Imperial College London

Georgina Mace Centre for the Living Planet

REPORT 2021
PROFESSOR VINCENT SAVOLAINEN

FOREWORD

This is the first annual report of the Georgina Mace Centre for the Living Planet, which was launched on 31 August 2021 at Silwood Park. The Centre is committed to producing science-based solutions to environmental problems.

The Georgina Mace Centre for the Living Planet is dedicated to Professor Dame Georgina Mace FRS in remembrance of her commitment to improving the environment for all wildlife. On 19 September 2020, Professor Dame Georgina passed away at the age of 67, leaving her legacy as an inspiration to those who observed and believed in her vision for environmental improvement.

Academics and family gathered for the Centre launch, which included a series of presentations to celebrate Professor Mace and the unveiling of a plaque in honour of her legacy.

To kickstart the day at Silwood Park, the Bugs, Birds and Beasts Day took place in which local residents and families gathered to explore the anatomy of plants, animals and bugs. This was a remarkable return for this much-loved event, being the first in-person event to be held at Imperial after the pandemic.

The launch of the Centre started with a talk from Professor Sir John Lawton, who was previously Director of the NERC Centre for Population Biology at Imperial. Professor Lawton discussed Professor Mace's influence and renowned scientific endeavours such as building new habitats for wildlife in order to target nature conservation. Professor Andy Purvis, Research Leader at the Natural History Museum, discussed her early career and establishment of the IUCN Red List index and the Living Planet Index. Professor Purvis said that her work has defined the way

Professor Mary Ryan, Interim Vice-Provost (Research and Enterprise), speaks at the Centre Launch

£78M
of external grant income*

49
enrolled PhD students excluding students on interruption (4) and awaiting viva/award (4)**

**This is the full list of grants won by Silwood Park's Life Sciences staff ending after 1 January 2021 and including subcontracts. It includes £ 2,462,806 M won by Silwood Park's Life Sciences staff starting after 1 January 2021.*

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

Professor Mary Ryan with Professor Sir John Lawton FRS and Lady Dorothy Lawton

researchers view the relationship between nature, people and economies. Professor Mace's former colleague Kate Jones, who is now Professor of Ecology and Biodiversity at University College London offered a few words about her experience meeting Professor Mace and how their relationship encouraged her academic development.

To conclude the dedications, Professor Mace's husband, Rod Evans, discussed his relationship with her and their family alongside her academic achievements.

Following the unveiling of the plaque, attendees were given the chance to explore different projects that researchers at the new Centre are undertaking in order to carry on Georgina's legacy. Seven themes were put forward to highlight the research that the new centre is conducting: (i) Agroecological Research for Sustainable Land Use; (ii) Behaviour, Environment and Societies; (iii) Global Ecological Networks; (iv) Life on the Chemical Planet; (v) Living Sustainable with Wildfires; (vi) Pathogens in the Environment; and (vii) Target Malaria.

The full report of the event can be found at https://www.imperial.ac.uk/news/229293/georgina-mace-centre-living-planet-launches/

Professor Vincent Savolainen
Director

Professor Matthew Fisher
Co-Director

122
Masters students from 24 countries

255
peer-reviewed scientific publications, of which 16 were in leading Nature and Science journals***

5
Outreach events****

Professor Vincent Savolainen and Professor Sir John Lawton FRS unveil the plaque in honour of Georgina Mace's legacy

****Nature, Nature Communications, Nature Ecology & Evolution, Nature Human Behaviour, Nature Reviews Microbiology, Nature Sustainability, Science, Science Advances.*

*****Launch of the Centre; Birds, Bugs, Birds and Beasts Day; Under 18 Work Experience – School Students 2021; Sunninghill and Ascot Green corridor project (ongoing); Fieldwork in Spring and Summer 2021 with Master students (results presented in the Annual Assembly on March 17 2022.)*

Professor Dame Georgina Mace FRS

Pond dipping at the Bugs, Birds & Beasts Day 2021

RESEARCH HIGHLIGHTS

RESEARCH THEME 1:
AGROECOLOGICAL RESEARCH FOR SUSTAINABLE LAND USE

RECOVERY OF LOGGED FOREST FRAGMENTS IN A HUMAN-MODIFIED TROPICAL LANDSCAPE DURING THE 2015-16 EL NIÑO

The past 40 years in Southeast Asia have seen about 50% of lowland rainforests converted to oil palm and other plantations, and much of the remaining forest heavily logged. Little is known about how fragmentation influences recovery and whether climate change will hamper restoration. Robert Ewers and colleagues used repeat airborne LiDAR surveys spanning the hot and dry 2015-16 El Niño Southern Oscillation (ENSO) event to measure canopy height growth across 3,300 ha of regenerating tropical forests spanning a logging intensity gradient in Malaysian Borneo. They show that the drought led to increased leaf shedding and branch fall. Short forest, regenerating after heavy logging, continued to grow despite higher evaporative demand, except when it was located close to oil palm plantations. Edge effects from the plantations extended over 300 metres into the forests. Forest growth on hilltops and slopes was particularly impacted by the combination of fragmentation and drought, but even riparian forests located within 40 m of oil palm plantations lost canopy height during the drought. Their results indicate that small patches of logged forest within plantation landscapes will be slow to recover, particularly as ENSO events are becoming more frequent.

Nature Communications 12:1526, 2021

Regenerating forest in Borneo following multiple rounds of logging (credit: SAFE Project)

RESEARCH THEME 2:
BEHAVIOUR, ENVIRONMENT AND SOCIETIES

THE NUTRITIONAL PROFILES OF FIVE IMPORTANT EDIBLE INSECT SPECIES FROM WEST AFRICA—AN ANALYTICAL AND LITERATURE SYNTHESIS

Undernutrition is a prevalent, serious, and growing concern, particularly in developing countries. Entomophagy—the human consumption of edible insects, is a historical and culturally established practice in many regions. Increasing consumption of nutritious insect meal is a possible combative strategy and can promote sustainable food security. However, the nutritional literature frequently lacks consensus, with interspecific differences in the nutrient content of edible insects generally being poorly resolved. C (Tilly) Collins, Ben Roberts and Vincent Savolainen presented full proximate and fatty acid profiles for five edible insect species of socio-economic importance in West Africa: *Hermetia illucens* (black soldier fly), *Musca domestica* (house fly), *Rhynchophorus phoenicis* (African palm weevil), *Cirina butyrospermi* (shea tree caterpillar), and *Macrotermes bellicosus* (African termite). These original profiles, which can be used in future research, are combined with literature-derived proximate, fatty acid, and amino acid profiles to analyse interspecific differences in nutrient content. Interspecific differences in ash (minerals), crude protein, and crude fat contents were substantial. Highest ash content was found in *H. illucens* and *M. domestica* (~10 and 7.5% of dry matter, respectively), highest crude protein was found in *C. butyrospermi* and *M. domestica* (~60% of dry matter), whilst highest crude fat was found in *R. phoenicis* (~55% of dry matter). The fatty acid profile of *H. illucens* was differentiated from the other four species, forming its own cluster in a principal component analysis characterized by high saturated fatty acid content. *Cirina butyrospermi* had by far the highest poly-unsaturated fatty acid content at around 35% of its total fatty acids, with α-linolenic acid particularly represented. Amino acid analyses revealed that all five species sufficiently met human essential amino acid requirements, although *C. butyrospermi* was slightly limited in leucine and methionine content. The nutritional profiles of these five edible insect species compare favourably to beef and can meet human requirements, promoting entomophagy's utility in combatting undernutrition. In particular, *C. butyrospermi* may provide a source of essential poly-unsaturated fatty acids, bringing many health benefits. This, along with its high protein content, indicates that this species is worthy of more attention in the nutritional literature, which has thus-far been lacking.

Edible caterpillars for sale in a West African market. Consumption of insect protein is a nutritious and culturally established practice with great promise in the field of sustainable food security (credit: T Collins)

a) Freshwater Biological Association Mesoscosm Facility, Dorset (20 pond array)

b) Silwood Park Mesocosms - Warming and Pollution Experiments (96 pond array in view; >300 mesocosms on site in total)

RESEARCH THEME 3:
GLOBAL ECOLOGICAL NETWORKS

WARMING IMPAIRS TROPHIC TRANSFER EFFICIENCY IN A LONG-TERM FIELD EXPERIMENT

In ecosystems, the efficiency of energy transfer from resources to consumers determines the biomass structure of food webs. As a general rule, about 10% of the energy produced in one trophic level makes it up to the next. Recent theory suggests that this energy transfer could be further constrained if rising temperatures increase metabolic growth costs, although experimental confirmation in whole ecosystems is lacking. Guy Woodward and colleagues quantified nitrogen transfer efficiency—a proxy for overall energy transfer—in freshwater plankton in artificial ponds that have been exposed to seven years of experimental warming. We provide direct experimental evidence that, relative to ambient conditions, 4 °C of warming can decrease trophic transfer efficiency by up to 56%. In addition, the biomass of both phytoplankton and zooplankton was lower in the warmed ponds, which indicates major shifts in energy uptake, transformation and transfer. These findings reconcile observed warming-driven changes in individual-level growth costs and in carbon-use efficiency across diverse taxa with increases in the ratio of total respiration to gross primary production at the ecosystem level. Our results imply that an increasing proportion of the carbon fixed by photosynthesis will be lost to the atmosphere as the planet warms, impairing energy flux through food chains, which will have negative implications for larger consumers and for the functioning of entire ecosystems.

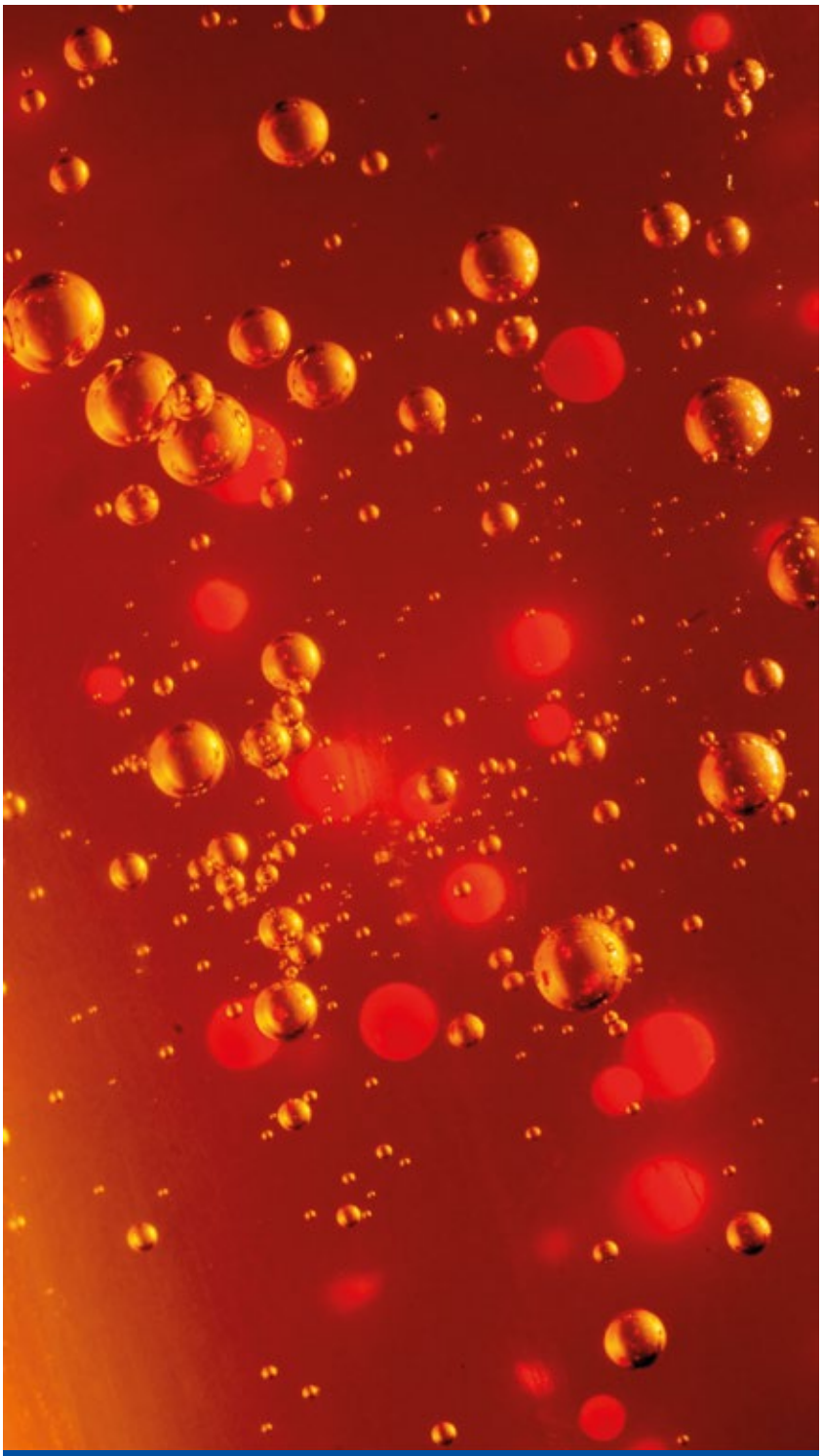
Nature 592:76, 2021

RESEARCH THEME 4:
LIFE ON THE CHEMICAL PLANET

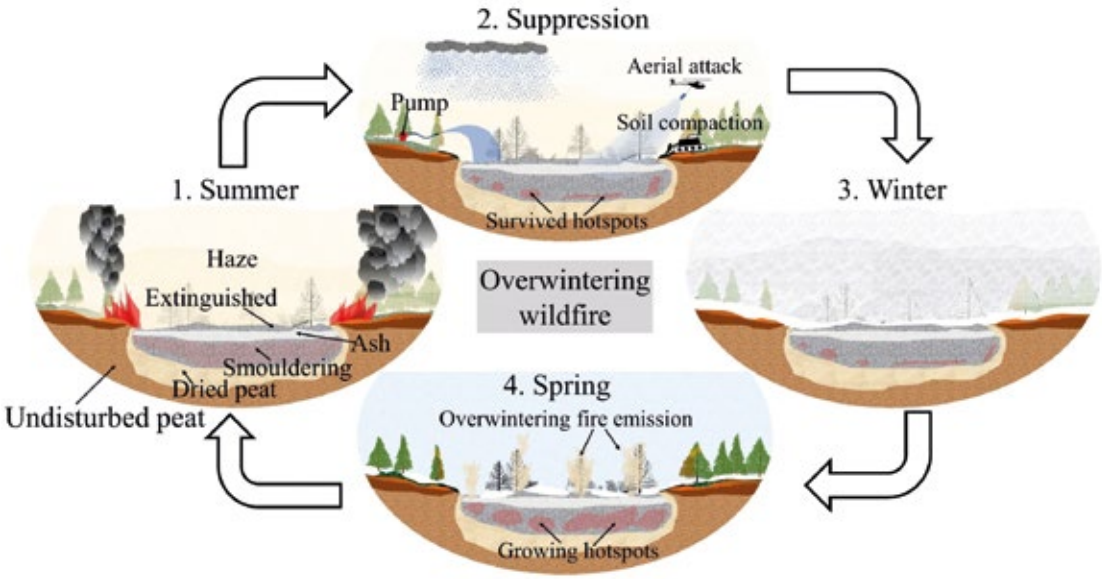
EVALUATING ALTERNATIVES TO PLASTIC MICROBEADS IN COSMETICS

In our haste to ban or regulate unsustainable and environmentally damaging materials and chemicals, we may overlook dangers posed by their substitutes. In light of the scientific evidence regarding the fate, persistence and toxicity of microplastics in the marine environment, many countries have banned the sale of rinse-off cosmetics containing plastic microbeads to prevent their release to the environment. However, the wider lifetime environmental impacts of the potential substitutes have not been considered, and care must be taken so that the environmental costs of using them do not potentially outweigh the benefits resulting from the bans. Nikolaos Voulvoulis and colleagues used life cycle assessment to compare the environmental performance of a wide range of potential alternatives. The study investigates the quantities of these materials required and the human health and environmental impacts of their manufacture, transport and inclusion in cosmetics. We highlight that the long-term environmental and human health effects of their disposal are unknown and are thus excluded from the life cycle assessment. In support of the responsible replacement of plastic microbeads in cosmetics, we identify several alternatives that will perform better, as well as substitutes that could pose additional risks and have undesirable effects.

Nature Sustainability 4:366, 2021



Environmentally friendly cosmetics - alternatives to plastic microbeads in body scrubs (credit: Mark Dunn)



Smouldering wildfires are emerging as a global concern because they cause extensive air pollution, emit very large amounts of carbon, are difficult to detect and suppress, and could accelerate climate change (credit: X Huang and G Rein, 2021)

RESEARCH THEME 5:
LIVING SUSTAINABLY WITH WILDFIRES

SMOULDERING WILDFIRES IN PEATLANDS, FORESTS AND THE ARCTIC: CHALLENGES AND PERSPECTIVES

Wildfires can be divided into two types, flaming or smouldering, depending on the dominant combustion processes. Both types are present in most wildfires, and despite being fundamentally different in chemical and physical terms, one transitions to the other. Traditionally, science has focused on flames, while smouldering is often misinterpreted. But smouldering wildfires are emerging as a global concern because they cause extensive air pollution, emit very large amounts of carbon, are difficult to detect and suppress, and could accelerate climate change. Central to the topic are smouldering peat fires that lead to the largest fires on Earth. Smouldering also dominates the residual burning after flames have died out and firebrand ignition. Finally, smouldering is an important part of Arctic wildfires, which are increasing in frequency. Guillermo Rein and Xinyan Huang presented a scientific overview of smouldering wildfires, the associated environmental and health issues, including climate change, and the challenges in prevention and mitigation.

Current Opinion in Environmental Science & Health 24:100296, 2021

DRY CORRIDORS OPENED BY FIRE AND LOW CO2 IN AMAZONIAN RAINFOREST DURING THE LAST GLACIAL MAXIMUM

The dynamics of Amazonian rainforest over long timescales connect closely to its rich biodiversity. While palaeoecological studies have suggested its stability through the Pleistocene, palaeontological evidence indicates the past existence of major expansions of savannah and grassland. Professor Colin Prentice and colleagues have integrated modelling evidence for a grassier Neotropics during the Last Glacial Maximum, congruent with palaeoecological and biological studies. Vegetation reconstructions were generated using the land processes and exchanges model, driven by model reconstructions of Last Glacial Maximum climate, and compared with palynological data. A factorial experiment was performed to quantify the impacts of fire and low CO_2 on vegetation and model–data agreement. Fire and low CO_2 both individually and interactively induced widespread expansion of savannah and grassland biomes while improving model–data agreement. The interactive effects of fire and low CO_2 induced the greatest 'savannafication' of the Neotropics, providing integrated evidence for a number of biogeographically relevant open vegetation formations, including two dry corridors (paths of savannah and grassland through and around Amazonia that facilitated major dispersal and evolutionary diversification events). Our results show a bimodality in tree cover that was driven by fire and further enhanced by 'CO_2 deprivation', which suggests biome instability in this region of climate space.

Nature Geoscience 14:578, 2021

Fire in the savanna (cerrado) of Brazil (credit: Imma Oliveras)

RESEARCH THEME 6: PATHOGENS IN THE ENVIRONMENT

NO EVIDENCE FOR ENVIRONMENTAL TRANSMISSION RISK OF SARS-COV-2 IN THE UK'S LARGEST URBAN RIVER SYSTEM: LONDON AS A CASE STUDY

The presence of SARS-CoV-2 in untreated sewage has been confirmed in many countries but its incidence and infection risk in contaminated freshwaters is still poorly understood. The River Thames in the UK receives untreated sewage from 57 Combined Sewer Overflows (CSOs), with many discharging dozens of times per year. Emma Ransome, Thomas Bell, Guy Woodward and Vincent Savolainen investigated if such discharges provide a pathway for environmental transmission of SARS-CoV-2. Samples of wastewater, surface water, and sediment collected close to six CSOs on the River Thames were assayed over 8 months for SARS-CoV-2 RNA and infectious virus. Bivalves were sampled as sentinel species of viral bioaccumulation. Sediment and water samples from the Danube and Sava rivers in Serbia, where raw sewage is also discharged in high volumes, were assayed as a positive control. They found no evidence of SARS-CoV-2 RNA or infectious virus in UK samples, in contrast to RNA positive water and sediment samples from Serbia. Furthermore, we show that infectious SARS-CoV-2 inoculum is stable in Thames water and sediment for ‹ 3 days, while RNA remained detectable for at least seven days. This indicates that dilution of wastewater likely limits environmental transmission, and that infectivity should be embedded in future risk assessments of pathogen spillover.

https://www.medrxiv.org/content/10.1101/2022.03.16.22272465v1

Collection of sediment and water to search for SARS-Cov-2 in sewage outflows (credit: S. Jones)

Small-hold mixed-species farms can increase zoonotic disease emergence risks. However, the alternatives may not fare much better — for instance larger scale, more industrial food production and trade may be more biosecure but still fail to eliminate disease emergence risks and can have larger negative nutritional, ecosystem or climate impacts (credit: M. Fisher)

EMERGING INFECTIONS AND THE INTEGRATIVE ENVIRONMENT-HEALTH SCIENCES: THE ROAD AHEAD

Matthew Fisher and Kris Murray discussed the integrative environment-health sciences including One Health, Conservation Medicine, EcoHealth and Planetary Health, and which embody the transdisciplinary synthesis needed to understand the multitude of factors that underpin emerging infections and their management. Future successes in confronting and resolving the complex causal basis of disease emergence to generate robust, systems-oriented risk reduction strategies that preserve both human health as well as promoting sustainable futures represent the 'Moon Shot' for the integrative environment-health sciences.

Nature Reviews Microbiology 19:133, 2021

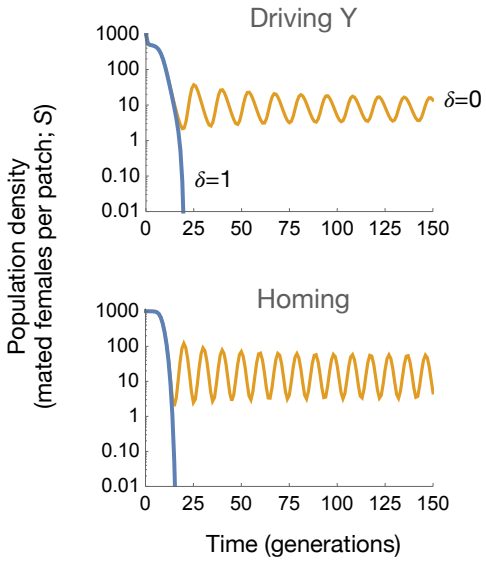
RESEARCH THEME 7:
TARGET MALARIA

GENE DRIVES AND POPULATION PERSISTENCE VS ELIMINATION: THE IMPACT OF SPATIAL STRUCTURE AND INBREEDING AT LOW DENSITY

Synthetic gene drive constructs are being developed to control disease vectors, invasive species, and other pest species. In a well-mixed random mating population a sufficiently strong gene drive is expected to eliminate a target population, but it is not clear whether the same is true when spatial processes play a role. In species with an appropriate biology it is possible that drive-induced reductions in density might lead to increased inbreeding, reducing the efficacy of drive, eventually leading to suppression rather than elimination, regardless of how strong the drive is. To investigate this question Austin Burt and PJ Beaghton analysed a series of explicitly solvable stochastic models considering a range of scenarios for the relative timing of mating, reproduction, and dispersal and analyse the impact of two different types of gene drive, a Driving Y chromosome and a homing construct targeting an essential gene. They found in all cases a sufficiently strong Driving Y will go to fixation and the population will be eliminated, except in the one life history scenario (reproduction and mating in patches followed by dispersal) where low density leads to increased inbreeding, in which case the population persists indefinitely, tending to either a stable equilibrium or a limit cycle. These dynamics arise because Driving Y males have reduced mating success, particularly at low densities, due to having fewer sisters to mate with. Increased inbreeding at low densities can also prevent a homing construct from eliminating a population. For both types of drive, if there is strong inbreeding depression, then the population cannot be rescued by inbreeding and it is eliminated. These results highlight the potentially critical role that low-density-induced inbreeding and inbreeding depression (and, by extension, other sources of Allee effects) can have on the eventual impact of a gene drive on a target population.

https://www.biorxiv.org/content/10.1101/2021.11.11.468225v2

Swarm sampling at dusk at a project site in Uganda © Target Malaria



Mathematical modelling shows that the presence or absence of effective inbreeding at low densities can male the difference between whether a gene drive eliminates a population or merely suppresses it. We show this for two different types of gene drive that are under development, a Driving Y chromosome and a Homing element. In both cases if inbred progeny die (i.e., there is strong inbreeding depression), then the drive can eliminate the population (blue line), whereas if inbred progeny are completely normal (no inbreeding depression) then the population is suppressed but not eliminated (orange line).

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

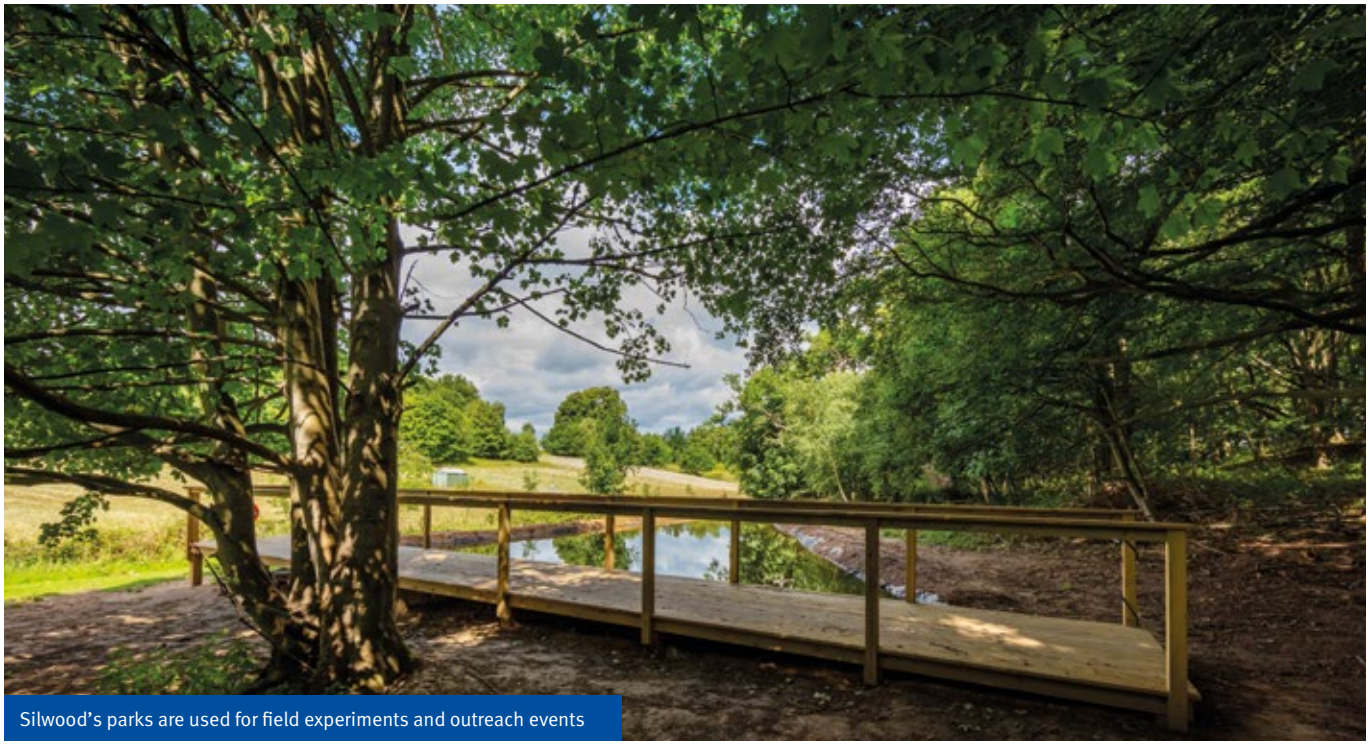
EXPERIENCING THE COVID PANDEMIC HAS HELPED US REFLECT ON THE IMPORTANCE OF SILWOOD PARK FOR RESEARCH AND EDUCATION PROGRAMMES AT IMPERIAL AND THE SCIENTIFIC COMMUNITY IN GENERAL.

Outdoor research and face-to-face teaching on campus was not only achieved during the pandemic but grew during 2021 relative to previous years. Now our fields host twelve long term field experiments and monitoring sites, numerous master and PhD projects, and a new apiary.

Four of our field experiments are part of collaborative research networks that aim to address a broad range of ecological questions replicating small experiments that are distributed at a global scale.

In 2021 we learnt from publications from Silwood long-term experiments about the evolution of reproductive plasticity in blue tits; the effect of rhododendron; an introduced invasive plant, in woodland regeneration; the use remote sensing for studying plant diversity and phenology in grasslands, and the effect of farming practices in the rise of unwanted weeds. Silwood fields were also used for teaching, not only for Life Sciences courses but also for students in the Department of Aeronautics and the Faculty of Medicine.

Blue tit eggs in nest box part of the breeding ecology long-term study of this bird species at Silwood Park (credit: C. Estrada Montes)



Silwood's parks are used for field experiments and outreach events

Imperial College London

THE GEORGINA MACE CENTRE FOR THE LIVING PLANET

Bugs, Birds and Beasts Day

at Silwood Park

Returns 26 July 2022

SAVE THE DATE!

GEORGINA MACE CENTRE PLAN & ASPIRATIONS 2022–2023

RESEARCH:

- Continue to produce outstanding science-based solutions to help resolve global challenges facing Planet Earth
- Explore potential links with new campus Business Park owners, Newcore, who are developing the Business Park into a Research and Development hub specialising in environmental and climate change research
- Upgrade and refurbish the Georgina Mace Centre building (ex NERC Centre for Population Biology) to accommodate workshop areas and students/postdocs desk open space

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 in the Centre's areas of expertise

OUTREACH:

- Organise events around the Diamond 75th Celebrations of Silwood Park, including the Georgina Mace Centre Biodiversity Debate (link) and Bugs, Birds & Beasts Day (26 July 2022)

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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