Institution: University of Stirling

Unit of Assessment: B7 Earth Systems and Environmental Sciences

a. Overview.

We seek to understand the fundamental processes driving the evolution and maintenance of biodiversity from the genetic to the ecosystem level, and to predict and mitigate perturbations of biogeochemical cycles that result from environmental changes, from local to global scales. The on-going and long-term goal for our research is to ensure a sustainable, healthy future for humanity and the environments on which we depend. From fundamental process-based studies we create and test policy and management solutions to give new approaches to natural resource management, mitigate or reverse the impacts of human activities on biodiversity, environmental services and natural resources.

This submission presents the integrated research programmes in Environmental Sciences within the University of Stirling's School of Natural Sciences. The fifteen staff (14.6 FTE) staff are organised into two research groups: *Ecology, Evolution & Conservation* and *Environmental Systems, Change & Protection*. The groups are collectively guided, co-ordinated and led by two Professors (**Billet**, *Environmental Systems, Change & Protection* and **Jump**, *Ecology, Evolution & Conservation*). Future strategic directions are identified, assessed and 'start-up' resourced through the School of Natural Sciences strategic planning process. This rigorously tests academic ideas against international, UK research council, government and industry agendas in discussion with our strong international collaborative networks. Our research environment includes extensive research collaborations with other parts of the School, notably in Environmental Studies, Psychology and Mathematics. We also have strong international networks and contribute to two RCUK Doctoral Training Partnerships.

b. Research strategy

i. Evaluation of Strategy

Our success has been in the creation of a new, rigorous and testing research environment from which solutions to numerous 21st century environmental challenges emerge. Since 2008 the School of Natural Sciences at Stirling has developed new integrated foci on evolutionary ecology, organismal and ecosystem ecology and conservation, and biogeochemical cycling, which address concerns associated with the biogeochemistry and biology of the environment. In doing so we provide scientific foundations for the University of Stirling's wider vision of inter-disciplinary research in *environment and communities* (University of Stirling Strategic Plan 2008, 2011) explicitly addressing needs set out by national and international government and non-governmental organisation imperatives. This addresses key aspects of the Living with Environmental Change challenge (NERC, 2007). During the assessment period we have appointed 14 new staff (seven lecturers, one professor and six research fellows) and we currently have 21 (FTE) post-graduate research students. We have strong research impact agendas and work closely with, and influence, government and non-government departments (UK, Scottish and international) and conservation NGOs (national and international). Our work has global reach and depth with long-standing research programmes in four continents. We were recognised in 2010 by Times Higher Education as the second university in Scotland and 20th overall institution in the UK for the impact of its ecological and environmental research, based on citation data.

In *Ecology, Evolution & Conservation* we conduct research on diverse aspects of a broad range of taxa, spanning organisational scales from biome to genome. Our understanding of how evolutionary and ecological pressures differentially impact individuals, populations, species and communities is the core science-base that underpins management and conservation action, and our theoretical research is complimented by work demonstrating its practical application and societal impact. The areas of forest ecology and plant-environment interactions have been the focus of significant investment since RAE 2008, beginning with the appointments of **Jump** and **Vallejo-Marin**, whose research has been funded from sources including NERC, EU FP7, the Royal Society, Leverhulme Trust and Esmeé Fairbairn Foundation. More recently, the appointments of

Dent and **Paine** have strengthened our work in tropical forest ecosystems; these staff focus on understanding the trait diversity of these exceptionally species-rich systems and how traits can be used to predict organismal function and response to perturbations, work that has been funded largely by the Panamanian Government. Complementing our research on impacts of perturbation within communities, we explore how changing environmental conditions will alter vital demographic rates across species ranges and hence lead to geographical shifts of species and biomes (**Jump, Matías**).

Whilst a significant proportion of our research focuses on understanding and predicting the impacts of environmental changes on biodiversity, much of the work we conduct aims to understand how that diversity is generated. We explore the impact of isolation and divergence of populations across heterogeneous environments leading to the adaptive radiation of species (**Abdelaziz**), together with how specialisation by both plants and pollinators can shape the mating strategies of populations and species (**Vallejo-Marin**). Work on conflict and exploitation between different sexes and species allows us to understand how different mating systems and life histories evolve and persist, and to explore how small intraspecific trait differences can generate large differences in organismal fitness (**Auld, Bussière, Tinsley**). Research on the evolutionary ecology of invertebrate host-parasite systems investigates disease transmission and the effects of ageing on the immune system (**Tinsley, Dobson**), with results to date suggesting that senescence of the Drosophila cellular immune response may underpin increased disease susceptibility. Complementing our work on understanding the fundamental processes generating and maintaining diversity, we strive to understand how biodiversity will be impacted by human activity. Conservation science at Stirling is supported by substantial funding from NERC, the Leverhulme Trust, Forestry Commission, government agencies and several conservation charities. At both the population and landscape level, changes in agricultural practice and agrochemical usage have been identified as having unexpected and far reaching consequences for pollinator behavior and ecosystem services (**Whitehorn**; see Impact Case Study). The development of this research theme led to NERC funding as part of the BiodivERsA project BeFoFu to assess conservation and policy impacts of the Natura 2000 protected areas network (**Jump**). Throughout our work across all areas, we combine manipulative experiments and extensive observational datasets with mechanistic and statistical modeling, with key staff leading on advanced statistical analysis (**Bussière**, **Paine**).

In *Environmental Systems, Change & Protection* we address key environmental challenges facing humanity, working from the ecosystem/catchment to the global scale in order to assimilate complex interactions between organisms (including humans) and their environment. The research focus within BES on terrestrial carbon (C) dynamics is strengthened by the new appointments of **Billett** and **Subke. Subke's** research investigates processes involved in C uptake and release, including complex interactions between plants and soils, exploiting laboratory- and field-based experiments (in predominantly Arctic and temperate ecosystems) and stable isotope techniques to quantify C turnover in ecosystems. **Billett** leads NERC-funded research on the biogeochemical cycling of C in the soil-water-atmosphere system, which includes the application of novel isotopic techniques to source and age aquatic C species. Research is focussed on the production, transport and transformation of gaseous and dissolved C in organic-rich systems in temperate, boreal and Arctic regions that are subject to environmental change. **Schroder**, a recent appointment through a University of Stirling Impact Fellowship, investigates biogeochemical cycling of iron and how this interacts with the cycling of carbon, sulphur and phosphorus across a range of environmental contexts, including Martian surfaces through the Mars Exploration Rover. In increasing the scope and capacity of our ISO 17025 accredited Environmental Radioactivity Laboratory, highlighted as excellent in the RAE 2008 report, with the appointment of **Copplestone** (formerly of the Environment Agency), we have expanded our strength in radioecology (see Impact Case Study). This has resulted in new synergies with evolutionary ecology through the NERC - RATE programme award (TRansfer – Exposure – Effects: integrating the science needed to underpin radioactivity assessments for humans and wildlife).

ii. Outline of main objectives and activities

Our *vision* for the next five years is to build on the unique environmental research framework that Stirling offers at the interface between ecosystems, environment and society. We will further develop our collaborative academic arenas in evolutionary, and conservation ecologies and in

biogeochemical cycling. In pursuing this vision, our ambition is to shape national and international environmental policy and management through the innovative and robust scientific foundations we provide. We contribute to shaping research agendas in RCUK, EU and internationally and our research groups reflect the priorities driving funding support from these sources. In turn, we will continue to invest strategically in new staff and in the science and technology infrastructure that underpins our research, including *molecular biology, community ecology and geospatial technologies.* This research agenda will allow a detailed understanding of ecosystem responses to natural and anthropogenic environmental perturbations to drive the development and implementation of appropriate management and mitigation strategies.

a) Building on recent funding successes: We will continue to develop our work on understanding the response of species to human induced stresses and disturbances, and the knock-on effects on key ecosystem services. These stresses and disturbances include agricultural activities in developed (pesticides) and developing (agricultural expansion) regions, tourism pressures, energy infrastructure projects and a limited capacity for conservation action. We are partners in the £1.6m ERA-Net BiodivERsA project BeFoFu (2009-13), which integrates conservation science and policy to assess the effectiveness of Natura 2000 for beech forest conservation, with Stirling leading on the NERC funded portion of this international project. The genetic diversity and ecological success of the invasive riparian plant, *Mimulus guttatus*, are being studied through a £50K NERC award to **Vallejo-Marin** (2012-13). In community ecology, **Jump** has recently been awarded £127K for a three-year project to assess plant community resilience to extreme drought. **Copplestone, Tinsley** are partners in a NERC - RATE programme award (£2.5m consortium award) within the radioactivity and the environment theme. This consortium funding provides a second area of focus - strengthening UK capacity in radioactivity and the environment, and Stirling will lead on the Wildlife assessment aspects of this work linking strongly with our evolutionary ecology research. **Billett** and **Subke** have funding in place from NERC (2 grants) and the Carnegie Trust to underpin a new research avenue on C cycling in the atmosphere-plant-soil-water system.

b) Prioritised development of new research initiatives: Through the School of Natural Sciences strategic planning process we align research activities of our research groups to major research challenges drivers set by funders. These include: UN - Post 2015 Sustainable Development Initiative; BBSRC - Food Security; NERC – Biodiversity, Sustainable Use of Natural Resources; EU 2020 - Food Security; Climate Action and Resource Efficiency, and Scottish Government priorities (Food and Drink, Heritage and Tourism, Energy. Our *committed* continuing investment is as follows

- Radioecology, geospatial and sensor technologies. Three core funded lectureship posts are agreed, building on high grant award success and complementing a recent early career appointment.
- Environmental biotechnology diversity core funded Reader / Professor post agreed.
- The above posts have additional University capital support for our 'big data' initiatives in bioinformatics and geospatial technologies ensuring appropriate computing power and technical support.
- Further continuing investment by adding by 3 to our early career research fellows (six submitted as part of this unit) to integrate existing research strands with funder challenges.

Our *intended* investments in environmental research as set out and embedded within our School strategic planning process are as follows:

- Applied biosciences. Four core funded lectureship posts to develop a major new research strand of molecular biology within our portfolio. These will link collaborative opportunities with organismal biology staff to explore fundamental ecological and biological mechanistic questions.

To realise our vision and deliver our objectives we have set quantifiable targets for individuals and research groups over the next five years. As a growing research area within the School of Natural Sciences we have targets to achieve a critical mass of 25 FTE research staff, increase research grant income (scaled for subject and career stage) sustainably above our subject area averages, increase PGRs to three FTE per research-based academic FTE, publish consistently at internationally excellent levels of quality, 100% graduate level employment of our research post-graduates and all colleagues publishing with international partners. Monitoring (with following

actions) of targets is at three levels. Our School strategic plan is reviewed annually by University 'Planning for Academic Success' group and by our external advisors. Individual research performance is reviewed annually through the University's 'Achieving Success' appraisal process, led by research group leaders with mediation by the Head of School. Research activity and performance is assessed by School research and knowledge exchange committee on a monthly basis.

c. People, including:

i. Staffing strategy and staff development: The period 2008-2013 has been one of major investment by the University in new academics, explicitly to give critical mass and balance to our two research groups (seven lecturers, one professor and six research fellows). Appointments are based on strategic directions developed from our School strategic planning process; our approach is to attract high quality junior staff and provide a supportive environment including financial assistance, mentoring through a senior colleague, reduced teaching loads of at least 50% in the first two years and training opportunities (5% of workload allocated) to enable them to achieve their full potential. In doing so we have created an outstanding atmosphere of enthusiasm and dynamism with a large complement of young staff (nine early career researchers) from diverse backgrounds and nationalities (48% of staff in this submission are international) integrating with more senior colleagues. We highlight in particular the successful University's Impact Fellowship scheme, now in its 3rd year, designed to enable appointments of highly qualified early career scientists with the explicit remit of developing research programmes with societal, economic and policy impact and with the opportunity to become permanent members of staff after two years. Six of our Impact Fellows are submitted within this unit. We also financially support postdoctoral fellowships gained through Leverhulme Trust and EU Plant Fellows programme (in which we are one of only two UK partners) and host fully funded fellows (e.g. Matias, Marie Curie IEF 2012-14). We maintain a ratio of open ended to fixed term contract staff (on core funds) of no less than 2:1.

In order to monitor and enhance the potential of individual researchers, a performance review scheme "Achieving Success" is undertaken by all staff, on an annual basis. This is recognised by all colleagues as an important aspect of personal development and staff reflect on their achievement in the last year, and plan short and long term goals for the future. This is facilitated by a regularly updated workload model to ensure a balance is achieved between administrative duties, teaching and research activities. The review scheme is also used as a means of providing information on staff activities, aspirations and resource requirements and allows development of the School's planning and promotions process.

Non-probationary academic staff are eligible for one six-month period of research leave after six full semesters of completed service. A case for research leave is made to the HoS, approved by Staffing Committee and reported within one semester of return to normal duties. Appropriate activities include development of new research proposals, extended field and laboratory research and research paper writing. Six staff from this submission have taken research leave during the census period amounting to 36 months.

The University has strategic commitments to valuing and promoting equality and diversity in research careers and there is an established a network of equality contacts to promote this. Flexible working is available to those with caring responsibilities, there are clear policies on consideration of career breaks and part time working in terms of advancement and promotion, and there are recently revised guidelines for appointing committees to address equality issues. Within the School of Natural Sciences there are locally agreed, flexible working arrangements. The School of Natural Sciences has led University Athena SWAN initiatives; the Athena SWAN national charter for women in science was signed in 2011 and the bronze level institutional award gained in 2013. We are now actively pursuing the Athena SWAN silver award.

The University was one of the first signatories in the UK of the RCUK Researchers Concordat in 2009, with its implementation earning Stirling the EU HR Excellence in Research Award in 2011. Further evidence of the Concordat's positive influence is the dedicated funds available for Research Fellows and Research Assistants to attend specialist training events and conferences. Limited bridging funding from one grant to another is also available. Following appropriate training, RFs and PDRAs are given opportunities to supervise research students as second supervisor and to contribute to research-based teaching. Fellows are mentored by a senior academic colleague,

and RAs by project PIs.

Our Honorary Staff play an important role in the department, collaborating on research grants, co-supervising postgraduates, delivering lectures and research seminars, and providing strong links with governments, NGOs and industry. Current honorary staff includes representatives of Royal Society for the Protection of Birds, British Trust for Ornithology, Scottish Natural Heritage, Scottish Environment Protection Agency, Historic Scotland and International Union for the Conservation of Nature.

The University implements a Code of Good Research Practice that all staff and PGR are expected to follow. This sets out standards and responsibilities for people involved in research – from project initiation through to publication and data curation - and serves to encourage and maintain a culture of respect for the highest standards of integrity and honesty. As part of this, we have a long-established ethics committee which scrutinises work conducted within this unit to ensure that these standards are upheld and which reports to the University Ethics Committee.

ii. Research students (RPG) We have made substantial and successful efforts to increase PGR numbers, which currently stand at 21 FTE. This has been achieved with NERC support, while international students are supported by prestigious government and national research council studentships. The University has also invested studentships in our research groups including both fully funded and matched with industry, support that enhances our employability and impact portfolios (see REF 3a). We fully recognise the challenges of employability and skills training in our PhD programmes and as an example of our commitment the School of Natural Sciences introduced in 2010 a new and innovative Research Apprenticeship Scheme. This offers exceptional candidates a five year stipend, during which period they are expected to complete a PhD, gain experience in teaching, and conduct research apprenticeship training in advanced environmental skills. Four such apprentices are currently in place, and we are actively planning the expansion of this scheme. We are a full partner in the IAPETUS NERC Doctoral Training Partnership (announced November 2013, with Durham, Newcastle, Glasgow, St Andrews and 38 industrial partners). The PhD programmes associated with this partnership will allow further enhancement of our partnerships with industry programme across our PGR cohort. PGRs receive a mix of training in a stimulating research environment proven to be successful in delivering timely high quality theses (>90% submission within < four years, and part-time students within eight years). Training and networking is via the principal and second supervisor (who undergo supervisory training) complemented by the generic research-training programme of the Stirling Graduate Research School and inter-University collaborations. Rigorous progress monitoring is via interviews and reports to the Research sub-Committee and then to the University's Admissions Progress and Awards Committee. PGRs are active attendees in the School research seminar programme, and all participate in the annual poster day and annual, two day, PGR conference, as well as a weekly internal seminar series. Virtually all students will have spoken at a national level conference by their second year and at an international conference by their third year. PGRs are expected to publish the majority of their data chapters, and submit their first manuscript before the end of their second year, so that by the time of submission they have already published one or more papers in international journals.

Our PGR training is guided by the NERC "Most Wanted' skills agenda (2012), graduate employability agendas set out by the University Strategy (2011) and by Scottish Government imperatives on employability (2012). Formal training modules are delivered and assessed by leading academics, and increasingly by industry partners, in the context of the Stirling Graduate School and SFC supported research pool Graduate Schools. We will develop these approaches further within the context of our new collaborative NERC DTP. PGRs also benefit from our collaborative international links, participating in field based research schools throughout the world.

d. Income, infrastructure and facilities

i. Income

Over the census period our income for this submission totals £2.1m. For income FTE ratios in the census period we note that 8 FTE colleagues have arrived since 2012). The main sources of income are Research Councils, Royal Society, British Academy combined (44%), UK based

charities through an open competitive process (27%) and UK central government bodies (18%). The last two years, however have seen a rise in income derived from EU and government bodies. Virtually all of our funding is competitively awarded. Research funding has consistently led to high quality research outputs. All our papers are in the upper quartile journals for the subject area (SCOPUS, Web of Science) with high citations evident in evolutionary ecology, conservation and biogeochemical cycling.

We have an integrated strategy for generating grant income co-ordinated by the School Research Committee; there is explicit expectation that all colleagues will hold a research grant. We focus on EU, RCUK, selected government agencies, selected research charities and selected international organisations. Our staff sit on advisory panels for governments and their agencies and charities, through which we influence research policy and practice. We actively participate in town house meetings and informal responses to consultation processes. From these intelligence gathering activities we explicitly match our research groups and facilities against emerging funding themes through our strategic planning process. Our Research and Enterprise Office develop and deliver information meetings (our most recent was Horizon 2020 and one planned for NERC: *The Business of the Environment)* that highlight opportunities and procedures. Grant writing (team and individual) is supported by time made available through workload management and by critical reading of drafts. Review of both successful and unsuccessful applications is disseminated by School Research Committee.

ii Infrastructure and facilities

We provide a high quality research infrastructure maximising the benefit of capital funding from the Scottish Funding Council and the UK Government's Department for Business Innovation and Skills. Infrastructure funding is developed, managed and optimised within the framework of our Campus Masterplan and through an integrated school and capital planning process; a total of £2m has been invested in environmental research during the REF period, with a further £66k committed to 2014. These facilities are shared with our 21.3 FTE colleagues submitted to C17. Our use of SFC-BIS monies for facilities were audited by SFC during 2011/12. Key outcomes of the audit included approval of our use of funding, recognition that that it had allowed entry into new research arena's and leveraged new funding, and enabled participation in national and international research networks. Our facilities, are supported by 11 Technical Staff, who provide skills training to PhD students and RAs in use of specialist equipment. Facilities that relate to the research groups of this submission include:

- *Controlled Environment Facility* (upgraded in 2011 to a state-of-the-art >£1 million facility), now supporting research funded by NERC, EU Marie Curie, Royal Society, Carnegie Trust, Scottish Environment Protection Agency (SEPA), and commercial activity.
- *Greenhouse and Experimental Garden facilities:* approx. 200m^2 of glasshouse space.
- *Environmental Radioactivity Laboratory*, an ISO 17025:2005 accredited laboratory supporting research funded by SEPA, Environment Agency, Sellafield Ltd, DTI–BGS.
- *Micromorphology, Microscopy and SEM-EDX Facility*, now supporting research funded by European Research Council and commercial activity
- *CAT2 microbial laboratory* supporting research funded by NERC and Scottish Government.
- *Molecular Ecology:* fully equipped recently refurbished suite of three molecular ecology laboratories, with fragment analysis and sequencing being provided through commercial agreements with external partners. These facilities currently support work funded by NERC, Leverhulme Trust, EU Marie Curie, and a range of conservation charities.
- *Ecosystem Ecology and Biogeochemistry:* NERC-funded work on global C cycles and climate systems is aided by extensive field and lab equipment including respirometers for CO_2 emissions from soils and sediments, field portable infra red gas analysers for ecosystem carbon flux measurement, gas chromatography for methane flux measurement, temperature cycling cooled incubators.

We also provide:

- *Map library and cartography unit*.
- Full range of *field equipment*, and electronic and mechanical *workshops*.
- Two full time IT technicians within BES and a University science-dedicated computing liaison

colleague provides IT hardware and software support to researchers; all researchers, PGRs and laboratories are provided with their own networked computer.

- *Library and IT support* include dedicated Science librarian, web site with guidance, and supporting documentation on information tools and resources aimed at early career researchers; electronic Document Delivery Service; membership of SCONUL Research Extra. We are an active participant in the University Open Access Digital Research Repository holding all research theses and research output from 2006. Current journal spend is just over £1M per annum; many journals are now bought collaboratively so the full spend is greater; journal packages include those delivered by ScienceDirect and Wiley.

All academic staff receive an annual discretionary fund of between ~£1k and £8k, calculated using a performance-based algorithm (including research output, grant income, RPG numbers). These funds are used to cover basic laboratory expenses and for pump-priming small research projects and attendance at meetings and conferences. RPG consumable monies are given directly to principal supervisors. Funds for equipment purchases (usually £60k-100kpa) are allocated to academic staff on the basis of competitive bids, moderated for early career researchers.

e. Collaboration and contribution to the discipline or research base

Much of our work involves interdisciplinary collaborations and publications. Broader ecological and environmental research at Stirling is strongly integrated through informal and professor led interdisciplinary forums (Energy and Environment is our most recent initiative).

We have an active internationalisation agenda that brings broader in interdisciplinary frameworks and have long-standing collaborations with over 30 countries. Consistent long-term funding has been achieved with colleagues in Taiwan and central America. These activities are supported by workshops (at least yearly), several of which are held at Stirling, and by extended field work activities. We encourage extended visits (>1 month) from International Research Collaborators, and during the review period we have hosted International Research Scientists from numerous countries (for example including Japan, Bangladesh, Pakistan, Nigeria, Taiwan, USA, Iran, Spain). Several staff have participated in fully funded visiting fellow/professorial programmes, both in the UK (e.g. Cambridge University 2010), and overseas (e.g. National Pingtung University of Science and Technology, Taiwan 2012; Beijing Normal University, China 2012). Within the census period 74% of our published papers include international authorship and collaborative papers contributed to have won journal awards (e.g. Biotropica Award for Excellence in Tropical Biology and Conservation 2009).

A testament to the relevance and impact of our research is demonstrated by our close working relationships with a wide range of Government departments and UK regulatory bodies and Statutory Nature Conservation Organisations, industry (e.g. Nuclear Decommissioning Authority), research centres (e.g. Centre for Ecology & Hydrology), and non-governmental organisations (e.g. Royal Society for the Protection of Birds). These partners fund or part-fund PhD projects, co-supervise PhD students, independently fund research projects or input into project advisory boards.

All colleagues included in this submission are members of and contribute to learned societies and councils by providing policy expertise guiding development of disciplinary areas. Within the census period we have conducted journal paper reviews (on average 10-15 per year each). We act as subject editors and editorial advisory board members of 10 international journals. We are reviewers of research grant applications both nationally and internationally (e.g. NERC, BBSRC, Leverhulme) and also sit on panels for grant awarding bodies (e.g. NERC College). Staff are also external examiners for PhDs, MPhils, MRes degrees, as well as taught Masters courses and undergraduate courses for other universities in the UK and internationally. Staff are regularly involved with organising symposia at national and international conferences and have been invited as international keynote speakers.