Institution: Plymouth University

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

a. Context

Plymouth has an integrated and dynamic group of research staff with common interests in: earth and ocean observation, the detection and quantification of environmental processes and ecological impacts, and interpretation using new hypotheses and theoretical treatments. Research continuity and impact have been achieved over the last 15 years by a coherent policy supporting four thematic research areas; namely **Biogeochemistry, Earth Sciences, Physical Oceanography and Marine Biology and Ecology**. Strategic planning and investment in these four areas maximises opportunities for developing world-leading research and focusing impact. Within this context we have multiple stakeholders in the academic and non-academic communities. We aim to provide underpinning evidence and decision support for environmental managers and policy makers in such areas as the behaviour and fate of chemicals in the environment and their impact on ecosystem health and the impact of climate change on the physical environment and biological communities. We also undertake research which is more directly targetted, interacting with commercial instrument manufacturers and the emerging technologies sector.

All staff are affiliated to the Marine Institute (MI) which provides a coherent focus for understanding marine and coastal systems and assessing and predicting climate change. Strong historical regional research links with the Plymouth Marine Laboratory, Marine Biological Association of the UK, Sir Alister Hardy Foundation for Ocean Science (SAHFOS), North Wyke Research (formally a BBSRC Institute, now part of Rothamsted Research), British Geological Survey and The Environment Agency have developed via grassroots collaborations and formal memoranda of agreement, evidenced by joint reports and publications. Specific examples of collaborations and beneficiaries, include national and international companies, local and national government agencies and international bodies, are provided below.

b. Approach to impact

Our research demonstrates four key approaches to facilitating impact, described using illustrative examples. Good practice is disseminated via bi-weekly meetings of staff and students in the four thematic research areas, supported by more formal annual conferences in each area and an overarching MI conference. The latter includes presentations from the Marine Innovation Centre (MARIC) at Plymouth and networking opportunities, with the objective of creating intelligent connections between businesses, world-class knowledge, technologies, people and infrastructure.

Engagement in industrially funded research and consultancy

As an example of direct engagement with industry, **Nimmo Smith** used two NERC grants to develop a digital holographic camera (digiholocam) for imaging suspended particles. A 10-year license agreement was signed with Sequoia Scientific Inc. in 2008 to develop a commercial version of the digiholocam, LISST-HOLO (www.sequoiasci.com/products/lisst-holo/) that is now used by leading international research and government organisations. EPSRC funded research has also led directly to revised design guidelines for offshore breakwaters to the benefit of UK end-users (Hydraulics Research Wallingford, Halcrow and DEFRA).

Industry involvement is also manifest through collaborative research projects under HEIF funding and through Technology Strategy Board engagement in Knowledge Transfer Projects (KTPs) designed to increase business productivity through the better use of knowledge, technology and skills in the UK knowledge base. This ensures that a substantial part of our research has a ready-made pathway to impact with outcomes being made directly available to end-users through reports, extension summaries and the implementation of decision support systems. For example **Worsfold** was the academic PI on a KTP project to design and implement technical and quality management systems for the Langage Farm Anaerobic Digestion (AD) Facility (2010-12), supporting government strategy to increase energy from waste. Langage Farm used to spend £80-90,000 on electricity annually, but this is now generated by the AD plant, which became profitable in just 6 months. HEIF funding (2010-2012) has been used by **Rundle** to develop new bio-imaging technology for monitoring the effects of environmental stressors on early development in aquatic embryos. This work resulted in a patent submission (Method and system for determining characteristics of an embryo and uses thereof; WO/2012.042, 228).

Enhancing the local, national and international knowledge base by engagement with public

bodies and non-governmental organisations

Attrill, Conley, Hall-Spencer, Hosegood and Shapiro have worked with the South West Regional Development Agency (SWRDA) to develop the south-west as an international centre of excellence in marine renewable energy and create the SW Marine Energy Park. SWRDA awarded Plymouth £4.07M (for 2007-10) for new academic staff, research students and facilities (wave tank and fast offshore research vessel) to provide research support for Wave Hub, a new test facility for prototype wave energy devices off the north coast of Cornwall (www.wavehub.co.uk). In conjunction with this, **Attrill and Howell** have developed new methodologies for large scale monitoring of offshore seabed habitats which has been central to the UK's monitoring programmes for marine protected areas (MPAs) and has included DEFRA commissioned research (2008-2012) into the impact of the first large MPA in the UK at Lyme Bay. Similarly, in a European context, the EU SESAME (Southern European Seas- Assessment and Modelling of the Ecosystem Change, €10M) has provided policy makers with a clear picture of the past and future of the marine ecosystem in the Mediterranean and Black Seas. The largest ever EU marine project, MyOcean (2009-2012, €55M) has created a pre-operational ocean monitoring and forecasting service for Europe, delivering 240 products to 1000 end users, with Plymouth (**Shapiro**) leading development of new modelling capabilities for the Black Sea. A NERC Partnership Grant (2010-13) for **Davidson** in collaboration with the Royal National Lifeboat Institution (RNLI) investigating the dynamics of rip currents and implications for beach safety has directly impacted on RNLI beach lifeguarding practices and risk assessment on beaches. In collaboration with the Met Office, **Davidson** has also developed a predictive tool to inform the general public of the risks presented by rip currents for all popular bathing beaches in the UK which is changing people's behaviour when visiting the coast. Research into diffuse mine water pollution in Southwest England (2008-2011) by **Braungardt & Worsfold** in collaboration with the Environment Agency was cited in the 2009 South West River Basin Management Plan as a "measure" to help deliver the EU Water Framework Directive. In collaboration with the British Geological Survey the outcomes of this research were applied to a policy challenge which was to identify abandoned mining waste facilities that are causing serious harm to the environment. This work was instrumental in creating an inventory of such sites that was published by DEFRA and the Welsh Government in May 2012 to satisfy the requirements of the EU Mining Waste Directive.

Engagement of staff on national and international bodies which influence environmental policy and practice

Parmesan's research publications are contributing to WG II of the IPCC 5th AR as follows: Parmesan et al. 2011(Nature Climate Change) and 2013 (Ecology Letters) were used to frame discussion of 'good practices' for Ch. 18 "Detection and Attribution" and Poloczanska et al. (Nature Climate Change 2013) has contributed the bulk of the text on observed impacts of climate change on marine species for Ch. 30 "Oceans". **Hall-Spencer** is a member of the IPCC ocean acidification working group (funded by UNESCO), represents the UK on the ICES Working Group on Deepwater Ecology and is a UNEP representative drafting guidelines for the management of deep-sea fisheries in the High Seas. **Attrill** was invited to advise the UN on marine renewable energy (May 2012). **Howell** has been working with the former DTI and the Joint Nature Conservation Committee to map the UK's deep sea habitats to inform the sustainable management of these areas, and contributed to the UK Government's Sea Map 2010 project. As a result, **Howell** sits on the ICES Working Group on Deep-Sea Ecology, advising the NE Atlantic Fisheries Commission, NW Atlantic Fisheries Organization and EU on conservation and management of the deep-sea ecosystem. **Stewart** is a member of the Board of the International Geoscience Programme (IGCP), the only advisory body within UNESCO with a remit for the Earth Sciences. **Hart** was chair of the Geological Society of London's Geoconservation Commission (2009-2011).

Active participation in the public dissemination of knowledge and enhancing the public understanding of science

The 2012 award to Plymouth University of the Queens Anniversary Prize, in recognition of 150 years of Marine & Maritime Research & Training, was driven by **Attrill**. The award was made by the Royal Anniversary Trust, an independent charity concerned with advancing education for public benefit that 'works to promote world class excellence in UK universities and colleges through The Queen's Anniversary Prizes for Higher and Further Education.' **Stewart** has presented numerous television and radio series, such as *Journeys from the Centre of the Earth*, *Earth: The Power of the Planet*, *Hot Rocks*, *The Climate Wars: How Earth Made Us and How to Grow a Planet*. This has

resulted in the award of an MBE in 2013 in recognition of his services to geology and science education. Output from **Bilton** and colleagues (2011) was highlighted as a 'must read' by 'Faculty of 1000' and produced an animated YouTube video entitled 'Oxygen' that was awarded 1st prize at the Marie Curie Researchers Symposium on "Promoting science: let's be innovative!". NERC and EU funded research by **Belt** (£0.5M since 2008) on reconstructions of past climate conditions using analysis of a suite of biomarker chemicals in Arctic and Antarctic marine sediments has resulted in extensive media coverage by the BBC. **Hall-Spencer** is a member of the IPCC ocean acidification working group and has gained much media coverage for his work in this area, including BBC News and the Discovery Channel and contributed to an International Union for Conservation of Nature educational video on ocean acidification (launched at the 3rd High CO_2 World Conference, Monterey Bay, 2012). He has also made three science documentaries based on his marine resources work (National Geographic, Canadian Broadcasting Company and Euronews). **Rowland** has recently received extensive media coverage after identifying the chemical that has resulted in hundreds of seabirds dying in the English channel. **Parmesan** has also received extensive media coverage, including major magazine profiles (e.g., *Scientific American*, the Guardian), radio and television interviews (e.g., ABC News world news webcast).

c. Strategy and plans

Our **aim** is to ensure that all research projects involve industrial or end-user partners or advisory boards and are focussed on deliverables that will be implemented to aid the manufacturing sector (e.g. analytical instrument companies), the emerging technologies sector (e.g. marine renewable energy development) and public bodies (e.g. coastal management decision making). To achieve this aim our **objectives** for supporting impact, which are in line with Plymouth University's Strategy 2020, are to:

- Require all projects (PhD and funded research) to define their potential impact and identify the pathways to impact for the project.
- Develop a partnership approach with individuals and organisations to embed an enterprising approach and spark creativity.
- Create an environment that supports knowledge exchange with businesses and other organisations, including the commercialisation of research outcomes for public good.
- Encourage public engagement in, and understanding of, research and innovation through a range of channels and media.
- Engage with international, national and local government, professional and statutory bodies, business groups and key opinion-formers to inform and influence environmental policy.

A key **strategy** to achieve this aim is to engage in industrially funded research and consultancy by harnessing our enterprise and entrepreneurial skills and utilising our knowledge base. Hence we will work in partnership with the University Research and Innovation team and our external advisors, Frontier IP Group, to evaluate and exploit opportunities for business, public and voluntary sector interaction. For example, a patent based on **Rundle**'s work on bio-imaging technology for monitoring the effects of environmental stressors on early development in aquatic embryos will form the basis of a project to develop this technology into an industrial and educational resource (BioDev). We will also interact directly with manufacturers to produce specialist instrumentation and supporting methodologies for environmental monitoring. For example, the final phase of a European Research Council funded Advanced Investigators Award (OUTREACH; agreement no. 228149) of €2M to **Rowland** will develop GC-GC-MS^n methods to characterise the chemical composition and toxicity of individual chemicals within the 'supercomplex' mixtures of organic pollutants resulting from oil spills and oil sands operations. Such chemicals are presently outside of the recently imposed EU REACH regulations (hence 'OUTREACH'). The work will have a major impact on the research and policy decisions of, amongst others, Environment Canada and the American Petroleum Institute, for whom **Rowland** is now a consultant. **Davidson, Russell and Masselink** will build on their knowledge of climate change and storm impacts on coastal areas to enhance the resilience of coastal energy supply by working with coastally located nuclear power stations (Sellafield and Sizewell) using a combined fieldwork and modelling approach. They will also work with Fugro UK to predict the impact of hazardous waves on oil/gas fields in the South China Sea, Andaman Sea and the Gulf of Guinea. Furthermore they will engage with coastal councils in the south of England (through the Channel and Plymouth Coastal Observatories) and one of the largest coastal engineering consultancies in the UK (HR Wallingford) to produce a tool

with which coastal managers will be able to predict the impact of extreme wave and water level conditions on gravel beaches and barriers. This tool will also be used to design recharged gravel beaches to optimise their shape and provide maximum coastal protection. **Watkinson and Anderson** will work closely with PDF (a petroleum consultancy company) on a range of exploration projects, most notably in Central Europe.

We will also enhance the local, national and international knowledge base by engagement with public bodies and non-governmental organisations. The unit will use its expertise in chemical analysis to disseminate to the user community new analytical methods for the quantification of organic and inorganic species in environmental matrices, particularly the aquatic environment. For example **Worsfold** will work with a consortium of European national metrology laboratories in a EURAMET funded project to produce templates for assessing the uncertainty of trace metal measurements in the marine environment in order to improve data quality and intercomparison between laboratories. The fundamental research by **Thompson and Rowland** on the potential for microplastics to cause harm in the marine environment will directly contribute towards DEFRA's commitment to achieving good environmental status within EU waters by 2020 as part of the Marine Strategy Framework Directive. **Russell** will work with the National Trust to provide science-based guidance on the management of their coastal properties, most of which are located along eroding coastal cliffs that are heavily used by tourists, such as the South West Coast Path.

A review of our pathways to impact has highlighted the need to reach end-users more effectively via project steering groups and open research meetings where we present our work to mixed audiences of practitioners and academics. These processes will facilitate discussion with end-users, leading to new collaborations, contract research and KTP proposals. We will monitor the impacts of our research outputs and measure success in academic terms through publications in high quality journals and citations and encourage all of our researchers and research students to join social network dissemination platforms such as ResearchGate. Internally we will disseminate impact successes through Research Centre websites, internal workshops and seminars. Researchers in training will catalogue outputs and public engagements in the individuals' thesis and an appendix to their European Commission Diploma Supplement.

d. Relationship to case studies

The five case studies chosen are exemplars of the wider philosophy of engagement with industrially funded research and consultancy and with public bodies and non-governmental organisations to enhance the local, national and international knowledge base. Reflection on, and dissemination of these case studies and other studies within the unit has informed our strategy for maximising good practice in future research.

- The coastal zones video technology study (**Davidson**) illustrates engagement with public bodies at the local and regional levels, e.g., local authorities. It also demonstrates the effective transfer of technology that has evolved from fundamental research. Beneficiaries include coastal managers, mariners, coastal communities, tourists and industries.
- The study describing strategies for measuring complex mixtures (**Rowland**) is an example of collaboration with instrument manufacturers and with industrial and public sector end users. The wider impact of this research was recently demonstrated by the application of the technology to identify the chemical responsible for the death of hundreds of seabirds in the English Channel.
- The study on marine contamination by microplastics (**Thompson**) is an example of fundamental studies influencing international environmental policy and practice by making a direct contribution to the EU Marine Strategy Framework Directive. It also demonstrates the wider engagement of the unit in providing independent scientific advice to policy makers such as the International Oceanographic Commission and United Nations Environment Programme.
- The Marine Protected Areas study (**Howell and Hall-Spencer**) demonstrates advocacy and proactive work with policy makers, governmental and non-governmental organisations and industry. It shows that the unit has contributed to delivering the UK Government's vision of "clean, healthy, safe, productive and biologically diverse oceans and seas".
- The study on Ocean Acidification (**Hall-Spencer**) further demonstrates how our research assists the UK government. This particular example shows how the unit has supported DEFRA and the Department of Energy and Climate Change in their delivery of statutory obligations under national legislative drivers.