IMPERIAL

Georgina Mace Centre for the Living Planet

Report 2023

Professor Vincent Savolainen

Foreword

With its headquarters at Imperial College London's Silwood Park Campus, the Georgina Mace Centre for the Living Planet unites scholars from across Imperial and the UK as a whole. A diverse team of experts are based here, poised to confront the planet's most pressing environmental dilemmas.

2023 heralded a significant milestone for the Centre, with the formation of a vital partnership with CABI, an international not-for-profit organisation with over 500 staff from more than 20 locations around the world. CABI provides information and applies scientific expertise to solve problems in agriculture and the environment, and will relocate its UK research facilities to Silwood Park next year.

The new partnership will foster collaborative research and teaching endeavours on key environmental challenges such as fragile ecosystems, sustainable agriculture, and biodiversity threatened by climate change. With shared scientific interests, both institutions foresee innovative solutions to global sustainability issues. This collaboration builds upon historical ties between the two organisations and emphasises the importance of interdisciplinary approaches in addressing pressing environmental concerns.

Our annual outreach event, *'Bugs, Birds and Beasts day'*, was also held on 25 July, with 500 nature enthusiasts of all ages attending the event.

Professor Vincent Savolainen
Director

Professor Matthew Fisher
Co-Director

Daniel Elger, CABI CEO and Professor Richard Craster, Dean of Imperial's Faculty of Natural Sciences, sign the Memorandum of Understanding.

Key indicators

£ 86.3 M
of external grant income*

36 PhD students
based at Silwood Park**

85 Masters students
based at Silwood Park from 16 countries

526 peer-reviewed scientific publications,
of which over 50 were in leading *Nature* and *Science* journals***

2 visits
by the 1st Sunningdale Beaver Club (Insects and pond dipping)

3 A level students
Work Experience placements

Master's students visited St Michael's Primary School, during
Science Week
to dissect owl pellets

*This is the full list of grants won by Silwood Park's Life Sciences staff ending after 1 January 2023 and including subcontracts. It includes £ 11.7 M won by Silwood Park's Life Sciences staff starting after 1 January 2023.

** PhD Students enrolled through the Centre for Doctoral Training in Quantitative Method in Ecology and Evolution and Doctoral Training Programme in Science and Solution for a Changing Planet, and other programmes

***Nature, Nature Communications, Nature Biotechnology, Nature Cardiovascular Research, Nature Climate Change, Nature Communications, Nature Ecology & Evolution, Nature Food, Nature Medicine, Nature Microbiology, Nature Reviews, Nature Sustainability, Nature Computation and Applications, Science and Science Advances

Research highlights

Release from sexual selection leads to rapid genome-wide evolution in *Aedes aegypti*

The yellow fever mosquito, *Aedes aegypti*, mates in flight as part of ephemeral aggregations termed swarms. Swarms contain many more males than females, and males are thought to be subject to intense sexual selection.However, which male traits are involved in mating success and the genetic basis of these traits remains unclear. Dr Lauren Cator and colleagues used an experimental evolution approach to measure genome-wide responses of *Ae. aegypti* evolved in the presence and absence of sexual selection. These data revealed for the first time how sexual selection shapes the genome of this important species. They found that populations evolved under sexual selection retained greater genetic similarity to the ancestral population and a higher effective population size than populations evolving without sexual selection. When they compared evolutionary regimes, they found that genes associated with chemosensation responded rapidly to the elimination of sexual selection. Several mosquito control technologies involve the release of males from captive populations into the wild. For these interventions to work, a released male must compete against wild males to successfully inseminate a female. Their results suggest that maintaining the intensity of sexual selection in captive populations used in mass-releases is important for sustaining both male competitive ability and overall genetic similarity to field populations.

***Current Biology* 10:1351 (2023)**

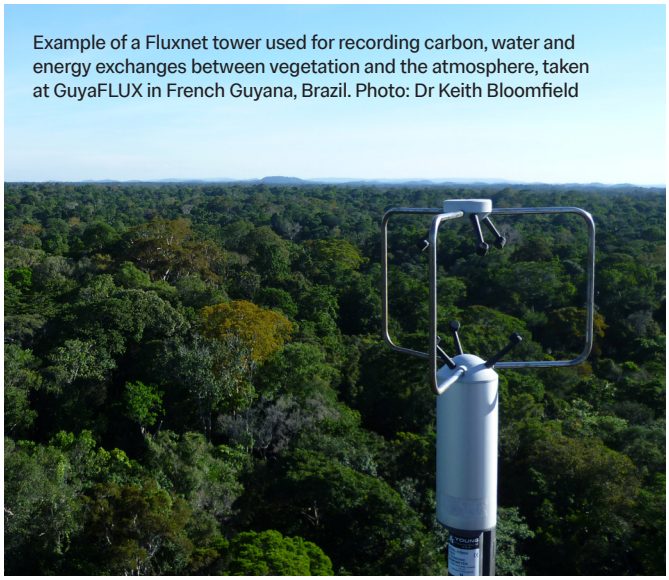
Female Aedes aegypti mosquito which transmits viruses such as those that cause Yellow Fever, dengue, and Zika virus. Photo: Alex Wild (alexanderwild.com)

An ancient river landscape preserved beneath the East Antarctic Ice Sheet

The East Antarctic Ice Sheet (EAIS) has its origins ca. 34 million years ago. Since then, the impact of climate change and past fluctuations in the EAIS margin has been reflected in periods of extensive vs. restricted ice cover and the modification of much of the Antarctic landscape. Resolving processes of landscape evolution is therefore critical for establishing ice sheet history, but it is rare to find unmodified landscapes that record past ice conditions. Prof. Martin Siegert and colleagues discovered an extensive relic pre-glacial landscape preserved beneath the central EAIS despite millions of years of ice cover. The landscape was formed by rivers prior to ice sheet build-up but later modified by local glaciation before being dissected by outlet glaciers at the margin of a restricted ice sheet. Preservation of the relic surfaces indicates an absence of significant warm-based ice throughout their history, suggesting any transitions between restricted and expanded ice were rapid.

***Nature Communications* 14: 6507 (2023)**

Deep fieldwork in West Antarctica, surveying the Institute Ice Stream using the British Antarctic Survey's airborne geophysical platform. Funded by NERC. Photo: Neil Ross



Example of a Fluxnet tower used for recording carbon, water and energy exchanges between vegetation and the atmosphere, taken at GuyaFLUX in French Guyana, Brazil. Photo: Dr Keith Bloomfield

A constraint on historic growth in global photosynthesis due to rising CO_2

Theory predicts that rising CO_2 increases global photosynthesis, a process known as CO_2 fertilization, and that this is responsible for much of the current terrestrial carbon sink. The estimated magnitude of the historic CO_2 fertilization, however, differs by an order of magnitude between long-term proxies, remote sensing-based estimates, and terrestrial biosphere models. Prof. Colin Prentice and colleagues constrained the likely historic effect of CO_2 on global photosynthesis by combining terrestrial biosphere models, ecological optimality theory, remote sensing approaches and an emergent constraint based on global carbon budget estimates. Their analysis suggests that CO_2 fertilization increased global annual terrestrial photosynthesis by 13.5 ± 3.5% or 15.9 ± 2.9 PgC (mean ± s.d.) between 1981 and 2020. Their results help resolve conflicting estimates of the historic sensitivity of global terrestrial photosynthesis to CO_2 and highlight the large impact anthropogenic emissions have had on ecosystems worldwide.

Nature Climate Change **13:1376 (2023)**

Chronic exposure to environmental temperature attenuates the thermal sensitivity of salmonids

Metabolism, the biological processing of energy and materials, scales predictably with temperature and body size. Temperature effects on metabolism are normally studied via acute exposures, which overlooks the capacity for organisms to moderate their metabolism following chronic exposure to warming. Prof. Guy Woodward and colleagues conducted respirometry assays in situ and after transplanting salmonid fish among different streams to disentangle the effects of chronic and acute thermal exposure. They found a clear temperature dependence of metabolism for the transplants, but not the in-situ assays, indicating that chronic exposure to warming can attenuate salmonid thermal sensitivity. A bioenergetic model accurately captured the presence of fish in warmer streams when accounting for chronic exposure, whereas it incorrectly predicted their local extinction with warming when incorporating the acute temperature dependence of metabolism. This highlights the need to incorporate the potential for thermal acclimation or adaptation when forecasting the consequences of global warming on ecosystems.

Nature Communications **14: 8309 (2023)**

Atlantic salmon

River in North East Iceland. Photo: Drone footage flown by Doris Pilcher

Common pipistrelle bat, a species found throughout the UK. Bats host a diversity of coronaviruses, including new viral species discovered in the UK. Photo: Hugh Clark/www.bats.org.uk

Genomic screening of 16 UK native bat species through conservationist networks uncovers coronaviruses with zoonotic potential

There has been limited characterisation of bat-borne coronaviruses in Europe. A team led by Prof. Vincent Savolainen, and including Dr David Orme, Dr Emma Ransome, Dr Will Pearse, Prof. Guy Woodward, Prof. Tom Bell, and Prof. Wendy Barclay, screened for coronaviruses in 48 faecal samples from 16 of the 17 bat species breeding in the UK. These samples were collected through a bat rehabilitation and conservationist network. They recovered nine complete genomes, including two novel coronavirus species, across six bat species: four alphacoronaviruses, a MERS-related betacoronavirus, and four closely related sarbecoviruses. They demonstrated that at least one of these sarbecoviruses can bind and use the human ACE2 receptor for infecting human cells, albeit suboptimally. Additionally, the spike proteins of these sarbecoviruses possess an R-A-K-Q motif, which lies only one nucleotide mutation away from a furin cleavage site (FCS) that enhances infectivity in other coronaviruses, including SARS-CoV-2. However, mutating this motif to an FCS did not enable spike cleavage. Overall, while UK sarbecoviruses would require further molecular adaptations to infect humans, their zoonotic risk warrants closer surveillance.

Nature Communications **14: 3322 (2023)**

The UK hosts a high number of non-native species, often escapees from estates during Victorian times, such as wallabies.

The impact of land use on non-native species incidence and number in local assemblages worldwide

While the regional distribution of non-native species is increasingly well documented for some taxa, global analyses of non-native species in local assemblages are still missing. Prof. Andy Purvis and colleagues used a worldwide collection of assemblages from five taxa - ants, birds, mammals, spiders and vascular plants - to assess whether the incidence, frequency and proportions of naturalised non-native species depend on type and intensity of land use. In plants, assemblages of primary vegetation are least invaded. In the other taxa, primary vegetation is among the least invaded land-use types, but one or several other types have equally low levels of occurrence, frequency and proportions of non-native species. High land use intensity is associated with higher non-native incidence and frequency in primary vegetation, while intensity effects are inconsistent for other land-use types. These findings highlight the potential dual role of unused primary vegetation in preserving native biodiversity and in conferring resistance against biological invasions.

Nature Communications **14: 2090 (2023)**

Climate-driven variation in dispersal ability predicts responses to forest fragmentation in birds

Species sensitivity to forest fragmentation varies latitudinally, peaking in the tropics. A prominent explanation for this pattern is that historical landscape disturbance at higher latitudes has removed fragmentation-sensitive species or promoted the evolution of more resilient survivors. However, it is unclear whether this so-called extinction filter is the dominant driver of geographic variation in fragmentation sensitivity, particularly because climatic factors may also cause latitudinal gradients in dispersal ability, a key trait mediating sensitivity to habitat fragmentation. Dr Cris Banks-Leite, Prof. Joe Tobias and colleagues combined field survey data with a morphological proxy for avian dispersal ability (hand-wing index) to assess responses to forest fragmentation in 1,034 bird species worldwide. They found that fragmentation sensitivity was strongly predicted by dispersal limitation and that other factors—latitude, body mass and historical disturbance events—have relatively limited explanatory power after accounting for species differences in dispersal. They also showed that variation in dispersal ability is only weakly predicted by historical disturbance and more strongly associated with intra-annual temperature fluctuations (seasonality). Their results suggest that climatic factors play a dominant role in driving global variation in the impacts of forest fragmentation, emphasizing the need for more nuanced environmental policies that take into account local context and associated species traits.

***Nature Ecology & Evolution* 7:1079 (2023)**

Crescent-faced Antpitta – example of a tropical species with very low dispersal capacity which is vulnerable to habitat fragmentation.

Rhesus macaques often engage in same-sex sexual behaviour among males, which likely provides advantages to their social groups.

Same-sex sociosexual behaviour is widespread and heritable in male rhesus macaques

Numerous reports have documented the occurrence of same-sex sociosexual behaviour (SSB) across animal species. However, the distribution of the behaviour within a species needs to be studied to test hypotheses describing its evolution and maintenance, in particular whether the behaviour is heritable and can therefore evolve by natural selection. Prof. Vincent Savolainen and two PhD students, Jackson Clive and Ewan Flintham, collected detailed observations across 3 years of social and mounting behaviour of 236 male semi-wild rhesus macaques. They combined these data with a pedigree dating back to 1938, to show that SSB was both repeatable (19.35%) and heritable (6.4%). Demographic factors (age and group structure) explained SSB variation only marginally. Furthermore, they found a positive genetic correlation between same-sex mounter and mountee activities, indicating a common basis to different forms of SSB. Finally, they found no evidence of fitness costs to SSB, but show instead that the behaviour mediated coalitionary partnerships that have been linked to improved reproductive success. Together, they results demonstrated that SSB is frequent in rhesus macaques, can evolve, and is not costly, indicating that SSB may be a common feature of primate reproductive ecology.

***Nature Ecology & Evolution* 7:1287 (2023)**

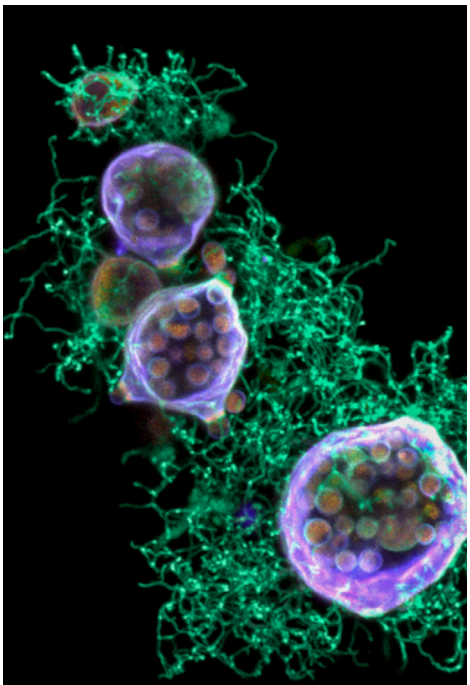
Primary tropical forests are important carbon sinks. Photo: Tijmen de Lorm

Logging of tropical forests impacts biodiversity. Photo: Chi'en

Tropical forests post-logging are a persistent net carbon source to the atmosphere

Logged tropical forests are counted as important carbon sinks in global carbon budgets due to the woody biomass they regain when they regrow following disturbance, but this assumption ignores the simultaneous carbon losses from the ecosystem. Prof. Rob Ewers and colleagues found that, when quantifying all the source and sink terms of the ecosystem carbon budget, logged tropical forests are a net source of carbon to the atmosphere. This source persists at least 10 years following logging, meaning rates of carbon sequestration in recovering tropical forests are likely much lower than estimated.

PNAS **120:e2214462120 (2023)**



Microscopic image of the salamander-killing chytrid fungus Batrachochytrium salamandrivorans. Photo: David Firer, McGill University

Two-speed genome evolution drives pathogenicity in fungal pathogens of animals

Batrachochytrium salamandrivorans (Bsal) and its closest relative *B. dendrobatidis* (Bd) are fungal pathogens that threaten amphibians globally. Pathogenicity in vertebrates by species of *Batrachochytrium* is thought to have emerged from nonpathogenic and saprobic relatives over millions of years through gene expansions of secreted proteolytic enzymes families. Using deep nanopore sequencing and comparative genomics, a study led by Ms Theresa Wacker, Dr Rhys Farrer (University of Exeter), Prof. Matthew Fisher and colleagues discovered that *Batrachochytrium* genomes have undergone a repeat-driven expansion characterized by flanking repetitive elements enriched around pathogenicity genes, genes with signatures of positive selection, and genes upregulated during infection. These genomic features are the hallmarks of two-speed genomes that have to date only been described in plant pathogens. These discoveries shed new light on the evolution of fungal pathogens of vertebrates driving global declines and extinctions.

PNAS **120:e2212633120 (2023)**

Silwood Park: an outdoor laboratory for the science community as a whole

The woodlands and grasslands of Silwood Park hosted more than 30 field research projects, half of which were led by Imperial undergraduate and Master's students, and half by researchers from other institutions. We also supported students' extracurricular professional development that contributed to the Silwood team winning the UK Mammal Society University Mammal Challenge, and the Imperial College London Rocketry team winning a prize in the International Lander Challenge.

In 2023 Silwood Park joined the Wellcome Sanger Institute's BIOSCAN project which over the next five years will study the diversity of flying insects and multiply the DNA barcoding data available for biomonitoring in the UK. In November 2023, the Nash's Field long-term experiment received a generous maintenance grant from the Ecological Continuity Trust. Their support, together with funding from Imperial's Department of Life Sciences made possible the replacement of the decades old and run-down wire fences that keep rabbits and other small mammals out of the experiment's large herbivores exclusion plots. This change safeguards the integrity and longevity of the experiment, and, we anticipate, will attract more researchers to discover the potential that it offers to study many of the environmental challenges we face today.

New fence in on of Nash's Field experimental plots. Photo: C. Estrada

Master students studying plant assemblages in the long-term grassland experiment Nutrient Network. Photo: C. Estrada

Georgina Mace Centre plan and aspirations 2024–2025

Research

- Continue to produce outstanding science-based solutions to help resolve global challenges facing Planet Earth.
- Help Imperial departments outside of Life Sciences to move part of their staff activities to Silwood Park.
- Continue to explore potential links with organisations close to the Centre's vision, such as NewCore at Silwood Park.

Teaching

- Streamline our portfolio of Master's courses, and connect our teaching and research evermore closely.

Outreach

- Hold Bugs, Birds and Beasts Day (30 July 2024).

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, and would particularly encourage businesses to contact us.

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We thank Laura Iskakova, Sarah Reid, Yusuf Ozkan, Anthony Fitzgerald, Emily Govan, Catalina Estrada Montes, and Helen Cliffe for their help with producing this report.