

“ I found the ESI to be a vibrant community of engaged and enthusiastic staff and students, undertaking some cutting-edge science and innovation. Despite the relatively early stage in its development, there was a high level of maturity and professionalism with a strong sense of shared purpose. It is a great credit to the Director and to the senior staff to have engendered such a strong culture in a rapidly developing organisation over a relatively short period of time. ”

Professor Dame Georgina Mace: Professor of Biodiversity and Ecosystems at University College London and Chair of the ESI Scientific Advisory Panel

“ The ESI is a valuable partner in delivering the strategy to ensure that Cornwall's natural capital is growing in the future, as it is essential that we use the quality of environment and local sustainability to realise our global value. ”

Rachael Bice, Cornwall Council Strategic Environment and Waste Manager

“ It's been a great privilege for me to have been a member of the ESI Stakeholder Group since the origins of what became the ESI project and to have taken part in the discussions and decisions which have led to the creation of the wonderful Institute which we have today. ”

Sir Robin Nicholson, former Chief Scientific Officer at the Cabinet Office



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To Travel Far, Travel Together

The second annual report of the Environment
and Sustainability Institute



The University of Exeter's Environment and Sustainability Institute (ESI) is a unique facility bringing together a diverse, interdisciplinary group of researchers dedicated to finding solutions to problems of environmental change. Based at the University's Penryn Campus in Cornwall, our world class work is enhancing people's lives by improving their relationships with the environment.

The ESI has been funded by the European Regional Development Fund Convergence Programme (£22.9m) and the South West Regional Development Agency (£6.6m), with significant support from the Higher Education Funding Council for England.

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Director's overview

The ESI is now a 'go-to' regional and national Institute for environmental expertise, evidence and data.



This has brought new and exciting research and development, business and education opportunities into Cornwall and the South West region. We are, for instance, working in partnership with Cornwall Council to implement the environmental growth strategy for Cornwall, to help deliver 'local values for global value'.

The ESI is gaining increasing recognition internationally by working with universities and research centres from all over the world. We now want to focus on working with partners in industry, providing opportunities for local businesses to collaborate with global players.

In so doing, we can address some of the 'grand challenges' of our time.

Professor Kevin J Gaston

Director of the Environment and Sustainability Institute, University of Exeter.

What have we been doing?



We have been building on our work to support local businesses and are currently involved in more than 300 research projects. We have attracted experts from all over the world to work in Cornwall.

We're working with more people than ever before. The Institute has engaged with more than 500 businesses, delivering 228 collaborations. Of these, 167 businesses are in the environmental goods and service sector. This has created significant benefits for Small and Medium Enterprises (SMEs) – £12.2m more profit and the creation of 93 jobs. Income to the ESI itself has amounted to £3.7m and we have created 72 jobs.

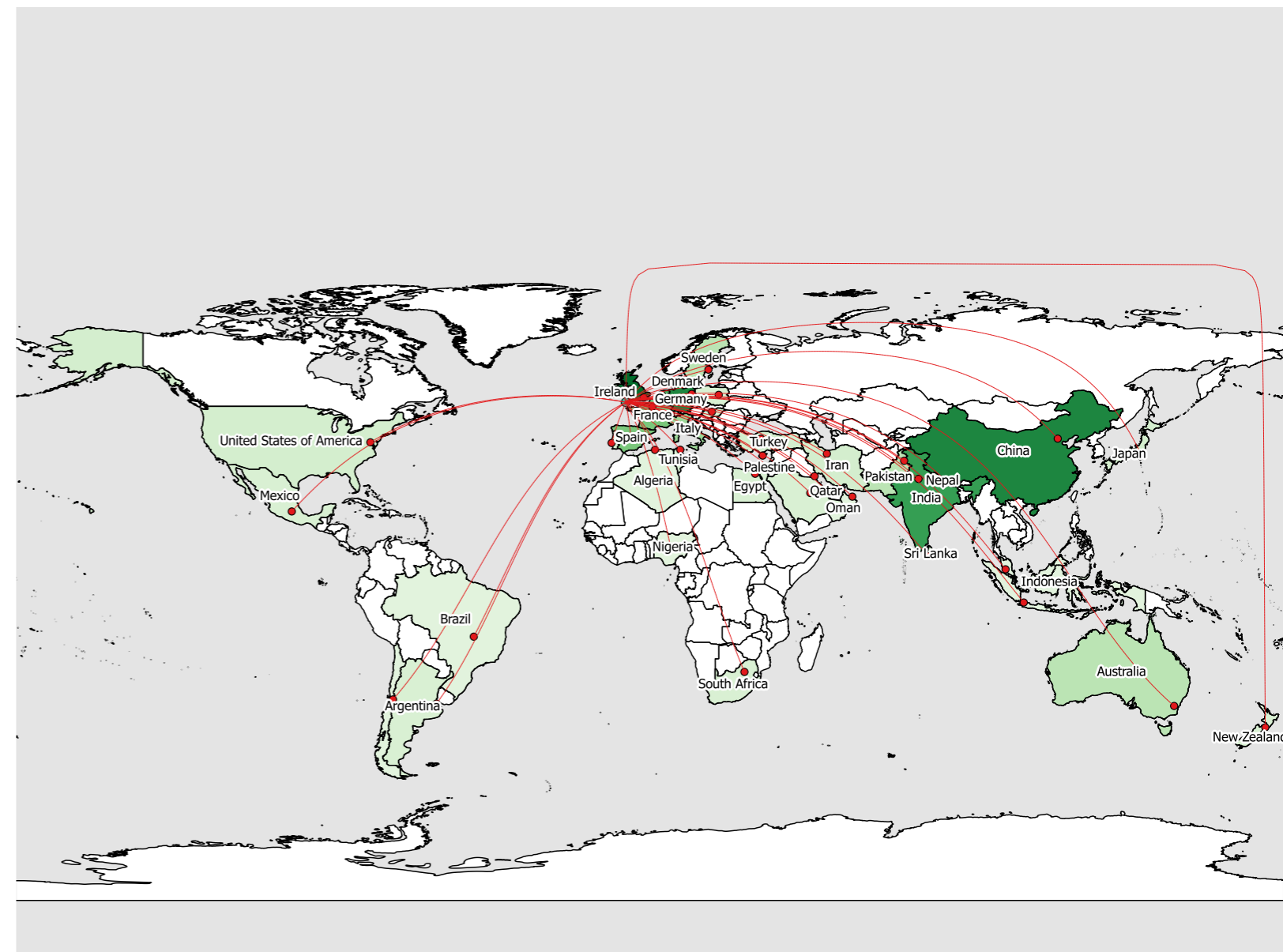
Some examples of our collaborations are:

- Cornwall Council and Cornwall Wildlife Trust worked with ESI staff to understand the value of green space to economic, social and environmental wellbeing, part of developing understanding of ecosystem services.
- Riviera Produce and ESI staff have developed a PhD studentship to investigate pollination of key, high yielding crops, such as courgettes to increase their pollination success and potentially lead to increased profit margins.
- Our research with Volunteer Cornwall is helping us understand drivers of community-level behavioural change, especially identifying and addressing environmental issues.

ESI staff are carrying out more than 300 research projects many of which have gained international media attention, including Dr Richard Inger's work on the decline of Europe's bird populations such as skylarks (see image). Other examples include Dr Chris Bryan's project on using algae to harvest resinous metals from the toxic sludge left over from mining activities and Professor Robbie McDonald's research into controlling the spread of bovine TB and the debate around culling.

We are working with colleagues in the University of Exeter's Business School – after a successful collaboration with Cornwall Council – on an exciting new project aiming to develop a Biodiversity Accounting System and methods for applying it. This tool will enable the Council to make more informed choices about resource allocation and, for the first time, assess the impact of projects on Cornwall's biodiversity.

We recently signed a Memorandum of Understanding with the Energy Research Institute Co., Ltd., which is part of the Henan Academy of Science in China. Together with our Chinese research partners, we are using life cycle assessment to investigate the energy efficiency and environmental emissions of biomass systems. Our findings will be used to decrease energy consumption and enhance production efficiency. ■



We have a global presence in Cornwall. This map highlights that our staff and students come from 24 countries and five continents.

Research highlight solar power

In six hours, the world's deserts could be used to harvest more energy than the planet needs in a year. Despite this, roughly 1.4 billion of the world's inhabitants are still without electricity of any kind. For example, India alone has approximately 300 million residents without electricity. Most of them, like many fellow villagers living in large areas of Africa and south east Asia, are physically remote from the grid.



Unlikely as it might seem, this is where the Cabbage White butterfly can help...

Our research shows that to better understand the butterfly might move us closer to cheaply and effectively converting the sun's light into usable, photovoltaic (PV) energy.

Cabbage Whites are known to enjoy a crucial advantage over their peers in that they're able to take flight before other butterflies on cloudy days, giving them more and earlier access to nectar. The butterflies engage in reflectance basking, during which they arrange their wings so as to maximise the concentration of solar energy onto the muscles they need to warm up in preparation for flight.

Our team of renewable energy experts, led by Professor Tapas Mallick, is working with expert biologists to understand whether striking this unique pose gives the Cabbage Whites an edge over other butterflies when it comes to flying during overcast days.

The angle of their wings, however, is only half the story. Their actual structure comprises a single layer of cells which are highly reflective and match the wavelengths required by solar cells to produce electricity.

Together, these two characteristics of the Cabbage White's wings combine to generate nearly 50 per cent more power in this species than in other similar butterflies.

Experiments and trials with panels made of lightweight material based on the wings' structure suggest the possibility of a 17-fold improvement in the power-to-weight ratio of future solar concentrators, making them significantly lighter and far more efficient.

This multidisciplinary research has revealed a new pathway towards the

development of low-cost solar power and shows why biomimicry can be so successful in engineering projects. Professor Mallick knows that biomimicry in engineering is not new. However, this research shows pathways to develop low-cost solar power that have not been explored before. ■



Our strategic priorities for the next year



We have identified two strategic priorities for the coming year:

Creating a leading global network

We want to develop a global network of the very best people working in environment and sustainability. This will include experts currently researching the impacts of environmental change, investors, policy makers, charities and businesses.

This will make it more straightforward than ever to find the right information and people and to keep up to speed with all that is happening in the sustainability sector. ■

Building innovation

Much of our initial research work is now moving into the development phase and we are looking forward to working with new partners to create economic and social value from our research. We have employed new expertise to help us with this next phase of our role as a catalyst for global innovation.

In particular, we will be focusing on work relating to unmanned aerial vehicles (UAVs, or drones), the impact of artificial light and new solar technologies. ■



The five themes of our research

In 2016 we developed five research themes which are of particular interest. Defining these themes makes it easier for potential collaborators to understand how they could benefit from engaging with the ESI. These themes change over time in response to environmental change and demand from stakeholders and we are working on many more exciting projects.

Small things, big impact: small organisms in antibiotic resistance, mining pollution and anaerobic digestion – our microbial research is hugely diverse and includes, but is not limited to, these areas.

Human-wildlife interactions: we are interested in measuring and managing human interactions with wildlife and vice versa. Locally and globally, on land, in the water, in the air: we focus on however and wherever we overlap with nature.

Adaptation to climate change: we research how the climate is changing and how we're responding, the range of risks arising, how we understand and respond to them, and the measures available to manage, mitigate and redefine these risks.

Global give and take: we are interested in what the world gives us and what we give back. Food and water, climate and disease regulation, nutrient cycles, crop pollination, cultural, recreational and spiritual benefits: these are the 'ecosystem services' we measure, map and determine how best to manage.

Cleaner, cheaper solar power: we develop materials, methods, cells and systems to harness more efficiently and effectively the sun's endlessly renewable clean energy. ■



Solving the problems of environmental change



As an interdisciplinary research institute, the ESI works on many projects that bring diverse perspectives together to shed light on some of the major challenges the planet is facing.

In looking for solutions to problems of environmental change, our researchers tackle an extensive range of topics: some solutions are technological, others might relate to land use, and sometimes they depend on a change in human behaviour. Most involve combinations of all three.

We are particularly interested in the insights that result from relating detailed knowledge about clean technologies, landscapes and living systems and sustainable communities to local, regional, national and international problems.

We combine multiple, in-depth local and regional studies to provide insights into how environmental growth can be achieved more broadly, and work in partnership with an array of stakeholders to further their strategic ambitions in this regard and to deliver practical solutions for them. ■

Research highlight putting mathematics to work

The ESI has joined forces with NJW Ltd to create an interactive, environmental dashboard.

This dashboard will be able to illustrate, in real time, the impact of industrial sites on wildlife and habitat as an example. It could also be used to create smart systems, for example by collecting data on energy use across multiple locations on a business park, calculating the solar energy required, and altering the angles of the solar panels automatically. ■

To do this, the ESI is working with NJW Ltd in a Knowledge Transfer Partnership (KTP) to explore what we can learn from how the manmade world is measured and managed to help us protect and improve the natural world. In order to explore this further, we have jointly funded a PhD student project which began in September 2016.

NJW Ltd is a hi-tech company, based in the home counties, which specialises in helping increase business efficiency. This could involve suggestions around how to better use physical assets such as buildings and workspaces, decrease energy consumption or create new services to help staff perform at their best. One innovative way to help businesses improve their efficiency is to help them visualise key pieces of information on interactive dashboards. NJW Ltd is keen to know whether this

information can be used to model or forecast the future, but does not have the mathematical modelling capability in-house.

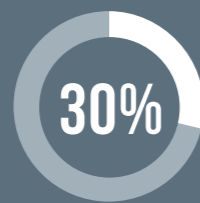
This is where the ESI comes in, because the mathematical systems team, led by Stuart Townley and Markus Mueller, is expert in modelling. The team is particularly interested in how one aspect of a system can influence another, especially if this could help us reduce the environmental impact of such a system.

We are also collaborating on European funding applications and, perhaps even more significantly, NJW Ltd is so excited by the possibilities such a partnership represents that it is looking into another KTP focused on energy usage, with the potential of setting up a satellite office in an innovation centre on the same campus as the ESI. ■





Staff from 24 countries



30% increase in PhD students in the last year (over 60)



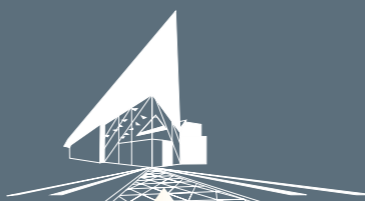
63 senior researchers

300

300+ R&D projects underway



125 media outlets publicising our work



Over £4 million of facilities for businesses to use



£15.9 million of profit created for local businesses

£15.6M of national and international funding across 161 projects over the last five years



164 jobs created

376 PAPERS

376 papers published in peer-reviewed journals



Five key research themes for 2016/17



500+ local businesses supported, resulting in 228 business collaborations

Working with others: strategic partnerships

We are working with the Centre for Environment, Fisheries and Aquaculture Science, Cornwall Council, the Eden Project and Plymouth Marine Laboratory to understand the scientific and economic value of projects across the south west, to explore the impact of environmental change on local communities and to help shape regional and national environmental policy.

Exchanging specialist knowledge helps us, for example, to create better models for predicting flood risk, or to work with local farmers to understand the impact of pesticides on pollinators. This means we can collaborate with the local community to understand emerging issues and find the best ways to manage environmental services.

All of this, in turn, helps us to shape how European, national and regional funding is spent in Cornwall. It also enables policy recommendations that can influence actions, environmental health, and wellbeing around the world. ■

OTHERS WE ARE WORKING IN PARTNERSHIP WITH INCLUDE:

- Building Research Establishment
- Cornwall College Group – Bicton College and Duchy College
- Cornwall Wildlife Trust
- Eden Project
- Environment Agency
- Isles of Scilly Wildlife Trust
- National Trust
- Natural England
- Royal Society for the Protection of Birds
- South West Lakes Trust
- South West Water
- Volunteer Cornwall

How we will work with the industry over the next five years

We have been re-focusing on the next phase of growth, designing new initiatives to put Cornwall-based research on the global stage and encourage collaborations with an even more diverse group of people.

We are co-creating projects and / or jointly applying for funding with local and national charities, national government agencies, further education colleges and local, national and international businesses.

Current partners include:

- A&P (Falmouth)
- Animal and Plant Health Agency
- Antiform Clothing
- Future Terrains
- Pilkington Glass
- Pump International
- Wardell Armstrong
- West Country Rivers Trust

We are working with a small number of partners – some of whom are international – on large scale, multi-million-pound cutting-edge research projects. Many of these involve focus on development and commercialisation of new products and services. ■



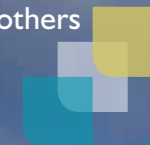
Our dedicated knowledge exchange team is part of the University's Innovation, Impact and Business (IIB) department. IIB supports collaborations between businesses and University researchers through seven key innovation services:

1. Business Engagement – highlighting opportunities available to businesses; developing research, development and innovation plans; matching people with expertise; monitoring progress; signposting to other business supporting services when necessary.
2. Knowledge Transfer – supporting collaborations between businesses, the public sector and higher education or further education institutions through meetings, events, workshops, consultancy, contracted research or provision of professional services.
3. Placements – facilitating collaborative research, joint projects or placements with undergraduate or masters students, and more in-depth collaborations involving PhD studentships, post-doctoral researchers or research assistants.
4. Networking – facilitating interaction and collaboration with local, national and international stakeholder networks.

5. Research – helping with funding applications and project management, as well as with the reporting and auditing of UK, European and international research projects and economic development projects related to Cornwall and the Isles of Scilly.
6. Development – helping with access to commercialisation know-how, including intellectual property expertise, guidance and advice when bringing products or services to the market.
7. Impact Assessment – calculating likely socio-economic benefits, such as job creation, new products being brought to market, profitability and skills development.

The ESI is an integral part of the Growth Hub Network, which consists of local public/private partnerships led by the Cornwall and Isles of Scilly (CloS) Local Enterprise Partnership. The CloS Growth Hub joins up national and local business support so it is easy for businesses to find the help they need.

We are keen to partner with industry, charities, academia, investors, policy-makers and thought leaders regardless of their sector. We are interested in pursuing collaborations around the world in order to further expand our extensive and highly skilled network of experts. ■



Working with others: how we're working with the industry

EXAMPLES OF COLLABORATIONS

Fuelstretcher Ltd worked with ESI to develop a boiler control product that can be an add-on to all industrial and domestic plant rooms, improving energy efficiency and optimising fuel consumption. Currently installed in seven Cornish leisure centres, this is saving 19 per cent of their total spend.

Cornish Eco Homes Ltd worked with ESI to develop modular eco homes, for self/cooperative builds using

thermal modelling and energy performance rating. The company is now successfully trading as Klaus EcoHomes Ltd.

ISO Spaces Ltd repurposes shipping containers with the help of ESI expertise to demonstrate that they can be used for flexible storage, showrooms and event spaces.

We are also lucky to have four project partners, including the Agriculture and Horticulture Development Board (AHDB), with whom we offer PhD studentships. ■

BUSINESS SUPPORT

We have supported more than 500 businesses across Cornwall and the Isles of Scilly with research, development and innovation support. As a direct result, these businesses have generated more than 90 new jobs and over £12m of additional income. Here at the ESI itself, we have created more than 70 new jobs, benefiting both our research and the local economy.

Of the 500 we have generated 228 business collaborations, 167 of which are in the environmental goods and services sector; we are now focusing efforts on specific innovation clusters, with like-minded businesses / stakeholders strategically connected through a key area, question or problem. ■



Research highlight economic development

Dr Joanie Willett argues strongly that regional economic development in Cornwall and political participation are deeply intertwined. ESI staff have developed a collaboration between economy, environment and identity that is at the heart of several of Dr Willett's projects.

INFORMING NATIONAL POLICY

Debates about devolution, localism and identity have been prominent over the past year, with a focus on how to improve governance and make the country more inclusive and participatory. Joanie was asked by Parliament's Constitution Committee consultation on the State of the Union and Devolution to give evidence on all these issues on behalf of The Political Studies Association. Joanie gave detailed responses to specific questions on the devolution settlement's current asymmetry and the effect of devolved taxation and welfare powers on economic and social union. She also talked about how undue emphasis on the North-South divide overlooks starker contrasts between the wealth of the South West compared with the relative poverty of Cornwall, The Isles of Scilly and West Wales and the Valleys.

ENCOURAGING ACTION, FROM CORNWALL TO EUROPE

To explore how to encourage political participation at a local level, Joanie is working with Cornwall Council, the Department for Communities and Local Government, and the National Association of Local Councils. A game devised with Politics students has been incorporated into a community development toolkit created by the European Association for Local Democracy.

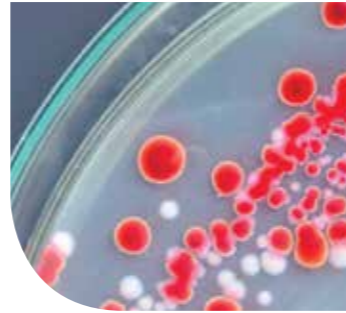
THE RELATIONSHIP BETWEEN POLITICS AND BUSINESS

Recently, Dr Willett has been collaborating with the University of Sheffield on 'Conversations on the Constitution'. The project explores how citizens and businesses would like to make changes in their communities, and how the power to effect such changes might be distributed. Joanie has found that very few business owners participate in local politics to influence changes that would make conditions easier for them. She also discovered that Councillors at town and parish level have often failed to consider that their role might involve shaping a positive local business environment. ■





Research highlight tackling superbugs differently



Work on antimicrobial resistance (AMR) has revealed that bacteria in humans and animals are becoming increasingly resistant to antibiotics. This is an increasingly serious threat to public health that has been highlighted by the Chief Medical Officer. The government has encouraged investigations into the ways in which agricultural use of antibiotics may be contributing to the emergence of AMR in humans.

In the first experiment of its kind, we are examining AMR in entire microbial populations rather than species living in isolation. Our researchers are focusing on the complex community of bacteria found in pig faeces, since pig meat forms an important part of our own food chain; this system therefore has extensive implications for human health.

Bacteria within these communities have different levels of antibiotic resistance, and the competition between these species influences whether, and how much, resistance is ultimately conferred to our focal species, *Escherichia coli* (E. coli).

Preliminary results suggest that AMR can develop at much lower antibiotic concentrations than previously thought. Our experts have designed follow-up studies to examine this process in more detail.

This research will inform academics, government agencies, vets, pharmacists, infection control practitioners, clinical microbiologists and private sector stakeholders within the animal and human biopharma industries. Ultimately, the work should inform future policy and identify key questions for further research. ■

E. coli + S. marcescens

Working with others: schools

Our eagerness to look outwards, work with others and foster relationships with a broad spectrum of groups and individuals continues to be exemplified by our work with schools and creative practitioners.

SCHOOLS

The cornerstone of our engagement with schools is our annual Environment and Sustainability Day, organised in collaboration with the University's outreach team. In March, more than 100 Year 10 students from ten Cornish schools took part in workshops to discuss four environmental challenges facing Cornwall – managing waste, ensuring a balanced ecosystem, managing conflict viewpoints and flooding. They then voted on which they thought was the most important. The winner? Flooding.

Other work with schools continues year-round. We ran our annual 'sharing good practice' meeting in November 2015 with teacher affiliates, and have initiated a new Social Science link with Brannel School in St Austell, which has reciprocal visits between Dr Joanie Willett and Brannel School students.

We are also beginning a new maths partnership with local secondary schools, based around the Python computer program language. Dr Karen Anderson, who runs our Drone Lab facility, took some drones to Falmouth's King Charles Primary to inspire younger children about environmental research. ■



Working with others: the Creative Exchange

The Creative Exchange Programme continues successfully to support collaboration between creative practitioners and ESI researchers who share an interest in issues of environment and sustainability. In partnership with Falmouth University's Research in Art, Nature and the Environment (RANE) research group, our aim is to help to develop the region's creative industries, inspire research and stimulate opportunities for public engagement and collaborative learning. Work can be seen here www.exeter.ac.uk/esi/research/creativeexchangeprogramme and here is a sample of some recent projects:

FOREIGN SOIL

ESI Associate Research Fellow Jonathan Bennie collaborated with artist and writer Gabrielle Hoad to identify and exploit microclimates where edible dessert bananas might be grown outdoors in the South West. This project opened up space for conversations about the future of UK food supplies and what it means to eat local food.

SOIL CULTURE

During her residency, the multi-talented artist and researcher Marissa Benedict worked with Professor Gabriel Yvon-Durocher who is investigating how agricultural practices can promote carbon sequestration, improve soil carbon storage and maintain viable yields. Marissa used video and photo to document the research and place a lens on the critical role carbon plays in our atmosphere, our soil and our future climate.

GOONHILLY VILLAGE GREEN (GVG)

Sara Bowler and Elizabeth Masterton are working with ESI academics and students who are conducting research on the Lizard Peninsula's Goonhilly Downs. Its unique landscape is protected by Site of Special Scientific Interest status and has a very distinctive geology including serpentine rock. So far, the project has seen an artist's commission, thematic workshops, walks, talks and social gatherings. Bowler and Masterton actively seek to foster discussion between amateur and professional groups, with a view to understanding how Goonhilly Downs and similar sites can be supported and managed in the future. ■

CRAFTING STABILITY, TIPPING POINTS AND CHAOS

A collaborative project between Dr Markus Mueller and artist Samantha Gerlach created artistic interpretations of mathematical models used to investigate climate and environmental change. The concepts of stability, tipping points and chaos are complicated for people to visualise and these models have enabled better understanding. ■

