning for sustainable waste management. www.gov.uk/government/uploads/system/uploads/attachment_data/file/11443/1876202.pdf.
6. Ellen MacArthur Foundation (2015) Circular economy. www.ellenmacarthurfoundation.org/circular-economy [Accessed 1 October 2015].
7. Department for Environment, Food and Rural Affairs (Defra) (2013) Waste legislation and regulations. www.gov.uk/waste-legislation-and-regulations [Accessed 23 March 2014].
8. Williams, I.D. (2015) Forty years of the waste hierarchy. *Waste Management*, 40, pp.1–2.
9. Farmer, T.D., Shaw, P.J., and Williams, I.D. (2015) Destined for indecision? A critical analysis of waste management practices in England from 1996 to 2013. *Waste Management*, 39, pp.266–276.
10. Banks, C.J., Lisney, R., and Riley, K. (2003) From waste to resource management: part 1. *Management Services*, 47, pp.8–14.
11. Upcycling (2015) Upcycling: why recycle when you can upcycle? www.upcycling.co.uk [Accessed 1 October 2015].
12. Research Excellence Framework (REF) (2014b) Assessment criteria and level definitions. www.ref.ac.uk/panels/assessmentcriteria-and-level-definitions [Accessed 1 October 2015].
13. University of Northampton, Driving the waste reduction agenda: facilitated uptake by Local Authorities of knowledge, ideas and techniques for developing waste prevention plans, REF2014 impact case studies, <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?id=38554> [Accessed 4 November].

Ecosystem services : the impacts of UK university research

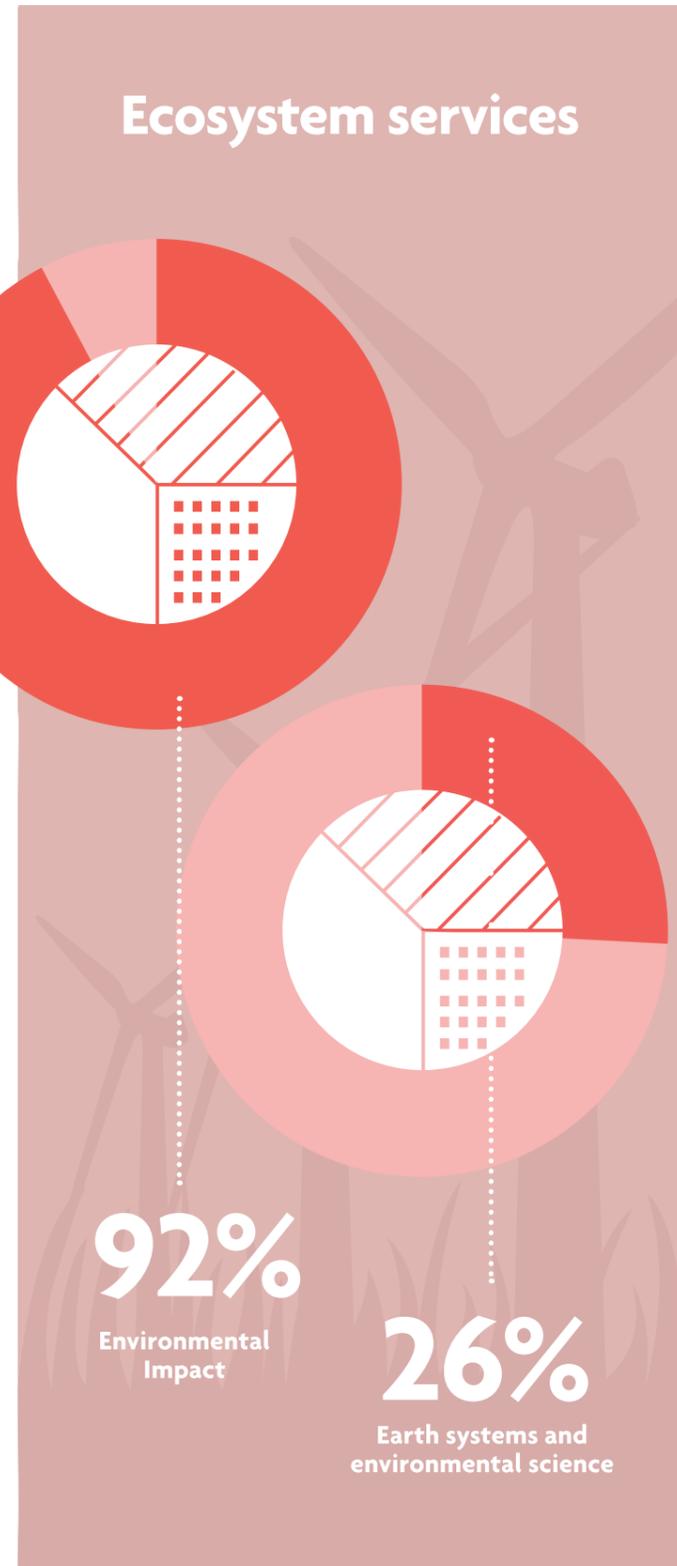
Mark Everard examines the political, environmental, technological and cultural impacts.

The topic of ecosystem services has been evolving since the late 1980s. Starting in a development context, ecosystem services then gained an international policy profile with publication of the UN Millennium Ecosystem Assessment (MA) in 2005¹. In essence, ecosystem services are the benefits that people derive from ecosystems. Consideration of the status of and trends in major global habitat types in the MA emphasised the vulnerability of societies to declining ecosystem services. The MA also proposed options for their protection and recovery.

BOX 1: ECONOMICS OF ECOSYSTEM SERVICES³

The economics of ecosystem services and biodiversity

The impact of this research from Aberystwyth University was primarily political, shaping policies, practices and behaviours affecting global biodiversity and the value of the ecosystem services that it provides. The research has had impacts on local communities, UK policy and international policy, providing valuation methods and assessments influencing policy formulation.



▲ **Figure 1. The percentages of case studies assigned the Summary Impact Type 'environmental', and which were submitted under the Earth systems and environmental science UoA. (Source: REF2014 impact case study database; search term: "Ecosystem services").**

Ecosystem services have since been the subject of significant research activity, with many resulting publications. Though originating as an approach to sustainable natural resource management in the developing world, the relevance and application of ecosystem services to developed world problems – from urban design to industrial practices, flood risk and water resource management, nature and heritage conservation, health and social inclusion – means that many ecosystem service case studies are directly relevant to societal decision-making.

“in essence, ecosystem services are the benefits that people derive from ecosystems”

BOX 2: INFLUENCING GOVERNMENT POLICY⁴

Costing the Earth: Influencing Government Policy for Ecosystem Services

This researching from the University of East Anglia has had a direct impact on UK Government policy, including the 2011 Natural Environment White Paper⁴ and various government guidelines and reports. It also generated substantial public outreach through exposure in the broader media. The underpinning research has been on valuation of the natural environment and the ecosystem services it provides, for which UEA research has developed theory and methods for valuing ecosystem services and incorporating them within decision-making.

KEY IMPACT TYPES

Ecosystem services are inherently systemic in nature, as they touch upon the environmental systems from which they emanate, the social and cultural benefits they underwrite, the political levers that influence their production and conservation, and their utility in technology and industry. Some 66 REF 2014 impact case studies² included 'ecosystem services' as keywords. These case studies demonstrate a great variety of impact⁵, which can be broadly categorised as influencing the political, environmental, technological and cultural dimensions (see **Boxes 1–5**). However, it should be emphasised that these dimensions are inherently interlinked, so that case studies often touch on more than one dimension.

BOX 3: LAKE NAIVASHA (KENYA)⁵

Restoring the ecosystem services of Lake Naivasha (Kenya) for globally-important exports, unique biodiversity and 3/4 million people

This impact case study is primarily environmental, addressing understanding and knowledge generation relevant to the conservation of the Lake Naivasha region, a globally important wildlife sanctuary (see **Figure 2**). There are links to economic and social benefits, including international tourism and the viability of adjacent businesses (particularly cut flower exports).

The research is long running, and shows that the sustained degradation of Naivasha's ecosystem by the early 2000s was driven by factors such as agricultural irrigation and the introduction of invasive non-native species. The development of a detailed understanding of the interacting causes of this ecological degradation is informing innovative solutions to restoring the lake ecosystem.



▲ **Figure 2. Great white pelicans in flight over Lake Naivasha in Kenya. (© Eovsyannikova | Dreamstime)**



▲ **Figure 3.** Research at the University of Central Lancashire has demonstrated the important role of earthworms in soil rehabilitation. (© clearviewstock | Fotolia)

POLITICAL INFLUENCE

One of the key ways in which ecosystem services research has impact is through informing policies at different scales of government. The direct link that the ecosystem services concept offers between the environment and human wellbeing makes it a useful policy tool. These impact case studies often draw heavily on work that investigates the economics (also called the valuation) of ecosystem services, which is attractive to policy-makers.

Boxes 1 and 2 are primarily economic in nature, with a significant influence on the political arena (nationally and internationally).

BOX 4: EARTHWORM APPLICATIONS⁶

Harnessing ecosystem services

This research addressed the applied use of earthworms in soil restoration, biomonitoring, agroecosystems and organic waste management (see **Figure 3**). This has benefitted a range of commercial interests (such as the Forestry Commission and BAE Systems) both in the UK and abroad, as well as attracting media attention promoting public outreach.

Supporting research includes a general earthworm survey across Britain and beyond, informing habitat suitability but also links with historical human activities and the effects of both rapid recent changes and longer-term factors affecting soil properties. The role of earthworms in soil rehabilitation has been a key element in this research.

ENVIRONMENTAL INFLUENCE

Some of the case studies presented have had impact through directly informing environmental management activities. An enhanced understanding of ecosystem services in environmental systems can enable managers to develop more holistic solutions that benefit both people and nature.

BOX 5: COMMUNITY OWNERSHIP⁷

Sustainability, Biodiversity Conservation and Indigenous Peoples: Community-Owned Solutions to Future Challenges in the Guiana Shield, South America

Though necessarily cross-cutting, touching multiple dimensions, this research took a community-owned approach to the sustainable management of social-ecological systems (SEs) within the Guiana Shield region of South America (Guyana, Suriname, French Guiana and areas of Brazil, Venezuela and Colombia). The region is globally significant for carbon storage, freshwater resources and biodiversity (see **Figure 4**).

The research recognised that indigenous communities have a crucial role to play in sustainable conservation policy and practice. Contemporary development pressures from the industrialised world, particularly from extractive industries, raise profound challenges for indigenous communities and their SEs. Central involvement of indigenous peoples in biodiversity science and sustainability policy has been found effective, not just in developing participatory research methods, but in identifying effective practices for surviving and thriving sustainably.

Box 3 focuses mainly on understanding the environmental processes, trends and pressures on the lake and adjacent ecosystem to inform innovative solutions to reverse the long-term decline in both lake ecology and the services it provides to local businesses and people.

TECHNOLOGICAL INFLUENCE

An understanding of ecosystem functioning can be extremely beneficial in designing efficient and sustainable industrial processes. Understanding ecosystem services can also lead researchers to develop novel and innovative technological solutions to a range of problems and challenges.

Box 4 includes an example of how ecosystem services can be harnessed for technological and potentially industrial uses.

CULTURAL INFLUENCE

The ecosystem approach places the interactions between people and environments at the centre of our understanding of the natural world. Numerous case studies presented to REF 2014 demonstrate the ways in which research involves communities, empowering them to interact sustainably with their environments.

Box 5 places indigenous, forest-dwelling communities at the centre of the research to inform sustainable approaches



▲ **Figure 4.** River valley in the Kaieteur National Park, Guyana. Part of the Guiana shield, this region is globally significant for carbon storage, freshwater resources and biodiversity. (© siempreverde22 | Fotolia)

to conservation and resource stewardship in the face of development pressures from the industrialised world.

WHAT CAN WE LEARN?

A key learning point is the systemic nature of ecosystem services, not merely from the highlighted five REF 2014 impact case studies, but from the full set of 66 case studies addressing ecosystem services. All case studies address multiple dimensions of cultural benefit or negative impact, potential technological applications and implications, and economic factors (be they monetised or reflecting broader value systems) that may be influential in policy formulation.

There remains a risk that ecosystem services, loosely defined or applied, could be interpreted as 'all things to all people', and thereby lose meaning and impact. However, the REF 2014 impact case studies collectively highlight how powerful the concept and associated tools are in making links between ecosystem assets and process, the benefits that people derive from them and

their associated and diverse values. It also highlights the importance of embedding ecosystems more centrally into policy formulation across all spheres of human activity.

Highly influential meta-studies such as TEEB (The Economics of Ecosystems and Biodiversity)⁸ and the UK National Ecosystem Assessment⁹ have been informed by REF 2014 impact case studies. Each of these broadscale studies has resulted in significant political and policy responses spanning a spectrum of policy areas and exerting influence at national and international scales. This snapshot of impacts from ecosystem services research emphasises the potential power and importance of the science and the return on investment in the work being done by environmental scientists.

GAPS

The involvement of the business community in more of the research would have been beneficial. All businesses use the environment in one way or another via services such as aggregate, forest and marine product extraction,

“the REF 2014 impact case studies collectively highlight how powerful the concept and associated tools are in making links between ecosystems assets and process, the benefits that people derive from them and their associated and diverse values”

water for consumptive and indirect uses, and waste broken down or disposed of in environmental media. Often, the dependency of business on ecosystem products and services – aside from exemplars such as the Marine Stewardship Council (MSC) and Forest Stewardship Council (FSC) schemes that create business differentiation on the back of sustainable resource stewardship – is substantially overlooked, resulting in vulnerabilities but also lost opportunities that could stem from innovations in sustainable resource use.

The involvement of financial institutions and the Treasury in ecosystem services research would also have been advantageous. England's recent Natural Environment Bill is significant in making legal provision for the setting of biodiversity and other targets, establishing (in practice renewing the mandate of) a Natural Capital Committee, and placing requirements on local authorities to:

- Maintain local ecological network strategies;
- Identify species threatened with extinction;
- Address access to quality natural green space; and
- Include education about the natural environment in the curriculum for maintained schools.

Most significant within the Bill is the commitment to investment in restoration or recreation of a range of habitats over a 25-year horizon, taking up the recommendation of the (former) Natural Capital Committee's third and final 2015 report¹⁰ not merely for altruistic reasons but reflecting the multiple values of ecosystem services that they provide.

Further Treasury involvement in ecosystem service search would further help embed the diverse values flowing from ecosystems to societal wellbeing – expressed through ecosystem services science – into a legacy economic system that has largely externalised them in the past and continues to do so in the present. Reform at this policy-spanning scale is vital if society is to address its commitment to attaining a sustainable future.

IMPROVING IMPACT

By their nature, many of the research teams behind REF 2014 impact case studies are cross-disciplinary. Further integration across disciplines would add greater potential for impact, particularly in recognising technological/ industrial and policy implications stemming from benefit flows from ecosystems to people.

Beyond the policy-influencing sphere, a number of case studies emphasise media interest as a significant element of public impact. Direct involvement of communicators and media professionals would promote this route to impact. Progressively greater integration across disciplines and, occasionally, the involvement of media expertise has been a feature of recent research. However, the

framing of knowledge in wider impactful forms is perhaps worthy of further exploration as impact becomes a driving force in research assessment. This is vital if we are to become serious about the discourse around science communication emerging since the 1980s, and if we are to ensure that the wealth of environmental scientific knowledge is taken up in the policy realm to accelerate progress with the era-defining challenge of attaining a sustainable pathway of development. **ES**

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REFERENCES

1. Millennium Ecosystem Assessment (2005) Ecosystems and human well-being: Synthesis. Island Press, Washington DC. www.millenniumassessment.org/en/index.html.
2. REF 2014 Impact case studies impact.ref.ac.uk/CaseStudies.
3. Aberystwyth University, The economics of ecosystem services and biodiversity, REF2014 impact case studies, http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?id=44000 [Accessed 4 November 2015].
4. University of East Anglia, Costing the Earth: Influencing Government Policy for Ecosystem Services, REF2014 impact case studies, http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?id=1446, [Accessed 4 November 2015].
5. University of Leicester, Restoring the ecosystem services of Lake Naivasha (Kenya) for globally-important exports, unique biodiversity and 3/4 million people, REF2014 impact case studies, http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?id=43505, [Accessed 4 November 2015].
6. University of Central Lancashire, Earthworm applications: harnessing ecosystem services, REF2014 impact case studies, http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?id=2790, [Accessed 4 November 2015].
7. Royal Holloway, University of London, Sustainability, Biodiversity Conservation and Indigenous Peoples: Community-Owned Solutions to Future Challenges in the Guiana Shield, South America, REF2014 impact case studies, http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?id=30230, [Accessed 4 November 2015].
8. The Economics of Ecosystems and Biodiversity, [Online] Available at: www.teebweb.org/ [Accessed 4 November 2015].
9. UK National Ecosystem Assessment (2011) Synthesis of Key Findings, http://uknea.unep-wcmc.org/ [Accessed 4 November 2015].
10. Natural Capital Committee (2015) The State of Natural Capital: Protecting and improving natural capital for prosperity and wellbeing, www.naturalcapitalcommittee.org/state-of-natural-capital-reports.html, [Accessed 4 November 2015].



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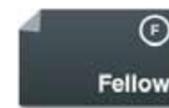
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- Preeyus Patel - Graduate
- George Payne - Graduate
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- Lee Shelton - Graduate Environmentalist
- Sarah Slater - Air Quality Consultant
- Richard Stenton - Environmental Engineer
- Daniel Stoneman - Hygiene Service Engineer
- Adam Stowe - Assistant Project Manager
- Joshua Tee - Graduate Air Quality Consultant
- Philip Walton - Environmental Scientist (Air Quality)
- James Wilson - Graduate
- David Wright - Assistant Air Quality Consultant
- Mary Yeadon - Graduate



is for individuals beginning their environmental career or those working on the periphery of environmental science.

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- Lisa Ashari - Graduate Environmental Consultant
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- James Barefoot - Graduate
- Bartosz Boraczynski - Technician - Stack Emission Testing
- Sevket Bostanci - Academician
- Samuel Bradley - Assistant Environmental Consultant
- James Clow - Graduate Environmental Scientist
- Taylor Cook - Graduate Sustainability
- James Cooper - Environmental Consultant
- John Cooper - Graduate
- James Corcoran - Air Vent Technician
- Blessing Digbani - Assistant
- Rachel Dunn - Graduate
- Rhiannon Ferguson - Environmentalist/Ecologist
- Hannah Figg - Graduate
- Charlotte Hammond - Environmental Consultant
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- Stephen Jay - Graduate Acoustic Consultant



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- Andrew Dale - Student
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- Alex Robinson - Student
- Adrian Rodriguez Santana - Student
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The marine environment: the impacts of UK university research

Ruth Bowyer dives deep into the world of marine research, and asks what's missing.



We have explored less than five per cent of the world's oceans¹, yet they contain 99 per cent of the habitable space on Earth². It is no surprise, then, that the study of the marine environment encompasses a wide range of scientific disciplines, from ecology to engineering. Thirty-six case studies were found in REF 2014 impact database using the search term "marine environment", with much of the research impact being for conservation and fisheries management, contaminant mitigation and energy resources. However, many had multiple impacts.

The primary types of impact measured fell broadly into the following categories.

ENERGY

The growing investment in offshore renewables is reflected in the large number of studies that informed

BOX 1: OFFSHORE ENERGY³

Impacts of offshore energy developments

Offshore oil and gas and renewable energy developments are recognised as essential to the UK's energy security, but there are concerns that seismic survey techniques and construction noise pose a risk to harbour seals and bottlenose dolphins. The University of Aberdeen's research on the coastal populations of these marine mammals in Scotland's Moray Firth has made them two of the most intensively studied species in the world. Researchers have used their long-term studies of population dynamics to develop frameworks for assessing and mitigating the impacts of offshore energy developments for marine mammals in EU protected areas.

The impact of this work is in the adoption of this assessment process by industry within their consent applications. Planning decisions are therefore better informed by research, consenting risk is reduced for industry and regulators are helped to ensure adequate environmental protection according to international legal frameworks and current government policy.

energy projects, although the research projects explored in this set of case studies informed both green and fossil-fuel industries. Many studies focused on mapping techniques, with the research being used specifically to understand, where to place wind turbines, where to look for gas and oil and possible storage locations for nuclear by-products. Other studies used modelling of turbulence and other ocean processes to inform the siting of renewable plants.

BOX 2: MEASURING FISH STOCKS³

High throughput molecular fish fingerprinting assay for measuring fish stocks

Research by two University of East Anglia researchers, Taylor and Rico, led to the development of a molecular fingerprinting assay that uses fluorescent dyes to classify visually indistinguishable fish eggs. The method allows surveyors to quickly identify large numbers of cod, haddock and whiting eggs and thereby enables them to carry out an accurate assessment of fish stocks. This is essential for setting fishing quotas to ensure healthy populations.

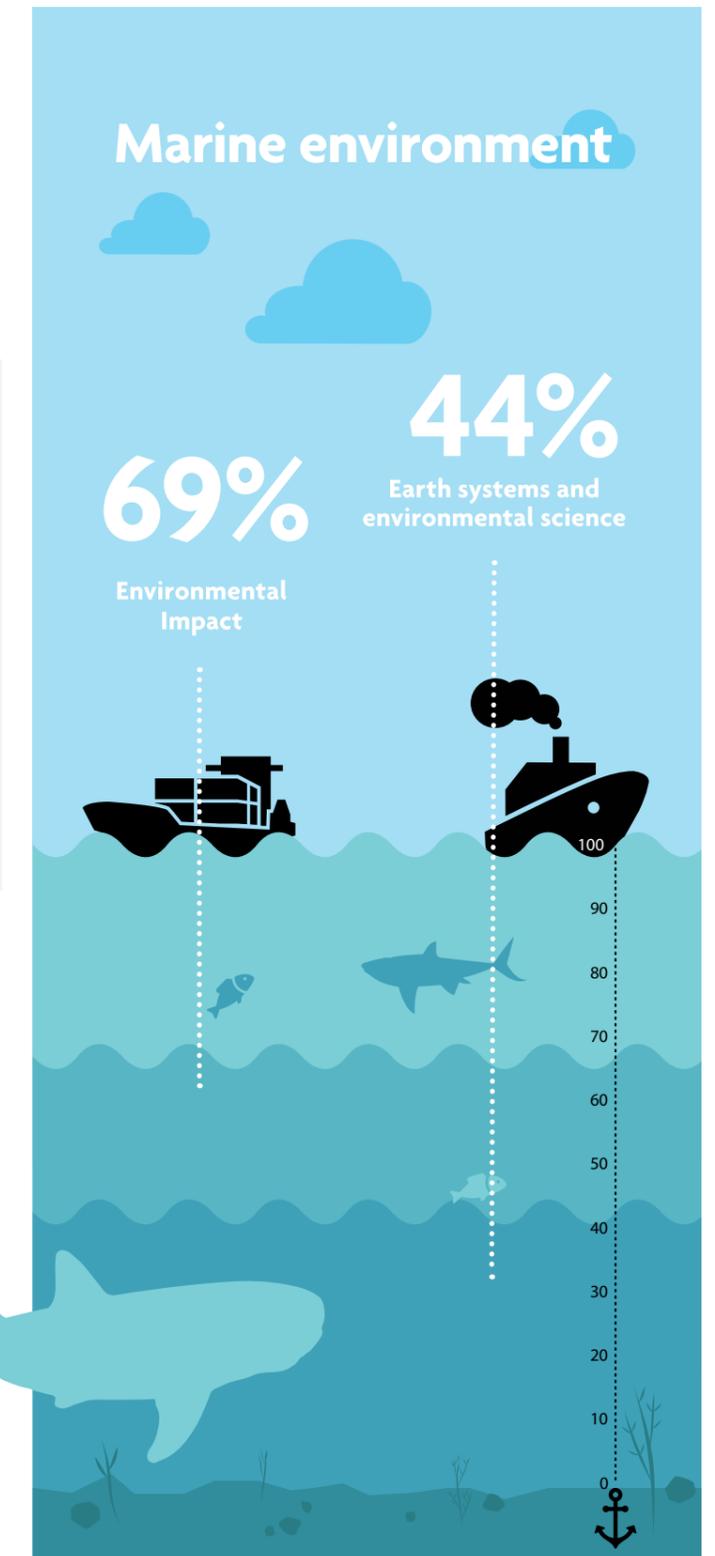
Based on this research, and with assistance from the researchers, the Centre for Environment, Fisheries and Aquaculture Science (Cefas) developed a molecular lab. Cefas used the assay in its annual assessment of cod and haddock stocks in the Irish Sea between 2006 and 2010. The Swedish Board of Fisheries also used the assay to map cod spawning grounds in the Eastern Baltic Sea.

CONSERVATION AND FISHERIES MANAGEMENT

Many of the ecological studies focused on keystone species, such as cetaceans, and how best to protect them from negative consequences of ocean exploitation. Several case studies demonstrated how models were used to better understand the ways of limiting by-catch and population disruption from offshore wind farms (see **Box 1**), with much of the research informing UK and EU policy. The Department for Environment, Food and Rural Affairs (Defra) has used this research to designate larger marine protected areas. Some case studies also demonstrated how researchers, in collaboration with regulators, are developing methods and technology that can assist with fish stock surveys and therefore inform regulators in setting fishing quotas to ensure the viability of healthy fish populations (see **Box 2**).

CONTAMINANT MITIGATION

Research into ways to limit the effects of pollutants and find more environmentally friendly ways to deal with biofouling are also common themes (see **Box 3**). The main routes to impact demonstrated in these case studies are through informing industry best practice and EU policies (see **Box 4**).



▲ **Figure 1.** The percentages of case studies assigned the Summary Impact Type 'environmental', and which were submitted under the Earth systems and environmental science UoA. (Source: REF2014 impact case study database; search term: "Marine environment").

BOX 3: HYDROCARBON CONTAMINATION⁴**Environmental Monitoring/Sampling in the Marine Environment**

Research by Robert Gordon University and the Marine Scotland Science Marine Laboratory formed the basis for a range of sampling, measurement and statistical methods and has been developed to improve assessment of hydrocarbons and other contaminants in the marine environment. Researchers developed an improved method of monitoring marine contaminants such as by enhancing the ability to monitor toxic polycyclic aromatic hydrocarbons (PAHs) and the associated metabolites in exposed organisms, and via development of an improved sampling strategy, which became known as the Random Stratified Statistical Sampling Regime, which was demonstrated to gather much more reliable data and be more cost and time effective. The regime has become internationally recognised as a method for protecting and enhancing the environment (such as fisheries) and for oil and gas exploration. The UK Marine Monitoring and Assessment Strategy adopted the survey protocol in 2009 and have since passed into wide policy as the accepted standard of marine monitoring in the oil exploration and production being undertaken on the UK continental shelf.

SEAFARING SAFETY

A few of the studies included in this search focused on ways to improve safety for seafarers via improved navigational charts and even psychological modelling to ensure safety. In one quite specific example, the University of Bournemouth also demonstrated how their research had informed the redesign of slipway panels and lubrication systems for the Royal National Lifeboat Institution (RNLI). These save the charity a large amount of money annually in wear and tear to vessels, as well as improving the safety and sustainability of the launch practice (as grease-based lubricants are no longer required)⁷. This demonstrates how some impact can be very specific in nature.

“opportunities to highlight the impact of marine science, such as that offered by the REF, are extremely valuable and should be used to maximum effect.”

WHAT CAN WE LEARN?

Research into the marine environment clearly has a wide range of impacts, with much research informing national and international legislation. Some of the more ecological- and conservation-based case studies do perhaps tend towards highlighting the economic benefits they have yielded for industry (for example, via improved modelling capabilities and higher efficiency) over their policy implications.



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BOX 4: MICROPLASTICS⁶**Discovery of microplastics as key anthropogenic contaminants in the marine environment**

A team from Plymouth University; Identified and documented how microplastic particles have accumulated since the 1960s and are found in oceans worldwide. Further research has demonstrated that marine organisms ingest microplastics, which have the potential to release chemical contaminants and pass up the food chain.

The case study explains that the main impacts of this research have been on policy. Parliamentary discussions were held within days of the publication of the first paper, and the regulation of microplastics was incorporated into the Marine Strategy Framework Directive in 2010. This research has also had impacts on policy in the USA.

Seventeen studies were submitted under the Earth Systems and Environmental Sciences unit of assessment (UoA; see

Figure 1), with the rest predominantly falling into engineering and biological sciences UoAs, perhaps partially due to the high number of ecological studies that fall across both the environmental science and biological subject areas. The majority of studies were submitted from Scottish-based institutions.

“there is surprisingly little focus on the impacts that research into the world’s oceans could have on understanding the effects of climate change.”

WHAT IMPACT IS NOT ILLUSTRATED?

Given the proximity to the Paris Climate Change Conference (COP21), there is surprisingly little focus

on the impacts that research into the world’s oceans could have on understanding the effects of climate change. REF 2014 is not of course designed to capture all impact from UK university research, but it is surprising that higher education institutions (HEIs) would not wish to highlight such projects. Perhaps it is harder to demonstrate the impact of research that deals with very long-term issues.

The limitations of this simplistic database search are recognised, but perhaps what is most surprising about the findings of this analysis is that more case studies do not focus on marine environmental research. Marine environmental science can help us to understand the state of the marine environment, our interactions with and impacts on these vital ecosystems, and how we can better live within environmental limits.

However, the importance of both the marine environment and marine science is widely underestimated, and this

is all too often reflected in staffing and funding across research institutions and government departments. This is also underlined by the fact that much of the impact captured by REF 2014 from research exploring the marine environment seems to focus on the management and industry. To begin to counter this and address the deficit in our understanding of this huge and hugely important area of our planet, opportunities to highlight the impact of marine science, such as that offered by the REF, are extremely valuable and should be used to maximum effect.

ES

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Ruth has an ecological background, and is commencing a PhD at Kings College London where she will be researching how diet and environmental factors affect the ecology of the human gut microbiome. She has previously worked in the conservation sector and contributed towards marine research whilst working for the University of Sheffield.



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REFERENCES

1. National Oceanic and Atmospheric Administration (NOAA). How much of the ocean have we explored? oceanservice.noaa.gov/facts/exploration.html [Accessed: 4 November 2015].
2. National Aeronautics and Space Administration (NASA). NASA Science Earth, Living Ocean. science.nasa.gov/earth-science/oceanography/living-ocean/ [Accessed: 4 November 2015].
3. University of Aberdeen. Impacts of offshore energy developments. REF 2014 impact case studies, impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=43284 [Accessed: 4 November 2015].
4. Robert Gordon University, Environmental monitoring/sampling in the marine environment, REF2014 impact case studies, http://impact.ref.ac.uk/CaseStudies/Results.aspx?val=monitoring+hydrocarbon+contamination [Accessed: 4 November 2015].
5. University of East Anglia. High throughput molecular fish fingerprinting assay for measuring fish stocks, REF 2014 impact case studies, impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=3398 [Accessed: 4 November 2015].
6. Plymouth University. Discovery of microplastics as key anthropogenic contaminants in the marine environment, REF 2014 impact case studies, impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=4586 [Accessed: 4 November 2015].
7. Bournemouth University. Green Tribology – The Sustainable Design of Lifeboat Launch Systems, REF 2014 impact case studies, impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=43144 [Accessed: 4 November 2015].

Air quality: the impacts of UK university research

Ben Williams shows that UK universities make a vital contribution to research into the causes, effects and management of air pollution.

Air pollution is the biggest environmental risk facing humanity in modern times. According to the World Health Organisation (WHO), 7 million people died as a result of exposure to air pollution worldwide in 2012, equivalent to one in every eight recorded. The greatest burden was carried by countries in the South-East Asian and Western Pacific regions, where 3.3 million deaths were linked to indoor air pollution and a further 2.6 million linked to outdoor air pollution¹ In Europe, air pollution has contributed to approximately 400,000 deaths a year², and in the UK both PM_{2.5} and NO₂ have been associated with more than 50,000 premature deaths a year.

Our ecosystems are also damaged by air pollution through mechanisms such as eutrophication, and it has a significant impact on crop yields annually. In financial terms, air pollution is thought to cost the UK £15 billion a year³.

Globally, the main impact from indoor air pollution is from burning solid fuel for cooking and heating. From a UK perspective, the biggest impact is from vehicle emissions, something that is exacerbated in cities with high population densities and therefore high vehicle numbers. Increasing urbanisation will expose more people to air pollution. Research and innovation in the field of air quality is therefore of the utmost importance for minimising the impact of air pollution on the health of citizens.

“air pollution is the biggest environmental risk facing humanity in modern times”

The air quality impact case studies summarised here were obtained by performing a search for “air quality” using the Higher Education Funding Council for England (HEFCE) online database⁴ of the 2014 Research Excellence Framework (REF). Of the 57 results, many merely refer to air quality, so the actual number of case studies dedicated to air quality is about 40.

The research undertaken beneath the umbrella of air quality is wide and varied; key topics include:

- Forecasting air pollution and understanding its causes;
- The impact of various pollutants on public health; and
- The development of monitoring tools.

The impact of this research manifests itself in various ways, for example:

- By informing policy development at national and international levels;
- By assisting in the development of regulations and strategies for air quality management; and
- Through the development of technologies and methods for reducing and mitigating the risk of harm caused by air pollution.

IMPACT ON POLICY

Impact is often realised by working closely with policy-makers, targeted funding mechanisms, publications and membership of the relevant committees. UK research has influenced changes in policy both at home and internationally, with institutions such as the Environment Agency (EA), the European Commission (EC), the US Environmental Protection Agency (EPA) and the International Civil Aviation Organization (ICAO) using this body of work both to help set regulations and put guidance in place as well as helping to make sure they are adhered to.

Evidence-based policies, underpinned by rigorous scientific research and cutting-edge tools and methodologies, are crucial. The research in the field of air quality is as varied as its impact on policy, which ranges from informing traffic regulations and control (e.g. the London congestion charge and low emission zones), emission limits and building regulations, to providing specific air quality management procedures for local authorities and methods for restoring pollution-affected landscapes.

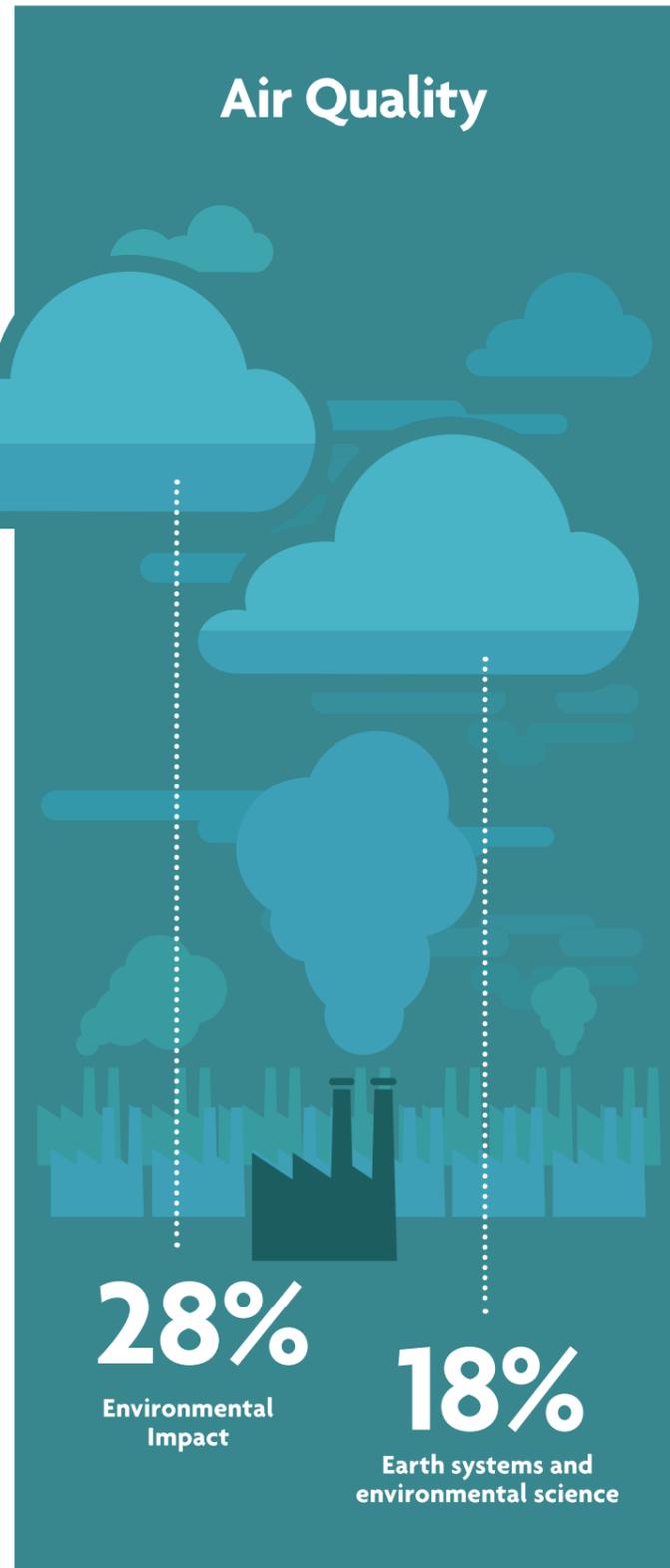
PUBLIC HEALTH

The efforts to reduce emissions are largely motivated by the need to reduce the negative health impacts of air pollution. One of the clearest and more immediate impacts on public health described in these case studies is the ability to warn the public of high-risk pollution events, due to the development of improved forecasting models. These allow vulnerable populations to take the necessary precautions when the air quality is particularly bad in a certain area. A number of case studies have demonstrated advances in remote sensing and modelling of meteorology and pollutants for the Met Office and for local organisations such as the fire brigade and other public agencies.

Other examples of emissions reduction include the development of efficient industrial air cleaners, and hybrid diesel-electric and electric-hydrogen vehicles.

AIR QUALITY MANAGEMENT

Air pollution is managed at an international and national level through the regulation of pollutant emissions and often more visibly at a local level through the introduction of Air Quality Management Areas and the development of air quality action plans (exemplar air



▲ **Figure 1. The percentages of case studies assigned the Summary Impact Type 'environmental', and which were submitted under the Earth systems and environmental science UoA. (Source: REF2014 impact case study database; search term: "Air quality").**



▲ **Figure 2. In many cities vehicle emissions are a major air quality and public health problem. (© Anizza | Dreamstime)**

quality action plans can be found on the Department for Environment, Food and Rural Affairs (Defra) website⁵). Relatively few case studies focused specifically on air quality management. One example was a case study that contributed to the improvement in local air quality management systems within the UK, Europe, Asia and South America by enabling the understanding of the spatial extent of air pollution. Research into how air pollution is managed at a local level identified the need for well-resourced and well-trained air quality specialists, which lead to the establishment of a professional body dedicated to the professional development of the air quality workforce (the Institute of Air Quality Management; IAQM).

INDOOR AIR POLLUTION

Indoor air pollution has a more significant impact on health globally, in spite of not being bound by the same legislation as outdoor air pollution in many places. For example, air pollution has been linked with heart disease and stroke, chronic obstructive pulmonary disease and acute lower respiratory infections, and reduced lung function in children⁶. It is considered that those households in which

solid fuel is used for heating and cooking would find it difficult both practically and economically even when more sophisticated (and often cleaner) fuels are available⁷. Some case studies submitted to REF 2014 have demonstrated improvements to air conditioning units, whilst others have demonstrated building design improvements as a means of improving indoor air quality.

IMPACTS OF NATURAL SOURCES OF AIR POLLUTION

In the wake of the 2010 eruption of Eyjafjallajökull in Iceland, a number of case studies focused on the impact of volcanic emissions on the aviation industry and how such impacts may be mitigated in future. One project resulted in the development of a system for identifying safe flying areas (based on pollutant concentrations) during an eruption, avoiding the need to ground all aircraft and thereby saving the industry millions of pounds.

Other impacts on health from natural sources of air pollution include a more detailed understanding of the relationship between radon and lung cancer leading to changes in building regulations that have reduced exposure to the radioactive gas in new homes.

BOX 1: AIR QUALITY MANAGEMENT¹⁰

Improving the management of air quality

The Air Quality Management Resource Centre (AQMRC) at the University of the West of England (UWE) operates at the interface of air quality science and policy. This case study demonstrates how evidence from research by this group "has enabled UK local and national governments and international governments (South Africa, Nigeria) to enhance their processes and procedures for managing air quality".

This case study outlines how research from the AQMRC has contributed significantly to a wider understanding politically and amongst the public of the risks posed by air pollution and promoted engagement in its management at the local level. In the UK, UWE research has informed official guidance issued to Local Authorities by UK governments, and researchers have advised devolved national and London administrations on the development of guidance, legislation and regulation. In recognition of the importance of a well-trained and resourced workforce, the AQMRC also co-founded the Institute of Air Quality Management, which is now acknowledged as the air quality professional body.

As well as contributing significantly to a review of the Local Air Quality Management process by the UK government's in-house policy consultants in 2010, this case study also shows how research from UWE has been recognised internationally. UWE findings were particularly influential in the development of a national framework in South Africa and practices adopted by national agencies in Nigeria.

WHAT CAN WE LEARN?

The battle to improve both indoor and outdoor air quality requires the focus of a quartet of research avenues, namely:

- Technological advances (e.g. improved emissions technologies);
- Monitoring and sensing developments (i.e. improved particulate and gas analysis techniques);



▲ **Figure 3. Eyjafjallajökull volcano erupting in Iceland. In the wake of this eruption several case studies focused on the impact of volcanic emissions on aviation.** (© Anders Peter Amsnæs | Fotolia)

- Improved air quality management plans and policies (e.g. local air quality management); and
- Communication.

To make significant impacts, not just on policy, but on the quality of our air, it will be vital to continue communicating with both policy-makers and the general public. In order to ensure governments and businesses pay attention it is becoming increasingly necessary for the impact of air quality research to demonstrate value in terms of savings and generating revenue.

Additionally, there are synergies between the aims of air pollution and, for example, sustainable development, where a reduction in energy use would lead to a reduction in pollutant emissions, or when strategic town planning reduces the need for commuting and thus reduces the number of vehicle journeys.

WHAT IMPACT IS NOT CAPTURED BY REF 2014?

Behavioural change is key when it comes to addressing the challenge of air pollution and yet almost none of the case studies submitted to REF 2014 described research that sought

to change the actions and attitudes of individuals. There may be plenty of research in this area, but the impact may be too difficult to measure for the purposes of REF 2014, or perhaps human behaviour is too difficult to influence on any meaningful scale over a relatively short space of time.

However, there are signs among these case studies that public engagement is increasingly on the agenda for researchers in this field – an impact case study described a community mapping project that involved thousands of citizens in mapping air pollution across their communities. Whether projects like this have any lasting impact on behaviours or contribute to a reduction in air pollution remains to be seen.

HOW CAN WE IMPROVE THE IMPACT OF OUR RESEARCH?

There are significant opportunities to boost the potential impact from UK researchers through greater engagement with institutions in countries experiencing the greatest effects of air pollution, most notably China, India and other south-east Asian nations. Best practice developed within the UK and Europe can be adapted and applied to these areas.

BOX 2: PARTICIPATORY MAPPING¹¹

Participatory GIS in action: new social enterprise Mapping for Change

In 2009, the social enterprise Mapping for Change (MFC) was established by researchers from University College London (UCL) in collaboration with partners from the London 21 Sustainability Network to make use of participatory mapping tools and software developed at UCL and associated knowledge. This case study concerns the impact this research has had through this social enterprise.

MFC projects help communities to use mapping and geographical technologies to collect, analyse and visualise information about their life and environment, and then develop action plans on this basis. Projects are developed through co-design with communities themselves. Since 2009 MFC has delivered over 30 projects in many communities with a range of impacts, including the implementation new environmental monitoring operations by several local authorities, and stimulated debate about the issues of noise and air pollution.

Work on air pollution has included a participatory pollution mapping exercise at seven locations around London, which has helped to demonstrate where emissions are above EU guidelines, and promoted action to protect residents.

BOX 3: RISK ASSESSMENT METHODS¹²

Development of risk assessment methods for the impacts of ground level ozone (O₃) on ecosystems to inform European atmospheric emission reduction strategies.

By the early 1990s, a large body of experimental data existed which demonstrated the adverse impacts of O₃ on crops, forests and grassland ecosystems. Lisa Emberson at the University of York has been researching the development and application of risk assessment methodologies for this pollutant, and this case study concerns the impacts of this work.

This programme of research has developed new risk assessment methods, based on knowledge of atmospheric exchange processes and plant eco-physiology, which assess O₃ uptake and related damage using a novel 'Critical Levels' classification system based on a stomatal flux model (which is based on O₃ uptake via the leaf pores). These methods are being used "by 26 parties (member states) who have signed and ratified the United Nations Economic Commission for Europe (UNECE) Gothenburg Protocol established under the Convention on Long Range Transboundary Air Pollution (LRTAP)". In this way, this research has led to tighter controls on emissions of ozone across Europe, benefiting crop and forest productivity and grassland species composition.

Closer collaboration between researchers and vehicle manufacturers could have multiple benefits. Some, including the development and improvement of alternative fuels and their efficiency are presented in these case studies. However, both strategic and technological opportunities exist, including collaboration on improving the fuel efficiency of cars and the transition of businesses from being dependent on fossil fuels to being pioneers in the use of renewable energy sources.

Because of the significant impact air pollution has on the human population and on the global ecosystem, the air

quality research community within the UK must continue to grow and develop. Despite the relatively small pool of researchers, the outputs presented here have had considerable reach globally and on the basis of current opportunities presented by funders such as the Natural Environment Research Council (NERC)⁸, the Newton Fund and the Wellcome Trust⁹ it is likely that a greater number of air quality impact case studies will be submitted to future REF exercises. **ES**

Dr Ben Williams is a Research Associate at the Air Quality Management Resource Centre at the University of the West of England. His current research interests include the modelling of bioaerosol emissions from composting facilities, the modelling of pollutant emissions from domestic solid fuel burning within the UK and understanding the importance of strategic decision making in the development of healthy urban environments. Prior to this he has worked as an environmental consultant developing and undertaking source apportionment investigations for industry and regulatory authorities.

REFERENCES

1. World Health Organisation (WHO) (2014) 7 million premature deaths linked annually to air pollution. WHO Media centre, 25 March, Geneva. www.who.int/mediacentre/news/releases/2014/air-pollution/en/ [Accessed 23 October 2015].
2. European Environment Agency (EEA) (2015) *The European Environment: State and Outlook 2015*. EEA, Copenhagen. www.eea.europa.eu/soer-2015/europe/air/keymessage-2015-01-30-1654211257.
3. Department for Environment, Food and Rural Affairs (Defra) (2010) Air Pollution: Action in a Changing Climate. Defra, London. www.gov.uk/government/uploads/system/uploads/attachment_data/file/69340/pb13378-air-pollution.pdf
4. REF 2014. Search REF Impact Case Studies. impact.ref.ac.uk/casestudies [Accessed 19 October 2015].
5. <http://laqm.defra.gov.uk/action-planning/good-practice.html>.
6. www.who.int/mediacentre/factsheets/fs313/en/.
7. [www.who.int/bulletin/archives/78\(9\)1078.pdf](http://www.who.int/bulletin/archives/78(9)1078.pdf).
8. www.nerc.ac.uk/research/funded/programmes/atmospollution/.
9. www.wellcome.ac.uk/About-us/Policy/Spotlight-issues/Health-impacts-of-climate-change/Trust-funding/index.htm.
10. University of the West of England, Improving the Management of Air Quality, REF2014 impact case studies, impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?id=40792, [Accessed 16 November 2015].
11. University College London, Participatory GIS in action: new social enterprise Mapping for Change, REF2014 impact case studies, impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?id=29988, [Accessed 16 November 2015].
12. University of York, Development of risk assessment methods for the impacts of ground level ozone (O₃) on ecosystems to inform European atmospheric emission reduction strategies, REF2014 impact case studies, impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?id=43427 [Accessed 16 November 2015].

Shifting cultures in UK environmental research

Robert Ashcroft talks to **Gary Kass** and **Kathryn Monk** about how the focus on impact may be causing a change of culture in our higher education institutions (HEIs).

Gary Kass is Deputy Chief Scientist at Natural England and Vice-Chair of the IES. He served as an impact assessor on the Archaeology, Geography and Environmental Studies panel of REF 2014.

Kathryn Monk is Principal Advisor for Science at Natural Resources Wales (NRW). She was an assessor on the Earth Systems and Environmental Sciences panel of the REF, having been nominated by Environment Agency Wales and various professional organisations. She had been previously invited directly to sit on the Research Assessment Exercise 2008 panel, and in the development of REF 2014 was a member of the impact pilot assessment committee.

As institutions and individual researchers increasingly need to consider what impact their research will have, it is important to assess whether this is simply a short-term change, or if a broader shift in culture across the UK higher education sector has begun. Kathryn and Gary drew on their experiences of participating in and using research, and being involved in the REF as impact assessors from the 'user community', to consider how the drive for impact may be changing the way research is done, what this means for HEIs and society, and what is next for the REF.

Are we witnessing a change in culture in UK HEIs? How is this affecting the environmental sector?

Kathryn For the general question, 'Is there a change in culture?', the answer is, 'Yes'. There was on both sides. There was a coming together of a need from the research users and a financial and social demand to know how money is spent in universities. These were the two main outside drivers towards developing impact.

Through the impact pilot assessment committee I was involved in designing and testing the impact section of the REF in the run up to the full REF 2014 process. It was really interesting to be able to work towards this, because it worked largely as we predicted. We thought that if we went to universities, we would obviously find some researchers who were really keen to have impact and worked closely with research users - they enjoyed doing that and understood it. However, for the vice-chancellors of universities, it would primarily be the REF or measures of academic excellence that was driving them. So, shifting money allocation to include impact has quite visibly changed the openness of universities to support research that can be more easily used, and this impact is now tracked much more clearly. Now there is a plethora of software that allows researchers to track their impact, and within universities themselves there are increased networks and support systems to allow identification of impact.

The other point I would add is that the research councils themselves do also demand impact. With the start of the Pathways to Impact programme¹ in 2009, Research Councils UK and individual research councils require demonstration of the use of some tracking software, and the next REF may as well. So recognising and tracking the impact of research from the universities and from the research councils is increasingly embedded.

Now I think we've almost come the other way - to help universities, I need the time of government evidence users to work with researchers, and that is a big challenge. We want to move from just identifying impact of work that's already been done to a form of co-production where we identify the question together and then develop a programme where users are involved throughout.

Gary I agree strongly with what Kathryn has just said. Certainly, my experience has been one where you can see a very explicit change in culture. But I think it's not actually that clear cut, and certainly reviewing a whole bunch of impact templates and impact case studies, you can see that some people have been doing it for a very, very long time but they just haven't necessarily been able to articulate it well. There is an issue, then, about whether 'impact' is meaningful as a term compared with the reality of practice. Even amongst those who didn't really seem to 'get' impact, there does seem to be a desire to use this as a learning process, otherwise you'd question why they submitted REF impact case studies at all. It's gearing up to get better at this in the future.

Things are definitely changing, but at the same time when you talk widely with academics you also have to consider the question, 'What else is the REF looking to do?'. Impact is still only up to 20 per cent of the REF score, which means that more than 80 per cent isn't! So, in that sense, while impact has been having some noticeable effect, and RAND Europe studies have confirmed it², it is still marginal and not necessarily being taken as seriously as it might be. And indeed, there has been discussion of looking at increasing the percentage of the REF score that impact may have in the future, which would help to make further progress.

As research users in your work, could you explain a little more what you mean by co-production?

Gary I think that at Natural England, and similarly at NRW, we're not just passively waiting and setting research questions, but actively getting involved in the research ourselves, because we're participants. There's a bigger model of co-production that's more than just using research.

Kathryn Well, co-production does mean just that, doesn't it? And I think you're right to say that at Natural



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England, particularly on the conservation side, there is a very strong tradition of co-production. You have lots of people who are active researchers. That isn't necessarily the case in a number of other areas. So, it's a change for users in other parts of government to be more involved and to be challenged more at the beginning. Instead of just saying, 'I want a survey of ...', giving universities the space to say, 'Why do you really want to survey that?', 'What is the problem?', 'Can we look at this a different way?', can potentially change the question, but that's a big shift for lots of government partners.

Also, there's a sense of confidence that is needed when working in partnership. Many researchers, much like our own organisations, find it easier to start with a nice clear question and have a tight, small team deliver an answer or paper. For many, both in government and research, to have adaptive management (which includes more iterations and changes of direction) is challenging as they are not used to it. There's a cultural change on both sides to allow this sort of good impact to be recognised and used.

Do you think it has been a challenge for researchers in our sector to demonstrate impact?

Kathryn It was quite noticeable as the REF impact case studies were developed that some people were almost like frozen rabbits when asked to write impact case studies, and then they gradually realised what it meant and were able to articulate it better, and many were pleasantly surprised. In fact, I think the whole community was actually a bit surprised about how impressive a lot of the impact studies were and how much material was available.

There were a number of people who said they should have just been trusted to deliver impact, but really it's been a PR coup, particularly for a number of other disciplines! In the environmental sciences, I think you would have expected a pretty good proportion to be actively involved in delivering more applied work, but in the arts and humanities there was a lot of fear initially about how they would manage that challenge.

In fact, the definition of impact does vary enormously. In environmental sciences, we became very demanding: if somebody said their impact was that they had produced a website or a book or organised a workshop, we would say, "Well, so what?". They would have to demonstrate the impact of the website/book/workshop. The humanities work more fluidly, particularly the whole area regarding the publication of literature, so they have their own way of identifying impact.

Gary I would agree. Actually, a lot of people go into environmental science because they want to have an impact anyway, in the same way really that medical researchers want to. It's mission-orientated research, so perhaps people are more receptive to doing that to start with.

One of the other trends I've identified is towards sustainability science. People like me having been doing it for 30 years, so it's not that new, but it links to thoughts on the future of impact in REF as there's an appeal to the wider science community to consider a new way of doing science. This new approach (which is what Kathryn and I have become used to really) is about science being defined by the problems we face and challenges we need to address; it's orientated towards actionable solutions

and not just about creating knowledge for knowledge's sake. So, I think in the environmental sciences this has been easier, as environmental scientists themselves are more driven to want to have impact.

You've shown how a change of culture is occurring, but do you think there are areas where the REF could better encourage or reward certain types of impact?

Gary I would suggest that the way the REF has been done hasn't necessarily been conducive to tackling the wicked problems that we face in the environmental sector. This is because of the structure of units of assessment (UoAs), with bits of research having to be squashed into particular boxes when actually what we are dealing with are inherently interdisciplinary issues that require approaches from different angles. So in that sense the REF doesn't articulate the full range of impact in environmental management terms, because of the way it gathers data around units of assessment.

Kathryn But I think that when we were developing this approach, one of the things we frequently repeated was that it wasn't trying to identify and pull out impact from all research, it was only going to be some of the impact from some of the research. Furthermore, it was only one case study per ten full-time equivalent research staff, so that made the case studies broader. You are right though, constraining impact to UoAs is causing problems and this has been recognised - there are various ways people can compensate for it.

Gary I think the problem is not just UoAs, it's the fact that you have to relate case studies back to individual pieces of research. The current system doesn't recognise



▲ Figure 1. Weather monitoring equipment in the field. Environmental science is generally a mission-oriented discipline, so researchers are keen to address big challenges, such as climate change. © Peternile | Dreamstime

that impact emerges mainly from bodies of knowledge rather than from single pieces of research. There's almost a far too simplistic, linear model of a piece of research being picked up and used, and that linear model has been discredited for many, many years, so I think a more sophisticated approach is needed.

However, as HEFCE (Higher Education Funding Council for England) still has to make some assessment of what people are doing with regard to impact. I would argue there is an opportunity to pay more attention to impact templates rather than just case studies, and look at what the strategy is and how people are responding to the impact agenda. This may also help overcome the atomisation of working with individual pieces of research forced into UoA boxes.

There has been concern from some researchers that they may not receive appropriate recognition when impact cuts across disciplines. How would you respond to that?

Kathryn I did hear quite a lot of concern, mostly unwarranted, that multi-disciplinary research might be penalised in some way. But, certainly on our panel, we had several people with inter-disciplinary backgrounds as well as core scientists. We also had the option of assessors sending a case study to be looked at by a different UoA panel if appropriate.

This is still a problem though: there will be people who are unable to recognise inter-disciplinary work appropriately in their assessment. I'm not saying the REF didn't have safeguards for this, but it is important as a community that we develop an understanding that different disciplinary methodologies are of equal value to our own. I would like to see more undergraduate and graduate students trained in this.

How can environmental scientists improve or develop the real impact that their research is having?

Gary Again it comes back to partnership with users. This needs to be an active process right from the generation or suggestion of an idea. We have recently been involved with NERC (the Natural Environment Research Council) on some corporate innovation projects around infrastructure, and they were happy to reflect the quite specific needs of Defra (the Department for Environment, Food and Rural Affairs) and Natural England in their call, because I think the research councils themselves are beginning to recognise that they need to take a more active role in enabling and encouraging impact and co-production.

We also need to clearly say to researchers, 'If you are thinking of putting a proposal together, make sure you speak to potential partners!'. This should be considered in the review process by the research councils. In many instances, users have been considered as passive recipients at the end of the

chain from knowledge creation to knowledge application... Increasingly, we're seeing a shift to active partnership, breaking down the unhelpful producer/user divide.

Kathryn I would totally agree with that. One of the things I would love to have from researchers is more upfront investment in understanding what our government bodies do, and working out how they can be rewarded for collaboration. Often the most valuable thing can be advice from an expert, but that requires some time investment. One thing that's improving is follow-up money. Government needs to recognise that projects don't necessarily end with the publication of research papers or dissemination through the pathways to impact identified in their proposals, because often impact takes a long time and further development with the stakeholders. Environmental science matures over time, and as more and more demands for impact are made it may be helpful to learn from the experiences and methods of other disciplines in harnessing this.

Are there any final points you'd like to emphasise to readers of the environmental SCIENTIST?

Kathryn Yes – I suspect there are many research users as well as researchers reading this journal, and I would like to call out to them. There were 898 academic members of the REF assessment panels, of which only 259 were classified as 'users', and that included people like me who straddle both. I think we really need to push for others to put themselves forward, as this helps balance the academic views. If HEFCE were open to increasing the numbers I think this would be really valuable.

Gary To pick up that thread, it's also vital that users be allowed to spend time in co-production as 'partners'. I would encourage members of the community within the IES and beyond to get involved and help to make this co-production a reality. **ES**

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REFERENCES

1. RCUK, 'Pathways to Impact', [online] www.rcuk.ac.uk/innovation/impacts/ [Last accessed 30 October 2015].
2. RAND Corporation (2015) Evaluating the impact component of REF 2014, RAND Europe, Available at: <http://www.rand.org/randeurope/research/projects/evaluating-impact-component-ref2014.html> [Last accessed 30 October 2015].

The Research Excellence Framework and institutional sustainability: making a difference at home?

Carolyn Roberts and **Robert Ashcroft** look for a connection between environmental science research expertise in UK universities and the 'greenness' of the host institutions.

The theme of research impact has been extensively discussed in this issue of the environmental SCIENTIST. For the purposes of the UK government's Research Excellence Framework 2014 (REF 2014), a peer-assessed audit of university research expertise, researchers in environmental sciences and all other recognised disciplines submitted evidence of significant impact from their findings in almost every country of the world. Environmental science is, to a large extent, a mission-oriented discipline in which researchers endeavour to develop an understanding of, and solutions to, environmental challenges at all scales. The wide variety of types of impact claimed by participants in REF 2014, potentially benefitting both the natural environment and the quality of human life, testify to this.

However, at first reading there is remarkably little translation of high-quality environmental research into measures to enhance the environmental performance and sustainability of universities themselves. We looked at data from two sources: the analysis of basic REF 2014 scores for research achievements in earth systems and environmental sciences, and the rankings achieved by host universities in the People & Planet University League tables¹. Our preliminary analysis suggests that many of the leading research-intensive universities are not using their scientific expertise to enhance their own sustainability ratings and environmental performance.

This article explores the nature of this disappointing lack of local impact and recommends that as higher education institutions (HEIs) increasingly focus on the international influence of their research, they should not forget to look at how they may be able to make a difference closer to home.

THE PEOPLE & PLANET UNIVERSITY LEAGUE

The Oxford-based network People & Planet has been supporting UK students in campaigning on the linked issues of poverty, human rights and the environment since 1969. It started compiling an annual league table that ranked universities on their environmental and ethical performances in 2007. Previously called the Green League, the People & Planet University League assesses every UK organisation that is legally registered as an HEI and receives public funding¹.

Each institution is asked to respond to a set of questions, which in 2015 embraced fourteen sustainability topics (see **Box 1**). The answers are assessed by a trained team of People & Planet staff and volunteers on the basis of the information returned²; raw scores are weighted by section (using a methodology explained in full on the People & Planet website³) and a summary ranking derived. The list of questions has been extended and tightened up over the years in consultation with experts from within the environmental and higher

BOX 1. PEOPLE & PLANET ASSESSMENT CRITERIA, 2015³

1. Policy and strategy
2. Human resources for sustainability
3. Environmental auditing and management systems
4. Ethical investment
5. Carbon management
6. Workers' rights
7. Sustainable food
8. Staff and student engagement
9. Education for sustainable development
10. Key sustainability impacts
11. Energy sources
12. Waste and recycling
13. Carbon reduction
14. Water reduction

education sectors, and the remit of the League has extended into new realms. Whereas the early questions included recycling percentages, renewable energy use, environmental auditing and Fairtrade status, the more recent surveys have requested additional information on student curricula and ethical investments, for example. Non-responding institutions are typically included as Failed Universities, whilst the remainder are graded according to UK undergraduate degree classifications from First Class to Third.

The organisers state that 37.5 per cent of all questions may now be answered using data taken directly from annual estates management statistics, routinely collected and published by the UK Higher Education Statistics Agency (HESA). The remaining questions are sent out as a survey issued as a freedom of information or environmental information request, to which universities have ten weeks to respond. Unfortunately, in 2014, there was evidence that many universities found the process unusually burdensome and the timescale for response inconvenient, so a number boycotted the process. The complainants also cited deficiencies in the methodology and disagreement with the weighting of different criteria. From 2015 assessors are being allowed to search for missing data themselves if universities have not responded fully. The dataset is far from perfect as a measure of institutional sustainability, but is probably sufficient to provide a rough guide.

As well as being a means by which HEIs can be compared and tracked on their sustainability activities and commitments, the People & Planet University League offers some incentive for universities to improve their own performance on 'green' issues. Indeed, some remarkable progress towards sustainability across the sector can be identified. For example, for all of the 2007 survey respondents, average renewable energy

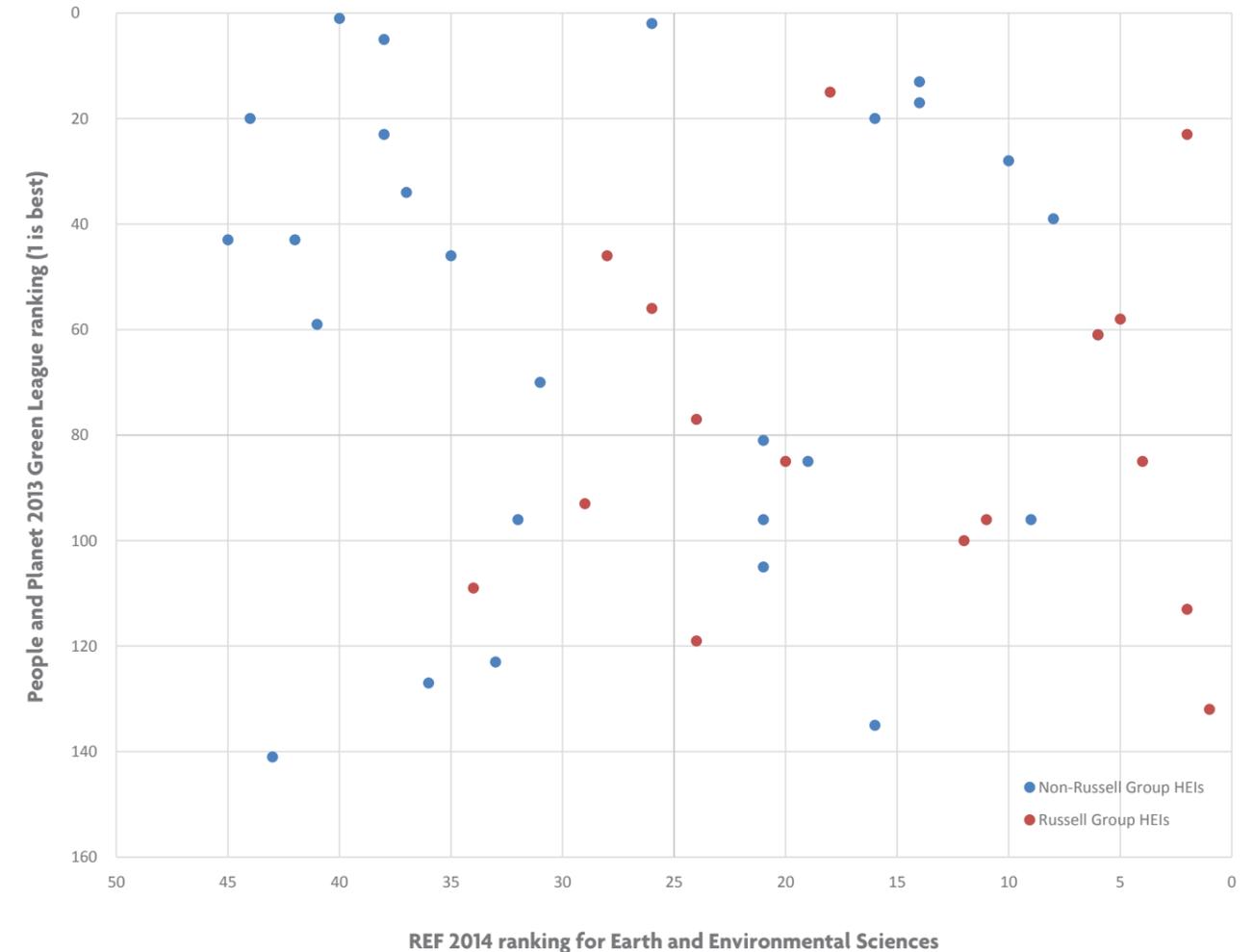
use on campuses was around 12 per cent, whereas by 2013 the figure had risen to approximately 75 per cent as universities shifted to suppliers with explicit commitments to renewables, and some began to use their own facilities to generate power from anaerobic digestion of food waste, wind turbines or solar panels. Some institutions also pressed ahead with experimental power generation by drawing on the research expertise of their academic staff, but this type of cogeneration of power and knowledge was unfortunately very restricted. It cannot be claimed that People & Planet's League tables were the sole influence on environmental performance, but they certainly provided a stimulus to some decision-makers.

WHO PERFORMS WELL?

The early stars of the 2007 League tables were Leeds Metropolitan, Plymouth, Hertfordshire, Glamorgan and Gloucestershire Universities, which surprised many readers, including in some cases the institutions themselves: many of the highly rated institutions turned out to be those whose principal focus was on teaching rather than on internationally celebrated research. Those rated as First Class nevertheless included four research-intensive universities from the Russell Group, the loose federation named after the London hotel where their vice chancellors used to meet. The four were Queen's University Belfast, Cambridge, Edinburgh and Leeds.

In the 2015 rankings, although several Russell Group institutions did receive First Class scores, the highest ranked was in 12th position, which was Newcastle University. Leeds kept its First Class status, Edinburgh moved to 2:1 Class, and both the University of Cambridge and Queen's University Belfast received only Third Class scores⁴.

In recent years the rankings have continued to be dominated by newer universities whose principal focus has been on teaching rather than research. Why this should be the case is an interesting question, especially when many of the low-scoring universities are academic homes for experts undertaking world-leading research on environmental themes. We are not asserting that the term 'environmental science' is synonymous with the sustainability that People & Planet purports to measure, but we do believe that good science is an underpinning requirement for strong sustainability, and that environmental scientists have some moral commitment to environmental improvement. Indeed, the Institution of Environmental Science's own Code of Professional Conduct⁵ makes reference to members being required to have "full regard for the enhancement of environmental quality and sustainable development and the mitigation of environmental harm". In our experience this principled stance is widely found across the sector.



▲ **Figure 1. REF 2014 rankings for Unit of Assessment 7 (Earth Systems and Environmental Sciences), plotted against the People & Planet 2013 rankings. In each case, the highest rank is 1.**

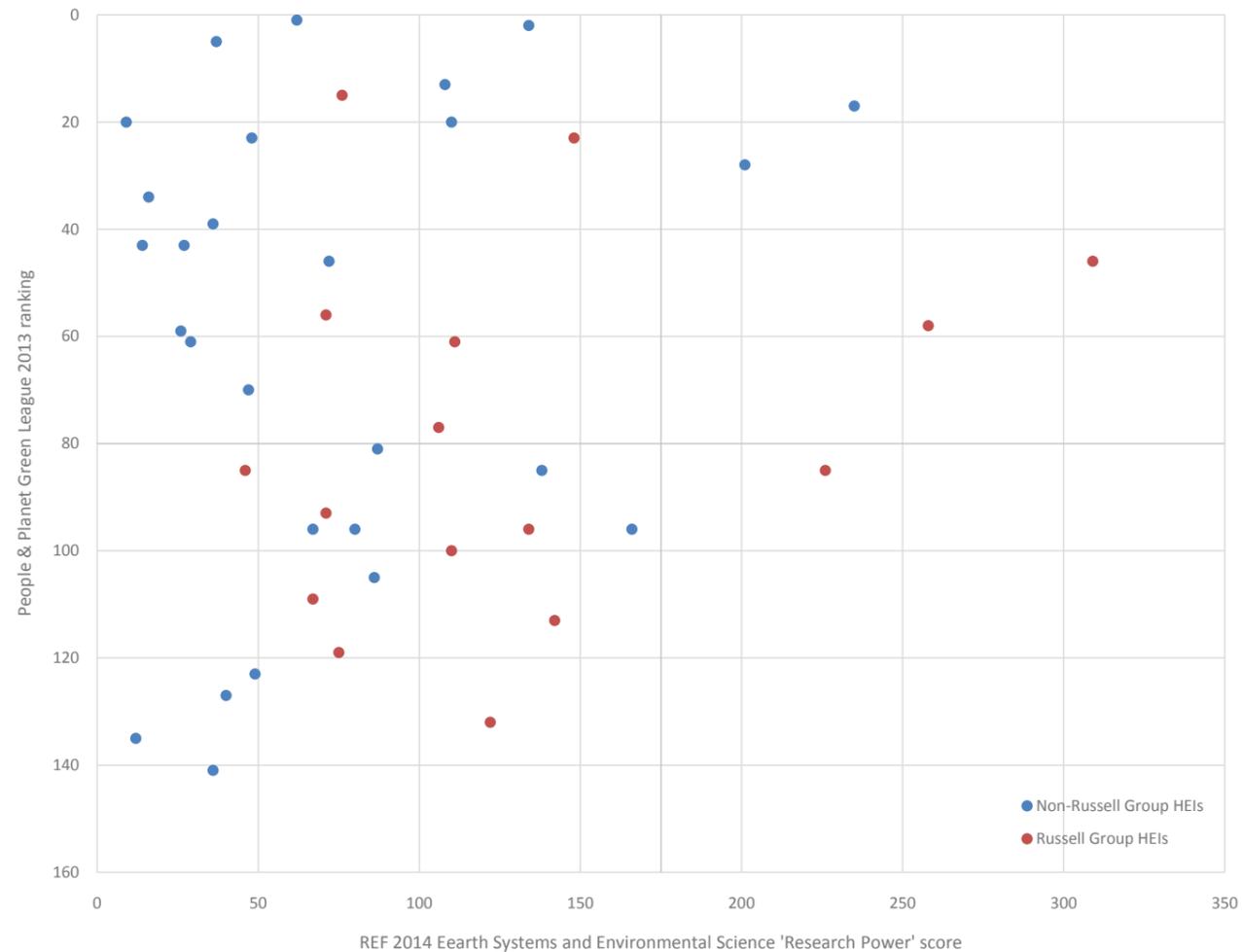
COMPARING PEOPLE & PLANET WITH REF 2014

Taking the People & Planet rankings for 2013, the year in which universities were required to make submissions to REF 2014, we can compare in more detail the rankings of HEIs in the League with their performance in the Earth Systems and Environmental Science category (unit of assessment 7) of REF 2014. Though this assessment of research expertise is contested as a source of useful information (and certainly as a basis for determining future research funding from central government), it does provide a broadly consistent measure. Research in environmental sciences is bundled with earth sciences to provide one unit of assessment.

Figure 1 shows the ranking based on REF 2014 scores for unit of assessment 7 (for those universities who made submissions) plotted against 2013 People & Planet rankings. The REF 2014 scores are largely weighted towards the quality of research

outputs in terms of originality, significance and rigour, but also include a 20 per cent weighting for impact and 15 per cent weighting for contribution to the research environment⁶. If expertise gained through high-quality research was being effectively translated into strongly sustainable institutional practice and environmental initiatives, we would expect to see a positive association between these two variables, with highly rated institutions concentrated in the top-right quadrant and low-rated institutions lacking such research expertise in the lower left. However, in **Figure 1** it is difficult to identify any association at all.

Looking exclusively at research quality, **Figure 2** plots People & Planet rankings against an index of research power. Again there seems to be no positive association, suggesting that the production of high-quality environmental research is largely disconnected from institutional sustainability.



▲ **Figure 2. Graph showing the REF 2014 research power scores for Unit of Assessment 7 (Earth Systems and Environmental Sciences) plotted against the People & Planet 2013 rankings. A higher research power score indicates higher-quality research and the highest People & Planet ranking is 1.**

WICKED PROBLEMS

The data presented here highlight a clear disconnection between environmental research and local practice in UK universities. The environmental science expertise and knowledge being generated in many of our world-leading institutions is not being applied to enhance their own performance on environmental and sustainability policies, on institutional resource use (energy, power, goods and services), or in stimulating students' interest and achievements. Perhaps local challenges are not being posed to researchers in academic departments as research questions demanding solutions? Or potentially, the research-intensive institutions do not find local sustainability challenges to be a mechanism for generating respect in research. Whatever the cause, this detachment must diminish our efforts and ability to address environmental challenges, not just on university campuses but in wider society.

The universities performing well in the People & Planet tables do not share any particular geographical attributes, or (at least in the 2015 breakdown) approaches to other characteristics such as an arts focus or a Church foundation. They do, however, tend to be institutions that have made the transition to university status more recently. It could be proposed simplistically that one reason for their more sustainable performance is the centralised managerial cultures that are found in these institutions: with a committed vice chancellor or chief executive, and a compliant culture, action follows. It is possible that the strong local community links of the former polytechnics and colleges of higher education are also a factor in delivering on-campus sustainability goals. These observations are of course highly generalised, and individual institutions will have their own views on their own achievements and challenges.

However, many of the environmental challenges we face can be described as 'wicked problems'⁷. These are complex problems characterised by a large number of conflicting or contradictory views and evidence that are usually not resolvable through consensus. In tackling these problems, we amplify the challenge through lack of effective communication. This seems to be at the root of the disconnection between expertise and action in many of our HEIs.

THE PATH TO SUSTAINABILITY

In research-intensive HEIs, such as those in the Russell Group, academic independence is fiercely defended. We should not underestimate the importance of this freedom in delivering high-quality research. However, in the age of impact measurement, perhaps these institutions could better harness this expertise internally to improve their own sustainability credentials and therefore lead by example. Effective internal communication and a strong sustainability vision could help to translate some of the innovation and expertise developed in these centres of excellence into real-world initiatives on campus. If we can bridge the gap between expertise and action in our own universities to deliver local impact, perhaps we would find ourselves better placed to deliver impact elsewhere. **ES**

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REFERENCES

1. People & Planet, <https://peopleandplanet.org/university-league>.
2. People & Planet (2014) Green League Guide 2014, <https://peopleandplanet.org/dl/greenleagueguide2014.pdf> [Accessed 20 November 2015].
3. People & Planet, Methodology, <https://peopleandplanet.org/university-league/methodology>.
4. People & Planet (2015) 2015 League Table, <https://peopleandplanet.org/university-league/2015/tables>.
5. Institution of Environmental Sciences, Code of Conduct, https://www.the-ies.org/sites/default/files/documents/code_of_conduct_0.pdf [Accessed 20 November 2015].
6. REF2014, Assessment criteria and level definitions, www.ref.ac.uk/panels/assessmentcriteriaandleveldefinitions.
7. Rayner, S. (2014) Wicked Problems, *Environmental Scientist*, 23(2), www.the-ies.org/resources/contentious-issue [Accessed 20 November 2015].



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