Institution: University of East Anglia

Unit of Assessment: 5 – Biological Sciences

a. Context

Our mission is to conduct fundamental and applied research that is world class, collaborative and which affects the wider world, beyond academia. We group the main areas of Impact into (i) environmental and conservation biology, (ii) biomedical science, (iii) applied plant biology and (iv) microbiology. These impacts map onto our four main research themes, and several are developed through cross-theme collaborations.

(i) **Environmental and conservation biology** impacts are led by the Organisms and Environment theme, and range through applied habitat restoration, individual species conservation, fisheries health and behavioural assays of agricultural pests. This research directly influences environmental NGO policy awareness, with a focus on salt marsh, sand dune and wetland habitats, and on avian and fish species. Beneficiaries include the Centre for Environment Fisheries and Aquaculture Science (*Cefas*) in Suffolk, the Swedish Institute of Marine Sciences and the Joint Nature Conservation Committee plus numerous other NGOs. Research from this theme forms two Impact Case Studies (see **d** below) and also contributes to agricultural protection, through (e.g.) formal collaboration with *Oxitec Ltd* in optimising pest control by releasing genetically sterilised medflies.

(ii) **Biomedical sciences** impacts are led by the Cells and Tissues theme, in collaboration with the nearby Norfolk and Norwich University Hospital, and the UEA Medical School. This research focuses on mechanisms that direct development, tissue maintenance and the pathogenesis of diseases including arthritis and cancer and visual disorders such as cataract. User groups include local medical charities such as "*Big C*", biomedical companies, surgeons and clinicians and the general public through extensive local and national media coverage, for example on our broccoli research which shows its beneficial effects on arthritis, and more directly through improved surgical techniques for cataract. Direct outcomes of research from this theme have included the development of a human lens model, which forms one of our impact case studies (see section **d** below).

(iii) **Applied plant biology** impact is led by our Plant Sciences theme. Our researchers not only discovered RNAi in plants but have since developed RNAi and RNAi suppression technologies, directly leading to research tools for medical and agribiotech, including the production of vaccines in plants by the company, *Medicago*. Our development of blight-resistant GM potatoes not only presents future potential impact on food security, but has also provided a stage for educating the public and decision-makers on the benefits of GM technology, given that blight was the disease that led to the Irish potato famine. Jonathan Jones has actively engaged on this topic, for example in the BBC's *Science Britannica*, 2013. Our researchers in this theme are also leading efforts to generate Open Source sequence data for the Ash dieback fungus and to identify resistance genes.

(iv) **Microbiology** impact has been led by our Molecular Microbiology theme's work on the molecular mechanisms of bacterial disease and drug resistance, the role of bacteria in the global nitrogen and sulphur cycles and the use of bacteria to make biobatteries. We are developing new natural product antibiotics from unusual environmental niches, including bacteria that live symbiotically with leaf-cutter ants, bio-energy production from *Shewanella* bacteria, and environmental protection stemming from detailed understanding of bacterially-produced climate change gases (dimethyl sulfide and nitrous oxide). We are realising impact through work with the biotech companies *Inspiralis* and *Procarta*, the energy company *Schlumberger* and by actively engaging with the general public through outreach and media events, for example on the BBC TV programme "*Coast"* on climate change gases and the Radio 4 *iPM* programme on antibiotics.

b. Approach to impact

(i) **Interacting with and developing relationships with end users**: Publicising our research to the general public via the media is led by the UEA press office, which identifies newsworthy research from a School database of new publications and by interacting directly with researchers at weekly sessions, where a UEA Press officer spends a morning in the School. Both approaches work well and our researchers are regularly interviewed on national and local Radio and TV including BBC

News 24, BBC Breakfast, the BBC programmes *Science Brittanica* and *Coast* and the Radio 4 *iPM* programme. Initial interactions and relationship-building with end-users are also initiated through conventional routes of peer-reviewed publication and presentations at international conferences. For example, commercial interactions with *Oxitec* (*Oxford Insect Technologies*) started when the *Oxitec* CSO read a research paper from Chapman's group and made contact with the aim of improving *Oxitec*'s sterile insect technology to reduce pest insects, including fruitflies, mosquitoes and tsetse flies. To date, it has resulted in two CASE PhD studentships and two project-partnered BBSRC research grants, including researchers from the Molecular Microbiology theme to investigate the effect of altered gut microbiota on breeding between captive and wild fruitflies. We also depend on Knowledge Transfer Networks (KTN), as a key way in which the Technology Strategy Board facilitates knowledge transfer between academics and industry, and the UEA consultancy service, which directs end users towards the most appropriate researchers. To promote interactions with commercial end users, we initiated a 'business day', where invited companies attend a day of presentations and networking with School staff and students. The first business day attracted representatives of 14 external organisations, including 6 companies and 2 KTNs, and was judged to be such a success that the Science Faculty adopted the scheme across all six science schools. We also champion 'public visit days', with open labs and science demonstrations for visitors. Recently, for example, BIO celebrated UEA's 50th Anniversary with 18 separate science demonstrations in our largest teaching laboratory and more than 1500 members of the public attended from all spectra of society to engage with the staff and students actually doing the research.

(ii) **Nature of relationships and evidence of follow through to identify impact**: Relationships with end-users take the form of consultancy or contract research, knowledge transfer (including public engagement), CASE PhD studentships and partnered Research Grants with companies or NGOs. Examples include our avian conservation work, done with the Royal Society for Protection of Birds and the British Trust for Ornithology, both of which funded CASE PhD studentships, MSc studentships and postdoctoral studies with School researchers. Initial interactions with these NGOs were formed through conference networking and resulted in an important role for Jenny Gill in the African and Eurasian Waterbird Association (AEWA) and a collaborative working relationship with the government body the JNCC to implement international EU and AEWA species action plans. Our researchers were also vital to the development of a £1M molecular biology lab at *Cefas* with the specific aim of using a molecular fingerprinting assay developed by Martin Taylor to survey fish stocks. Examples of commercial research spanning all four research themes include *Oxitec*, the biotech companies *Inspiralis* and *Procarta*, the energy company *Schlumberger*, the animal feed company *AB Vista*, the lens development company *Anew Optics* and the vaccine development company *Medicago.* Impact is monitored and identified by the researchers themselves and logged on the School Enterprise and Engagement tracker databases to be followed up by the School Director of Enterprise (DoE), the Faculty's Associate Dean for Enterprise and the Business Development manager. Funding is made available if necessary and teaching and administrative workloads are adjusted to allow the researchers to develop their research impacts. The impacts described in our case studies were identified by the researchers and DoE and are evidence of follow-through to identify some of the different impacts of our wide ranging research in the biological sciences.

(iv) **Evidence of an agile approach to opportunities and how the unit enables staff to achieve impact**: Our DoE can provide immediate funding to attend networking events, non-academic conferences, and other events to promote and develop research impact. For example, our collaboration with *AB Vista* came about when the DoE recognised the commercial opportunities in a project proposal prepared by Brearley, passed it to the KTN who then made contact with *AB Vista*. Brearley applied for (and got) £30K seedcorn and proof of concept funding from UEA and, within a year of initial contact, this spawned £200K in consultancy and additional funding for two *AB Vista*–supported PhD studentships. The impact from this relationship will likely develop further over the next few years. Our links with *Oxitec* were established through visits by our researchers to the company HQ and were then facilitated by a targeted £1M investment by UEA to refurbish a Controlled Environment Facility (CEF) annexed to the School, allowing Tracey Chapman to expand the pest sterile insect technology work. Our research into the climate change gas nitrous oxide and in developing bacterial protein production platforms was facilitated by a £2M investment to refurbish the Wolfson fermentation suite, funded by a Royal Society Wolfson award and matched funding from

UEA. The School has also been strategic in its staff appointments with a view to further developing the impacts of their research. For example, the postdoctoral researchers that developed the human lens model (Wormstone) and the molecular fish fingerprinting assay (Taylor) described in two of our impact case studies are now Senior Lecturers in the School, the Research Fellow (Gill) that initiated the avian conservation work is a Reader and one of the postdoctoral researchers that discovered RNAi (Dalmay) is Professor of RNA Biology.

(v) **Other mechanisms deployed to support impact**: Impact education is coordinated by our Enterprise and Engagement (E&E) club, which is organised and run by younger contract research staff and by PhD and undergraduate students with the aim of encouraging the next generation of researchers to consider the impacts of their research and to make useful contacts with successful entrepreneurs and science engagers. The E&E club committee meets monthly and has funding from the Science Faculty (£3K per annum) and School (£10K total) to facilitate its activities. Recent speakers include Amy Mokady, who runs the iTeams programme in Cambridge, Gunter Pauli, a serial entrepreneur and author of '*The Blue Economy'*, Adam Rutherford the science broadcaster, Will Spooner the founder of *Eagle Genomics,* David Klenerman, the co-founder of *Solexa* sequencing (which was sold to Illumina), Mun-Keat Looi, Wellcome Trust science writer and author of "The Big Questions in Science" and Martin Goymour, founder of the *Zoological Society of East Anglia*. The E&E club also organises and mentors teams that enter various national and international competitions including the "*iGem*" synthetic biology competition, *iTeams* and the BBSRC *Biotech YES* competition, in which teams invent and market technology ideas. The School has had recent successes in *Biotech YES* with two teams from the School winning their regional heats and reaching the national finals in 2009 and 2010. *iTeams* combines multi-disciplinary teams of students with industry mentors and University inventions to assess the commercial viability of new technologies and product designs. The School entered its first *iTeam* into the Cambridge programme in 2012 and UEA will start its own *iTeams* programme in 2014. For the past three years, undergraduate teams have also entered the innovative *iGem* competition, the world's premier synthetic biology competition, winning medals in 2012 and 2013. More details of the E&E club and their recent activities can be found on the E&E club website at http://www.eandeclub.co.uk.

c. Strategy and plans.

The importance of Impact has taken increasing hold among our researchers over the REF period. Thus, our fielding of teams in the *iGem*, *iTeam* and *Biotechnology* YES competitions have been rewarding by bringing students and staff to focus on an applied end-product. Similarly, the student-run E&E Club brings a new dimension to life in the School and in its links with stakeholders. These activities will continue, and will command increased financial support from the School and the Faculty of Science.

Future strategy will benefit from "*Project 26*", which is being developed with £26M of government funding, and will stimulate economic growth and job creation from the science innovation activity on the Norwich Research Park. *Project 26* includes a new £14M *Enterprise Centre*, located on the UEA campus and additionally funded by the European Regional Development Fund, the Department for Business Innovation and Skills (BIS) and UEA. It will provide a hub to develop new start-up commercial activity and ideas arising from research. Another major recent development that will underpin our impact strategy for the next five years was the creation of the Norwich Research Park Translational Fund of £1.7M, with support from BBSRC as well as Norwich City and Norfolk County Councils. This will promote priority areas of translational science across the Research Park. UEA was also recently awarded both BBSRC (£100K) and NERC (£70K) Impact Accelerator Funding to develop societal and economic impact from RCUK-funded research. Awards have already been given to four of our researchers: Tom Clarke, to explore the commercial applications of an electricity-generating biobattery based on *Shewanella* bacteria; Tamas Dalmay to further develop and market a new technology for enriching siRNA sequences in RNA seq experiments; Matt Hutchings, to develop (with *Procarta*) decoy oligonucleotides that block a specific and highly conserved global repressor of antibiotic biosynthesis in actinomycete bacteria and use them to unlock "silent" antibiotics; and Jonathan Jones to develop a rapid screen to test cloned blight resistance (*Rpi*) genes for novel activity against their library of *Phytophthera infestans* effector proteins. Other major projected developments include:

- A collaboration with the *Zoological Society of East Anglia* (*ZSEA*), a charity that owns two local wild-life parks with world-ranking expertise in zoo-based breeding programmes. These major tourist attractions play an important role in public outreach and education. We will assist *ZSEA* with science education and in setting up a Tropical Eden project in East Anglia which offers the potential to incorporate our research base into a new area that opens up novel ways of bringing important areas of science to wider public attention. The development of this project has formed part of our invited application for the second round of NERC Impact Accelerator funding.
- The *Ecology, Conservation, and Environment Centre* (*ECEC*) is a collaboration between us, the Chinese Academy of Sciences and its Kunming Institute of Zoology in China. Douglas Yu, from our Organisms and Environment theme, was seconded to the Kunming Institute in 2008 to establish the *ECEC* which has developed DNA-based technologies to accelerate the measurement of biodiversity; for example, using blood from leeches to find populations of the highly endangered saola antelope in Vietnam and Laos. It is also helping the Yunnan environmental protection agency to develop DNA-based methods to conduct their first-ever census of water quality in the province's many lakes.
- *InCrops* promotes commercialisation of plant-derived products and technologies, working closely with our researchers in the Plant Science theme. *InCrops* is at the hub of a partnership of 19 academic organisations in the UK, supporting innovation and growth in the bioeconomy and providing support to more than 270 regional businesses. Mark Coleman from our Plant Science theme was seconded to *InCrops* and has been involved in linking the School to a range of projects in applications of bio-renewables, low-carbon technologies, biofuels, organic waste utilisation and assessment of novel plant products for health applications. This association with *InCrops* will continue and will grow when it moves to the new UEA Enterprise Centre as part of the Adapt low carbon innovation centre in 2014.

d. Relationship to case studies.

Our five Impact Case Studies reflect the different ways in which our research work has been nurtured, with a view to bringing a variety of types of Impact, as follows.

The importance of Jenny Gill's work on "*Avian Conservation*" was apparent from her time as a PhD student at UEA, after which active support was provided in her application for, and award of, a NERC Research Fellowship and her subsequent appointment as a member of Faculty. Further support for her work took the form of enabling extended leaves of absence for fieldwork and the AEWA working group. This has included School funding towards costs for these trips plus adjusted teaching and administrative workloads to facilitate her absences from UEA. Gill also benefited from strategic awards of PhD studentships from the School's quota, some directly funded by UEA.

Martin Taylor's work to develop the "*Molecular Fish Fingerprinting*" technique was done with colleagues in *Cefas* while he was a post-doc at UEA. Although Taylor left UEA to work at the University of Bangor, he re-joined UEA as a Senior Lecturer and is further developing the impact of this research by adapting the technique to identify the contents of fish guts and the contents of fish products in supermarkets.

Applied Human Lens research at UEA was started by the late George Duncan and was given real impetus through links with surgeons and physicians at the Norwich Hospitals. IP from this group led to the establishment of "medical technology transfer" processes at UEA, exemplified by "*Improving Surgical Treatment of Cataract*", an Impact Case Study that was initiated by Michael Wormstone. He was a PhD student and post-doc in Duncan's lab who was appointed to the Faculty, and continues to develop the impact of this applied research as head of the Human Lens research group.

From its inception, The Sainsbury Laboratory at UEA saw the importance of translating its work on the fundamentals of plant disease into avenues with outside benefit. In 2009, it set up *TSL+* with the *Two Blades Foundation,* a charity that supports the development of disease-resistant crops for agriculture worldwide. Our close association with *Plant Biotechnology Limited* ensured that Baulcombe secured, and licensed, the crucial patents on RNAi and RNAi suppression; these underpin the two Impact Case Studies on "*RNAi – a Change in the Landscape of Biotechnology*" and "*Suppression of RNA Silencing"* respectively.