Imperial College London

Georgina Mace Centre for the Living Planet

REPORT 2022
PROFESSOR VINCENT SAVOLAINEN

FOREWORD

The year 2022 marked the 75th anniversary of Imperial College London's acquisition of Silwood Park. The Georgina Mace Centre for the Living Planet (GMC) joined the rest of Silwood to celebrate this milestone with a variety of exciting events and activities, showcasing the unique history, culture and achievements of the campus, as well as looking ahead at what the future might hold.

A key tenet of the GMC is to bring diverse perspectives and expertise together around biodiversity. On 21 July 2022 GMC hosted a panel debate between academics and policy professionals at Silwood Park, as part of its 75th anniversary celebrations. Mr Adam Afriyie, then MP for Windsor, Professor Gideon Henderson, DEFRA Chief Scientist, Professor Kate Jones, Director of the People and Nature Lab at University College London, and Professor Andy Purvis, Research Leader at the Natural History Museum and Research Investigator at Imperial, presented their perspectives on valuing biodiversity's future in a changing world. Imperial's Dr Bonnie Waring then chaired a Question & Answer session with the floor, which was attended by over 100 members of GMC and VIP guests.

Our annual outreach event, '*Bugs, Birds & Beasts* Day', was held on 26 July, and saw a record number of attendees with over 500 nature enthusiasts of all ages attending the event.

On 22 November, the *Sir Ernst Chain Lecture* was delivered by Professor Hopi Hoekstra from Harvard University. The lecture is an annual event held by Imperial's Department of Life Sciences.

Professor Hopi Hoekstra, Harvard University, speaks about 'Nature's Palette' at the Sir Ernst Chain Lecture 2022. © Brendan Foster.

£86.3M
of external grant income*

39
PhD students based at Silwood Park**

** This is the full list of grants won by Silwood Park's Life Sciences staff ending after 1 January 2022 and including subcontracts. It includes £13.1M won by Silwood Park's Life Sciences staff starting after 1 January 2022.*

*** 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.*

Panel discussion at the Silwood 75th Anniversary alumni event.
© Brendan Foster.

Professor Guy Woodward speaks at the Silwood 75 alumni event.
© Brendan Foster.

It commemorates the achievements of renowned British biochemist Sir Ernst Chain, both for humankind and for the founding of the Biochemistry Department, a predecessor of the current Department of Life Sciences. In 2022 we chose an ecological and evolutionary theme to mark the Silwood Park campus 75th anniversary, as Imperial's rural campus is key for these disciplines. Professor Hoekstra is an integrative biologist, whose work brings an evolutionary perspective to the fields of genetics, development, and neuroscience to understand how and why organisms have evolved variation in morphology and behaviour in nature. Her lecture was extremely well received, with over 500 attendees and followed by a networking event and dinner in South Kensington.

This year also saw successful funding applications by the GMC. The centre was allocated a £50k-Cross-Disciplinary Research for Discovery Science Award on '*Envirobotics: Robotic Solutions to Environmental Grand Challenge*'. With co-applicants from the departments of Life Sciences, Engineering, and Medicine, the project developed innovative robotic, deep learning and analytic solutions to tackling the world's most pressing environmental issues at larger scale, and provided a springboard for assembling larger funding applications. The Centre was also awarded a £30k-Policy Support Fund for '*Biosensing novel pathogens in the wild: readiness and policy response*'. This project brought together scientists from various universities but also research councils and government organisations such as DEFRA and APHA to develop a new integrative environment-health framework to understand viral zoonosis transmission. Finally, a new sister centre to the GMC, the '*Centre for the Holobiont*' with headquarters at Silwood Park (PI Professor Tom Bell), was launched on 22 November. This centre is funded by the Leverhulme Trust, which will provide £10m of funding over 10 years to understand the numerous ways by which microbes interact with their hosts, and how this knowledge can be used to address global challenges.

*** *Nature, Nature Communications, Nature Medicine, Nature Physics, Nature Microbiology, Nature Computational Science, Nature Ecology & Evolution, Nature Geosciences, Nature Plants, Nature Reviews, Science and Science Advances*

Finally, we are in the process of revising our research themes (formerly Sustainable Agriculture; Behaviour, Environment and Societies; Global Ecological Networks; Life on The Chemical Planet; Living Sustainably with Wildfires; Pathogens in the Environment; and Target Malaria) to align them more closely with the development of a new vision for Silwood Park as well as with Imperial's 20-year plan.

Professor Vincent Savolainen
Director

Professor Matthew Fisher
Co-Director

The full biodiversity debate can be viewed here:
https://www.youtube.com/watch?v=wkxgKhgQEBk

The Sir Ernst Lecture by Professor Hopi Hoekstra can be viewed there:
https://www.youtube.com/watch?v=r8XLyohZl-Y

The Silwood 75th Anniversary event can be viewed here:
https://www.imperial.ac.uk/silwood-park/75th-anniversary/75th-anniversary-alumni-event/

121
Masters students based at Silwood Park from 23 countries

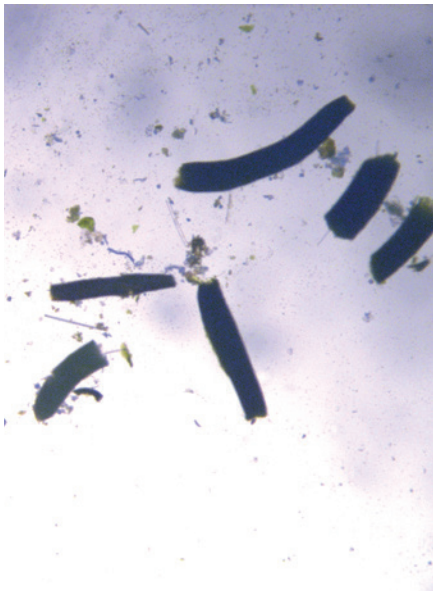
551
peer-reviewed scientific publications, of which 31 were in leading *Nature* and *Science* journals***

A THEORY OF RESISTANCE TO MULTIPLEXED GENE DRIVE DEMONSTRATES THE SIGNIFICANT ROLE OF WEAKLY DELETERIOUS NATURAL GENETIC VARIATION

CRISPR-based gene drives have the potential for controlling natural populations of disease vectors, such as malaria-carrying mosquitoes in sub-Saharan Africa. If successful, they hold promise of significantly reducing the burden of disease and death from malaria and many other vector-borne diseases. A significant challenge to success is the evolution of resistance. Dr Bhavin Khatri and Professor Austin Burt developed a theory of resistance for multiplexed drive, which shows the importance of weakly deleterious naturally occurring genetic variation, whose effect is significantly amplified compared to de novo mutation. These results provide a fundamental basis to estimate how many guide RNAs are required to prevent resistance in the face of natural genetic variation.

PNAS 119:e2200567119, 2022

Close-up of an *Anopheles* mosquito © Target Malaria.



Antarctic krill poo, one of the many components of the ocean biological pump that helps carbon sink quickly to the deep ocean. Each of these faeces is a few mm long. Photo taken by Dr Emma Cavan at the Australian Antarctic Division krill research aquaria.

UNCERTAIN RESPONSE OF OCEAN BIOLOGICAL CARBON EXPORT IN A CHANGING WORLD

The transfer of organic carbon from the upper to the deep ocean by particulate export flux is the starting point for the long-term storage of photosynthetically fixed carbon. This 'biological carbon pump' is a critical component of the global carbon cycle, reducing atmospheric CO_2 levels by ~200 ppm relative to a world without export flux. This carbon flux also fuels the productivity of the mesopelagic zone, including important fisheries. Dr Emma Cavan and colleagues showed that, despite its importance for understanding future ocean carbon cycling, Earth system models disagree on the projected response of the global export flux to climate change, with estimates ranging from −41% to +1.8%. Fundamental constraints to understanding export flux arise because a myriad of interconnected processes make the biological carbon pump challenging to both observe and model. Their synthesis prioritizes the processes likely to be most important to include in modern-day estimates (particle fragmentation and zooplankton vertical migration) and future projections (phytoplankton and particle size spectra and temperature-dependent remineralization) of export. They also identified the observations required to achieve more robust characterization, and hence improved model parameterization, of export flux and thus reduce uncertainties in current and future estimates in the overall cycling of carbon in the ocean.

Nature Geosciences 15:248, 2022

Old-growth forests are important for energy flow and biodiversity.

LOGGED TROPICAL FORESTS HAVE AMPLIFIED AND DIVERSE ECOSYSTEM ENERGETICS

Old-growth tropical forests are widely recognized as being immensely important for their biodiversity and high biomass. Conversely, logged tropical forests are usually characterized as degraded ecosystems. However, whether logging results in a degradation in ecosystem functions is less clear: shifts in the strength and resilience of key ecosystem processes in large suites of species have rarely been assessed in an ecologically integrated and quantitative framework. Professor Rob Ewers and colleagues adopted an ecosystem energetics lens to gain new insight into the impacts of tropical forest disturbance on a key integrative aspect of ecological function: food pathways and community structure of birds and mammals. They focused on a gradient spanning old-growth and logged forests and oil palm plantations in Borneo. In logged forest there was a 2.5-fold increase in total resource consumption by both birds and mammals compared to that in old-growth forests, probably driven by greater resource accessibility and vegetation palatability. Most principal energetic pathways maintained high species diversity and redundancy, implying maintained resilience. Conversion of logged forest into oil palm plantation resulted in the collapse of most energetic pathways. Far from being degraded ecosystems, even heavily logged forests can be vibrant and diverse ecosystems with enhanced levels of ecological function.

Nature 612:707, 2022

Logged forests can also hold significant species diversity.

POPULATION GENOMICS CONFIRMS ACQUISITION OF DRUG-RESISTANT ASPERGILLUS FUMIGATUS INFECTION BY HUMANS FROM THE ENVIRONMENT

Infections caused by the fungal pathogen *Aspergillus fumigatus* are increasingly resistant to first-line azole antifungal drugs. However, despite its clinical importance, little is known about how susceptible patients acquire infection from drug-resistant genotypes in the environment. Professor Matthew Fisher and colleagues presented a population genomic analysis of 218 *A. fumigatus* isolates from across the UK and Ireland (comprising 153 clinical isolates from 143 patients and 65 environmental isolates). First, phylogenomic analysis showed strong genetic structuring into two clades (A and B) with little interclade recombination and the majority of environmental azole resistance found within clade A. Second, they showed occurrences where azole-resistant isolates of near-identical genotypes were obtained from both environmental and clinical sources, indicating with high confidence the infection of patients with resistant isolates transmitted from the environment. Third, genome-wide scans identified selective sweeps across multiple regions indicating a polygenic basis to the trait in some genetic backgrounds. These signatures of positive selection are seen for loci containing the canonical genes encoding fungicide resistance in the ergosterol biosynthetic pathway, while other regions under selection have no defined function. Lastly, pan-genome analysis identified genes linked to azole resistance and previously unknown resistance mechanisms. Understanding the environmental drivers and genetic basis of evolving fungal drug resistance needs urgent attention, especially in light of increasing numbers of patients with severe viral respiratory tract infections who are susceptible to opportunistic fungal superinfections.

Nature Microbiology 7:663, 2022

Food security depends on modern agricultural methods, however emerging fungicide resistance in the environment presents a one-health dilemma as pathogenic fungi such as the ubiquitous mould *Aspergillus fumigatus* evolve resistance to modern antifungal drugs. © Matthew Fisher, 2023.

Preparing a transition to zero pollution is an important challenge tackled by Imperial researchers.

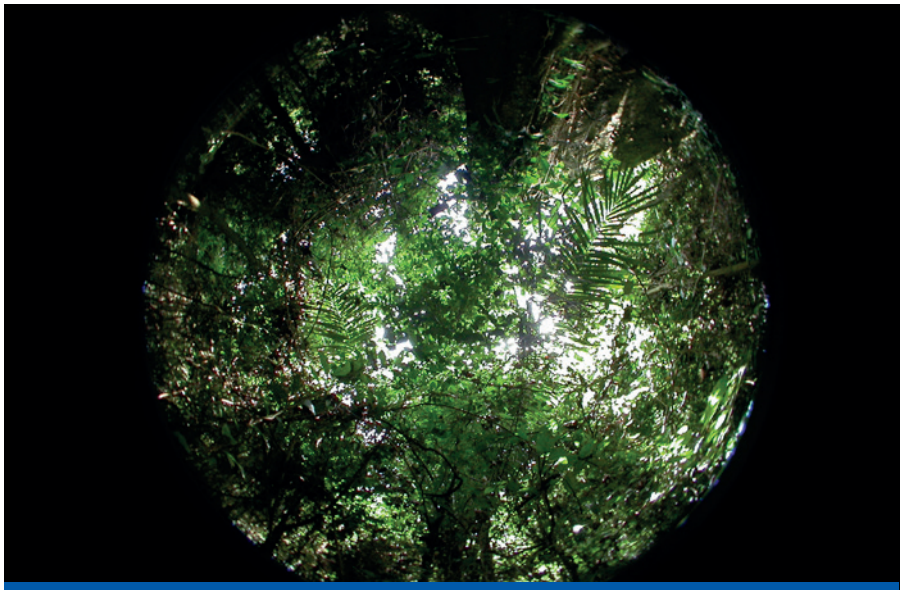
METABOLIC PLASTICITY CAN AMPLIFY ECOSYSTEM RESPONSES TO GLOBAL WARMING

Organisms have the capacity to alter their physiological response to warming through acclimation or adaptation, but the consequence of this metabolic plasticity for energy flow through food webs is currently unknown, and a generalisable framework does not exist for modelling its ecosystem-level effects. Professors Samraat Pawar, Guy Woodward, and colleagues showed, using temperature-controlled experiments on stream invertebrates from a natural thermal gradient, that the ability of organisms to raise their metabolic rate following chronic exposure to warming decreases with increasing body size. Chronic exposure to higher temperatures also increased the acute thermal sensitivity of whole-organismal metabolic rate, independent of body size. A mathematical model parameterised with these findings showed that metabolic plasticity could account for 60% higher ecosystem energy flux with just +2 °C of warming than a traditional model based on ecological metabolic theory. This could explain why long-term warming amplifies ecosystem respiration rates through time in recent mesocosm experiments, and highlights the need to embed metabolic plasticity in predictive models of global warming impacts on ecosystems.

Nature Communications 13:2161, 2022

Wildfires are increasing worldwide © EU Civil Protection and Humanitarian Aid.

CO_2 FERTILIZATION OF TERRESTRIAL PHOTOSYNTHESIS INFERRED FROM SITE TO GLOBAL SCALES



Hemispherical photograph of the tree canopy at a tropical rain forest site in Ghana. Here, and probably in many such ecosystems, the standard satellite data products underestimate the density of the tree cover (used by models to calculate primary production) because there is 100% cloud cover every day. © Huanyuan Zhang.

The magnitude of the CO_2 fertilization effect on terrestrial photosynthesis is uncertain because it is not directly observed and is subject to confounding effects of climatic variability. Professor Colin Prentice and colleagues applied three well-established eco-evolutionary optimality theories of gas exchange and photosynthesis, constraining the main processes of CO_2 fertilization using measurable variables. Using this framework, they provided robust observationally inferred evidence that a strong CO_2 fertilization effect was detectable in globally distributed eddy covariance networks. Applying their method to upscale photosynthesis globally, they found that the magnitude of the CO_2 fertilization effect was comparable to its *in situ* counterpart but highlighted the potential for substantial underestimation of this effect in tropical forests for many reflectance-based satellite photosynthesis products.

PNAS 119:e2115627119, 2022

SILWOOD PARK

AN OUTDOOR LABORATORY FOR THE SCIENCE COMMUNITY AT LARGE

In 2022 the grounds of Silwood Park were the arena for training courses and research projects for more than 500 students in the departments of Life Sciences, Civil Engineering, Aeronautics, and Robotics. Microplastics pollution, soil carbon storage, disease vectors and soil acoustic monitoring were the themes of just a few of the 25 fascinating undergraduate, masters and PhD thesis projects that took advantage of the long-term experiments and diverse ecosystems and resources the campus fields have to offer. 2022 was also the 30th anniversary of Silwood Park's longest running project, the Nash's Field Experiments. Nash's Field plot, which is part of The Ecological Continuity Trust (ECT) and the European Join Program on Agricultural Soil (EPJ soil), has been used by researchers from a broad range of disciplines to assess the impact of common agricultural practices on vegetation dynamics, soil bacterial communities and the cycling and storage of soil nutrients. It has also been useful to delineate management practices to control agricultural pests and to test monitoring methods using new technologies. For the College, the experiment has been a key resource to form a new generation of scientists, through undergraduate and graduate courses and student final research projects. In 2022 alone, three of the six scientific publications that resulted from work in Silwood Park field experiments studied the Nash's Field plots, showing the continued relevance of the experiment today.

Silwood Park Campus © Dan Weill.

GEORGINA MACE CENTRE PLAN & ASPIRATIONS 2023–2024

RESEARCH:

- Continue to produce outstanding science-based solutions to help resolve global challenges facing Planet Earth.
- Explore potential links with organisations close to the campus' and GMC's visions, including NewCore and CABI.

TEACHING:

- Strengthen but streamline our portfolio of Masters courses, and connect our teaching and research evermore closely.

OUTREACH:

- Organise Bugs, Birds & Beasts Day (25 July 2023).

The annual Bugs, Birds and Beasts Day returned to Imperial's Silwood Park campus on 25 July. © Brendan Foster Photography.

ENGAGE WITH US

The Georgina Mace Centre for the Living Planet is always looking to involve dynamic individuals with innovative ideas and a drive to tackle environmental 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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