

GRAND CHALLENGES IN ECOSYSTEMS
AND THE ENVIRONMENT

SCIENCE FOR THE LIVING PLANET

REPORT 2019
PROFESSOR
VINCENT SAVOLAINEN

FOREWORD

Many challenges facing human society depend on the interactions among ecological systems, the environment and human wellbeing.

With headquarters in Life Sciences at the Silwood Park Campus, GCEE brings together a multi-disciplinary group of researchers from across the College and beyond to tackle some of the planet's greatest environmental challenges.

Last year has been busy again, and some of our research highlights are presented here together with plans for the year ahead. We have continued to excel in research and teaching as shown by our key indicators. Notably, I am pleased that our aims and activities fit so well with the new College Academic Strategy 2020–2025 launched by our Provost, Professor Ian Walmsley FRS, especially with regard to the theme 'Understanding Complex Ecosystems for a Sustainable Society'. We have also expanded our main outreach event, Bugs Day, to include Birds and Beasts with highest attendance and level of satisfaction by the public so far. This was followed by a timely reunion with Silwood alumnus Shahid Naeem, now Professor of Ecology in the Department of Ecology, Evolution and Environmental Biology at Columbia University, delivering the keynote lecture: 'Misfortunes of a misguided mutiny and the quest for safe passage in the Anthropocene'.

Finally, I am particularly thankful to our new external advisory board, which we will meet during 2020 to help review our plans. This new board is composed of: Professor Nina Wedell, Professor of Evolutionary Biology and Associate Dean for Research, University of Exeter; Professor Julie McCann, Professor of Computer Systems, Imperial College London; Professor Sir Charles Godfray FRS, Director of the Oxford Martin School at the University of Oxford; Professor Richard Bardgett, Professor of Ecology and the University of Manchester and President of the British Ecological Society; Professor Martin Siegert, Co-director of the Grantham Institute for Climate Change and the Environment, Imperial College London;

Professor Kate Jones, Professor of Ecology and Biodiversity, University College London; Dr Jonathan Baillie, Vice President and Chief Scientist, the National Geographic Society.

Professor Vincent Savolainen
Director of GCEE



£53M

of external grant income*

47

PhD students based at Silwood Park**

114

Masters students based at Silwood Park from 19 countries

104

peer-reviewed scientific publications, of which 16 were in leading *Nature* and *Science* journals***

7

outreach events****

**This is the full list of grants won by Silwood Park's Life Sciences staff ending after 1 January 2019 and including subcontracts. It includes £8.6M won by Silwood Park's Life Sciences staff starting after 1 January 2019.*

***PhD Students enrolled through the Centre for Doctoral Training in Quantitative Method in Ecology and Evolution led by GCEE and Doctoral Training Programme in Science and Solution for a changing Planet co-led by GCEE, and other programmes*

****Nature, Nature Climate Change, Nature Communications, Nature Ecology & Evolution, Nature Geosciences, Science, Science Advances*

*****Bugs, Birds & Beasts Day, Cheapside Primary School, Bracknell Forest Scouts, Kensington Scouts, Wildfowl & Wetlands Trust, Bioblitz, Wildlife in Ascot*

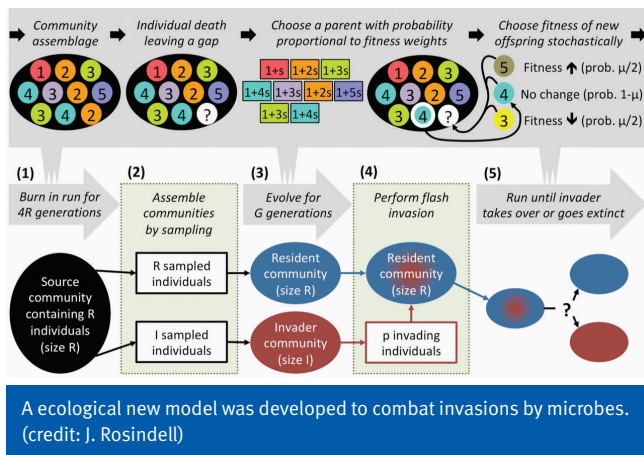
Image: Under the GCEE umbrella, Professor Vincent Savolainen, Director, and Dr Tilly Collins, Senior Fellow at Imperial's Centre for Environmental Policy, organised a symposium in Ghana with attendees from Côte d'Ivoire and South Africa, on 'Sustainable palms futures for Africa', funded by Research England Global Challenges Research Fund.

RESEARCH HIGHLIGHTS

CHALLENGE 1: UNDERSTANDING BIODIVERSITY ORIGINS AND LOSSES

UNDERCOVERING THE RULES OF MICROBIAL COMMUNITY INVASION

Understanding the ecological and evolutionary processes determining the outcome of biological invasions has been the subject of decades of research, with most work focusing on macro-organisms. In the context of microbes, invasions



remain poorly understood despite being increasingly recognised as important. To shed light on the factors affecting the success of microbial community invasions, Dr James Rosindell and colleagues performed simulations using an individual-based nearly-neutral model that combines ecological and evolutionary processes. Their simulations qualitatively recreated numerous empirical patterns and led to a description of five general rules of invasion: i) larger communities evolve better invaders and better defenders; ii) where invader and resident fitness difference is large invasion success is essentially deterministic; iii) propagule pressure contributes to invasion success if and only if invaders and residents are competitively similar; iv) increasing the diversity of invaders has a similar effect to increasing the number of invaders; v) more diverse communities better resist invasion. This work has huge ecological and medical implications for combating invasions by microbes.

Nature Ecology and Evolution 3: 1162 (2019)

EXTINCTION FILTERS MEDIATE THE GLOBAL WARMING EFFECTS OF HABITAT FRAGMENTATION ON ANIMALS

Habitat loss is the primary driver of biodiversity decline worldwide, but the effects of fragmentation (the spatial arrangement of remaining habitat) on animals are still only partially understood. A team led by Prof. Matt Betts from Oregon University and including GCEE members Prof. Rob Ewers, Dr Cris Banks-Leite, Dr David Orme and Dr Joe Tobias tackled this problem. Using 73 datasets collected worldwide (encompassing 4,489 animal species), they found that the proportion of fragmentation-sensitive species was nearly three times higher in regions with low rates of historical disturbance than in regions with high rates of disturbance



Orangutans inhabit some of the most threatened forests in South East Asia. (credit: B. Jordan)

(i.e., fires, glaciation, hurricanes, and deforestation). These disturbances mapped onto a latitudinal gradient in which sensitivity increases six-fold at low versus high latitudes. They concluded that conservation efforts to limit edges created by fragmentation will be most important in the world's tropical forests.

Science 366:1236 (2019)

CHALLENGE 2: NEW APPROACHES TO ENVIRONMENTAL MONITORING AND EVALUATION

DROUGHT IMPACTS ON TERRESTRIAL PRIMARY PRODUCTION UNDERESTIMATED BY SATELLITE MONITORING

Satellite retrievals of information about the Earth's surface are widely used to monitor global terrestrial photosynthesis and primary production and to examine the ecological impacts of droughts. Methods for estimating photosynthesis from space commonly combine information on vegetation greenness, incoming radiation, temperature, and atmospheric demand for water (vapour-pressure deficit), but do not account for the direct effects of low soil moisture. They instead rely on vapour-pressure deficit as a proxy for dryness, despite widespread evidence that soil moisture deficits have a direct impact on vegetation, independent of vapour-pressure deficit. Prof. Colin Prentice and colleagues used a globally distributed measurement network to assess the effect of soil moisture on photosynthesis. They identified a common bias in an



Drought has a strong effect on vegetation and carbon cycle; when estimated gross primary production from satellite-based data, it is crucial to include soil moisture information to avoid biased predictions. (credit: Bruce Dupree for The Alabama Cooperative Extension System, flickr)

ensemble of satellite-based estimates of photosynthesis that is governed by the magnitude of soil moisture effects on photosynthetic light-use efficiency. They developed methods to account for the influence of soil moisture and estimated that soil moisture effects reduce global annual photosynthesis by ~15%, increased interannual variability by more than 100% across 25% of the global vegetated land surface, and amplified the impacts of extreme events on primary production. These results demonstrate the importance of soil moisture effects for monitoring carbon-cycle variability and drought impacts on vegetation productivity from space.

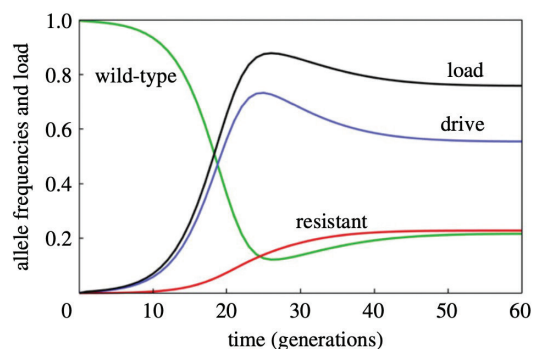
Nature Geoscience 12: 264 (2019)

CHALLENGE 3: ENGINEERING COMPLEX ECOSYSTEMS

GENE DRIVE FOR POPULATION GENETIC CONTROL OF MALARIA: NON-FUNCTIONAL RESISTANCE AND PARENTAL EFFECTS

Gene drive is a natural process of biased inheritance that, in principle, could be used to control pest and vector populations. As with any form of pest control, attention should be paid to the possibility of resistance evolving. For nuclease-based gene drive aimed at suppressing a population, resistance could arise by changes in the target sequence that maintain function, and various strategies have been proposed to reduce the likelihood that such alleles arise. Imperial researchers Dr Andrea Beaghton, Dr Andrew Hammond, Prof. Andrea Crisanti and Prof. Austin Burt used population genetic modelling of a strategy targeting a female fertility gene to demonstrate that even non-functional resistant alleles can also be expected to accumulate and reduce the reproductive load on the population. It will be important to account for these effects to better predict the dynamics of constructs in cage populations and the impact of any field release.

Proc. Roy. Soc. B 286: (2019)



Dynamics of a homing construct targeting a female fertility gene, showing the change in load and in the frequency of wild-type, drive and resistant alleles over discrete generations. Leaky expression (fitness $W/D = 0.4$, $W/R = 1$). (credit: A. Burt)



Models are being developed to use gene drive in mosquitoes to eradicate malaria. (credit: Target Malaria © All rights reserved)

ECOLOGICAL NETWORKS REVEAL RESILIENCE OF AGRO-ECOSYSTEMS TO CHANGES IN FARMING MANAGEMENT

Sustainable management of ecosystems and growth in agricultural productivity is at the heart of the United Nations' Sustainable Development Goals for 2030. New management regimes could revolutionise agricultural production but require an evaluation of the risks and opportunities.

Replacing existing conventional weed management with genetically modified, herbicide-tolerant (GMHT) crops, for example, might reduce herbicide applications and increase crop yields, but remains controversial owing to concerns about potential impacts on biodiversity. Until now, such new regimes have been assessed at the species or assemblage

level, whereas higher-level ecological network effects (i.e. across whole food webs) have been ignored. Here, Prof. Guy Woodward and colleagues conducted a large-scale network analysis of invertebrate communities across 502 UK farm sites to GMHT management in different crop types. They found that network-level properties were overwhelmingly shaped by crop type, whereas network structure and robustness were apparently unaltered by GMHT management. This study highlights current limitations of ecological assessments of effect in agriculture in which species interactions and potential compensatory effects are overlooked. They advocate adopting more holistic system-level evaluations, which complement existing assessments for meeting our future agricultural needs.

Nature Ecology & Evolution 3:260 (2019)



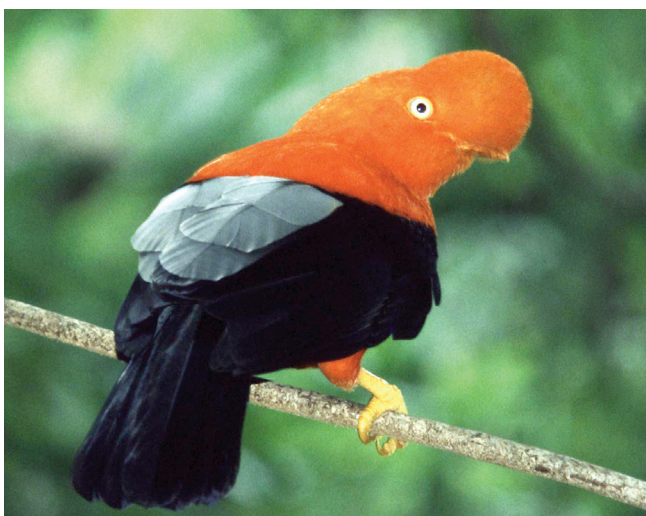
Oilseed rape, one of the four focal crops in the study. (credit: Myrabella, Wikimedia Commons)

CHALLENGE 4: PREDICTING AND MITIGATING ENVIRONMENTAL CHANGE

LAND-SPARING AGRICULTURE SUSTAINS HIGHER LEVELS OF BIRD FUNCTIONAL DIVERSITY THAN LAND SHARING

The ecological impacts of meeting rising demands for food production can potentially be mitigated by two competing land-use strategies: offsetting natural habitats through intensification of existing farmland (land sparing), or elevating biodiversity within the agricultural matrix via the integration of “wildlife-friendly” habitat features (land sharing). However, a key unanswered question is whether sparing or sharing farming would best conserve functional diversity, which can promote ecosystem stability and resilience to future land-use change. Focusing on bird communities in tropical cloud forests of the Colombian Andes, Dr Joe Tobias and colleagues tested the performance of each strategy in conserving functional diversity. They showed that multiple components of avian functional diversity in farmland are positively related to the proximity and extent of natural forest. Using landscape and community simulations, they also showed that land-sparing agriculture conserves greater functional diversity and predicts higher abundance of species supplying key ecological functions than land sharing. The latter also became progressively inferior with increasing isolation from remnant forest. These results suggest low-intensity agriculture is likely to conserve little functional diversity unless large blocks of adjacent natural habitat are also protected, consistent with land sparing. To ensure the retention of functionally diverse ecosystems, we urgently need to implement mechanisms for increasing farmland productivity whilst protecting spared land.

Global Change Biology 25:1576 (2019)



Bird assemblages, including the Andean Cock-of-the-Rock, were used to assess the benefits of different farming practices on biodiversity. (credit: J. Tobias)



CITES AGREEMENT

CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora) is an international agreement between governments. Its aim is to ensure that

international trade in specimens of wild animals and plants does not threaten their survival. GCEE has been working with CITES so that Imperial College London is now registered with them as a Scientific Institution, number GB038, for the exchange of animal and plant samples. Using CITES labels, Imperial can now exchange material between CITES-registered institutions for non-commercial loans, donations and exchanges of legally obtained scientific specimens and samples, which trade is normally regulated by CITES and requires CITES permits. These CITES labels are available from Professor Vincent Savolainen and Dr Alba Herraiz in Life Sciences. This CITES registration will facilitate research on the conservation of globally threatened animal and plant species.

PUBLISHING DEBATES

Academic publishing in its current format is a controversial topic, and many people would like to see changes to make it fairer on the producers and users of academic research. We organised two series of workshops to discuss these controversies. On 22 May, editors from iScience (Cell Publ.) sponsored a workshop on writing for interdisciplinary journals. On 27 November, another workshop was organised by Dr Matteo Fumagalli and colleagues on “Preprints: how they can improve scientific publishing”. Denis Bourguet and Thomas Guillemaud, two of the founders of Peer Community In (PCI), were invited to Silwood Park to discuss their project. PCI applies the principles of peer review to preprints, using a network of invited recommenders to review as yet unpublished articles in repositories. We also heard from Imperial College Library on Plan U and from Prof. Chris Jackson, founder of EarthArXiv at Department of Earth Sciences and Engineering, on his take on the challenges of engaging researchers in Open Science. Both these workshops were well attended by scientists at all career levels.



SILWOOD PARK: AN OUTDOOR LABORATORY FOR THE SCIENCE COMMUNITY AT LARGE

SILWOOD MESOCOSM FACILITY EXPANDS TO 234 MESOCOSMS AND HOST SUCCESSFUL FIRST INTERNATIONAL SUMMER SCHOOL

Mesocosms are becoming increasingly central to a range of ecological disciplines, but in particular for studying the effects of climate change and pollution, which are challenging to measure in natural systems. To match demand, this year Silwood Mesocosm Facility (SMF) has expanded to 234 mesocosms, funded by a £3.7M NERC Large Grant (2015–2019) and a new £2.5M NERC ERCITE Programme grant (2018–2022) entitled “A Novel Framework for Predicting Emerging Chemical Stressor Impacts in Complex Ecosystems” to Prof. G. Woodward, Prof. T. Bell, Dr E. Ransome, and Dr S. Pawar from GCEE. A new PhD studentship was also co-funded by Unilever to Prof. Savolainen, to expand the facility and research on pollutants. This is now the largest freshwater warming and pollution experiment in the world. In 2019, 15 researchers from 5 countries joined SMF experiments and we held the first our first SMF Summer School entitled “Freshwater mesocosms as tools for gauging ecological consequences of climatic and chemical change”, funded by AQUACOSM (Network of Leading European AQUATIC MesoCOSM Facilities, >€10m). This two-week



Silwood Mesocosms Facility is the largest freshwater warming and pollution experiment in the world. (credit: V. Savolainen)

course introduced 15 early-career researchers, based in over 10 countries, to some of the world’s largest field experiments currently underway. Students were taught state-of-the-art techniques in statistical analysis, experimental design, and field sampling techniques, and were introduced to the associated theoretical underpinning and global mesocosm efforts by eminent international experts.

GCEE@SILWOOD: AN OUTREACH PLATFORM OPEN TO LOCAL COMMUNITIES

BUGS! DAY EXPANDS TO INCLUDE BIRDS AND BEASTS WITH ROARING SUCCESS

Sponsored by Public Engagement Grant awarded to Prof. Vincent Savolainen, Imperial’s Silwood Park campus welcomed over 400 visitors to its expanded community outreach day, where visitors got involved with science and activities ranging from pond dipping to face painting as part of the Bugs, Birds and Beasts Day.

This year marked a twist to the usual Bugs! Day with the addition of Birds and Beasts. The aim of Bugs, Birds and Beasts Day is to help visitors engage with and discover the natural world through engaging activities and information stands. This year’s event was organised by GCEE (organising committee: Prof. V. Savolainen, Dr J. Tobias and Dr A. Abzhanov) and sponsored by the Genetics Society.

Insects are key players in natural and agricultural systems given their important roles such as in pollination, recycling nutrients in our soil and acting as a food source for both birds and beasts (and us!).

As part of the new birds display people were in awe of the flying ability of birds as a falcon swooped through the legs of six people during the falconry display. Inside the Jurassic Lab, there was a demonstration of the process of chick



Jurassic Lab with hatching eggs, dinosaur skulls and mosquito larvae to learn about development genetics and phylogenetics. (credit: T. Angus)



Falconry display. (credit: T. Angus)

development. “The children are fascinated by the hatching chicks,” said Jack Murphy, an MSc Conservation Science student at the campus, while placing a chick egg with a window cut out of it to show chick development under a microscope.

Children could discover the local aquatic wildlife by ‘pond dipping’, where they scooped their nets through the small pond located behind the picturesque Manor House and inspected their findings in a tray, before excitedly going over to add the species they had found to the ever-growing list of species that had already been discovered in the pond.

Sean, an MSc Ecological Applications student at the campus, said that the children were mostly finding mayfly larvae, newts and damselflies. Pond dipping proved to be a highly popular activity for another year running, with many children saying it was their highlight of the day, listing every species of aquatic life that they had found in the pond.

Tasty brownie bites were on offer throughout the day. However, although they looked like your typical brownie they were actually crafted with mealworm flour with crickets sprinkled on top. “The brownies are incredible,” said Meghan, while tucking into the insect treat, remarking how gooey and delicious they were and that she would never have known that they contained mealworms if she was not told.

Bugs, Birds and Beasts Day attendees were able to get muddy and create seed bombs, a combination of clay, compost and wildflower seeds, to take home with them at the end of the day to help increase the flowers available for pollinators around their homes. The compost offers nutrients for the seeds and the clay binds the seed bomb together so it can be launched over fences and into inaccessible areas. Eventually the seeds will germinate and grow into flowers for pollinators, such as bees and butterflies.

Although an educational day, Bugs Birds and Beasts Day also connects Silwood Park with the local community, with many members of the public remarking how it was great to

finally see what was going on inside and look around the campus. Butterfly Conservation were also there to promote and encourage people to take part in the Big Butterfly Count to increase the number of counts in the local area.

The day was a success: while being educational, it also inspired and provoked an interest in science among the children and their parents. This was made evident by one child asking their mum if they could come back again the next day!

Professor Vincent Savolainen said: "I am so pleased with the feedback we received, with 71% of attendees describing the event as 'awesome', and already planning to come back next year."

The day ended with a reception for Silwood staff, students and alumni, with an inspiring keynote lecture delivered by Silwood alumnus Prof. Shahid Naeem from Columbia University.

Text modified from L. Keen



Environment DNA experiments in the Marquee. (credit: T. Angus)

GCEE PLAN & ASPIRATIONS 2020–2021

RESEARCH:

- Continue to produce outstanding science-based solutions to help resolve global challenges facing planet earth
- Make a significant contribution to the REF2020 (research outputs and 4 impact case studies currently in preparation)
- Explore potential links with new campus Business Park owners, Newcore, who are planning to turn the Business Park into a Research and Development hub specialising in environmental and climate change research

TEACHING:

- Strengthen our portfolio of Masters courses and increase the number of students that join them, including plans to set up a new multidisciplinary Masters programme in the Agritech area that plays to both our existing strengths and also the emerging funding landscape in the UK and overseas, and to connect our teaching and research evermore closely.
- Develop short, international courses, e.g. Ancient DNA to study of adaptation during Summer 2020, funded by the European Society for Evolutionary Biology.

OUTREACH:

- Rerun Bugs, Birds & Beasts Day and related Alumni Lecture
- Organise a VIP event focusing on ‘science for the living planet’, inviting local VIP(s) from around Ascot and Windsor, and involving other groups and bodies across College, to showcase our activities and vision

ENGAGE WITH US

GCEE is always looking to involve dynamic individuals with innovative ideas and a drive to tackle Grand Challenges.

Why not spend your sabbatical with us? We welcome applications from individuals in any related sector. Furthermore, we are eager to create new working relationships that unite different communities, industry and academia together, and would particularly encourage businesses to contact us.

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