ANNUAL REPORT

2018 2019

BIOCHANGE

Center for Biodiversity Dynamics in a Changing World

BIOCHANGE
CENTER FOR BIODIVERSITY DYNAMICS
IN A CHANGING WORLD

AARHUS
UNIVERSITY

BIOCHANGE

Center for Biodiversity Dynamics in a Changing World

ANNUAL REPORT 2018/2019

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MARIE CURIE ACTIONS

BIOCHANGE
CENTER FOR BIODIVERSITY DYNAMICS IN A CHANGING WORLD

AARHUS UNIVERSITY

BIOCHANGE – Center for Biodiversity Dynamics in a Changing World
Annual Report 2018/2019

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Front-page: Background photo: Just before take-off. Mapping vegetation and terrain structure with a LiDAR and multispectral sensor mounted on a octocopter drone. Blæsedalen, Disko Island, Greenland, July 2018 (Photo: Urs A. Treier, BIOCHANGE). Vertical BIOCHANGE theme images (Photos: Colorbox; collage photos: Anne Blach Overgaard, Dennis Pedersen, Jens-Christian Svenning, and Peder Klith Bøcher).

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WORDS FROM THE DIRECTOR

Dear readers,

It is my pleasure to present the second annual report from BIOCHANGE – Center for Biodiversity Dynamics in a Changing World. The center started in August 2017, with the official inauguration on November 9 the same year. The basis for starting the BIOCHANGE center was a VILLUM Investigator grant of nearly 40 million DKK (~5.4 million EUR) awarded to me by VILLUM FONDEN for 2017-2023. Overall, my ambition with the VILLUM Investigator project is to improve our understanding of the complex biodiversity dynamics under anthropogenic global change and their consequences for people and society, and on developing novel solutions to promote a biodiverse, liveable future to the benefit of humans and all our co-beings on this planet.

To maximize progress on this challenging, crucial research area, I decided to build a research center around it, joining forces with a select team of innovative colleagues sharing this ambition and providing complementary expertise. The senior core members of the BIOCHANGE center are Professor MSO Felix Riede (archaeologist with expertise on human-environment relations and quantitative approaches; recipient of an ERC Consolidator Grant to start in 2019); Associate Professor Signe Normand (ecologist with expertise on vegetation dynamics under climate change and new technologies for ecological field-based research); and tenure-track Assistant Professor Alejandro Ordonez Gloria (ecologist with expertise in ecological Big Data and ecology-climatology integration), all positioned at Aarhus University. All bring their own projects and funding to the center, which in essence is a committed research collaborative. The central idea in forming a center is that scientific progress is best achieved in a cooperative, interdisciplinary research environment of critical mass and with a strong focus on joint development of ideas and expertise sharing.

We have organized the research in BIOCHANGE around four themes: [1] Fundamental Biodiversity Dynamics, [2] Global Challenges, [3] Ecoinformatics and New Technologies, and [4] Interdisciplinary Innovation. Notably, we work towards breakthroughs in:

(i) our understanding and predictive capacity of the complex Anthropocene ecological dynamics that will determine future levels of biodiversity and ecosystem functioning, including the many crucial services to society, in a world with a large, rapidly growing human population and massive climate change,

(ii) our ability to exploit the rapidly rising possibilities in the growing richness and quality of relevant Big Data, notably from remote sensing, for studying, monitoring and handling these dynamics, and

(iii) the ways nature and society interact, notably in terms of our capacity to develop land-use strategies and design landscape development to promote biodiversity in the face of the human-driven pressures, and to maximize associated co-benefits (ecosystem services) in relation to climate change adaptation, climate change mitigation, and human well-being.

On the following pages, we present the organization and activities of BIOCHANGE, covering both the basis for the center and updates on important outcomes of our efforts over the last year. I hope you will enjoy reading about it.

Jens-Christian Svenning, Professor
VILLUM Investigator and Director for
BIOCHANGE – Center for Biodiversity Dynamics
in a Changing World

BIOCHANGE's four senior core members from left: Associate Professor Signe Normand, Professor and Center Director Jens-Christian Svenning, Professor MSO Felix Riede, and Assistant Professor Alejandro Ordonez Gloria at Skanderborg Lake, Denmark.

Photo: Dennis Pedersen, BIOCHANGE.

BIOCHANGE in a nutshell – Center Director Jens-Christian Svenning's take on how the four themes of BIOCHANGE and his own research can be summed up using LEGO. At our recent Center retreat, we used LEGO Serious Play as a tool to get the BIOCHANGE community to build and talk science and interact, each member presenting their BIOCHANGE research. As Director, JCS developed this LEGO creation to illustrate the four BIOCHANGE research themes. Further reading under Communication and Outreach.

Photo: Jens-Christian Svenning, BIOCHANGE.

BIOCHANGE RESEARCH THEMES AND OBJECTIVES

BIODIVERSITY is what makes Earth habitable and a wonderful place to live. Critically, however, it is eroding and facing strong future risks from the large, growing human population, intensifying human activities, and massive climate change. To safeguard and restore biodiversity, we need to improve our understanding and predictive capacity of the complex human-driven biodiversity dynamics and their consequences for people and society, and to develop novel solutions to promote a biodiverse future.

BIOCHANGE will address this crucial challenge via four linked research themes:

THEME 1:

FUNDAMENTAL BIODIVERSITY DYNAMICS

We aim to deepen our understanding of three phenomena that are likely to characterize future ecosystems, namely: (1) Transient biodiversity dynamics, as ongoing and future global change is likely to further increase ecological disequilibria. (2) Assembly and functioning of novel ecosystems, as such ecosystems without historical precedent are likely to become widespread due to globalization's transport of organisms around the world and due to the rise of anthropogenic novel environmental conditions. One crucial unresolved question that we will address concerns the biodiversity capacity of such ecosystems. (3) Megafauna ecosystem ecology, as there is a strong need to understand how the large animals affect the rest of biodiversity, ecosystem structure and even the whole biosphere, both from a fundamental perspective and because the planet is now experiencing both strong losses of large animals in much of the world (defaunation), but also comebacks via re-expansions and introductions elsewhere.

THEME 2:

GLOBAL CHALLENGES

Humanity is facing massive global challenges, as highlighted in the global sustainable development goals (SDGs). One of the most challenging is the looming, increasing risk of strong future climate change. We see this as one of the biggest future ecological risks, and while subject to much work and discussion, we think the scope is constantly underestimated. At the same time, our ability to forecast the consequences for biodiversity and ecosystems remains limited. Linking to theme [1] Fundamental Biodiversity Dynamics, we aim to: (1) Strengthen our predictive capacity by developing forecasting models that robustly capture the likely widespread disequilibrial transient dynamics and assembly of novel ecosystems and are able to predict the impacts on ecosystem functioning and services, as well as (2) develop methods for society to optimize its responses to these dynamics.

BIOCHANGE OBJECTIVES:

- BIOCHANGE strives to produce excellent top-level science
- BIOCHANGE aims to make a real-world impact on the biodiversity crisis
- BIOCHANGE aims to be a platform for excellent research training

THEME 3:

ECOINFOR-MATICS & NEW TECHNOLOGIES

We see the informatics revolution and the linked rapid development in sensor technologies as a key opportunity for achieving the urgently needed progress on how to tackle the massive and building pressure on the biosphere that we all depend on, as well as to address core unanswered questions in ecological science. Our research has two key foci: (1) Development of new and stronger ecoinformatics capabilities, to be able to realize the potential in the increasingly massive amounts of relevant data. There will be strong synergy with theme [2] Global Challanges in developing forecast models, so that they are computationally efficient and can run on the massive high-resolution spatiotemporal data sets needed for maximum relevancy for landscape planning. (2) Exploiting the rising potential for extremely high-resolution analyses and modelling of dynamics in biodiversity, ecosystems and their services using novel sources of remote sensing.

THEME 4:

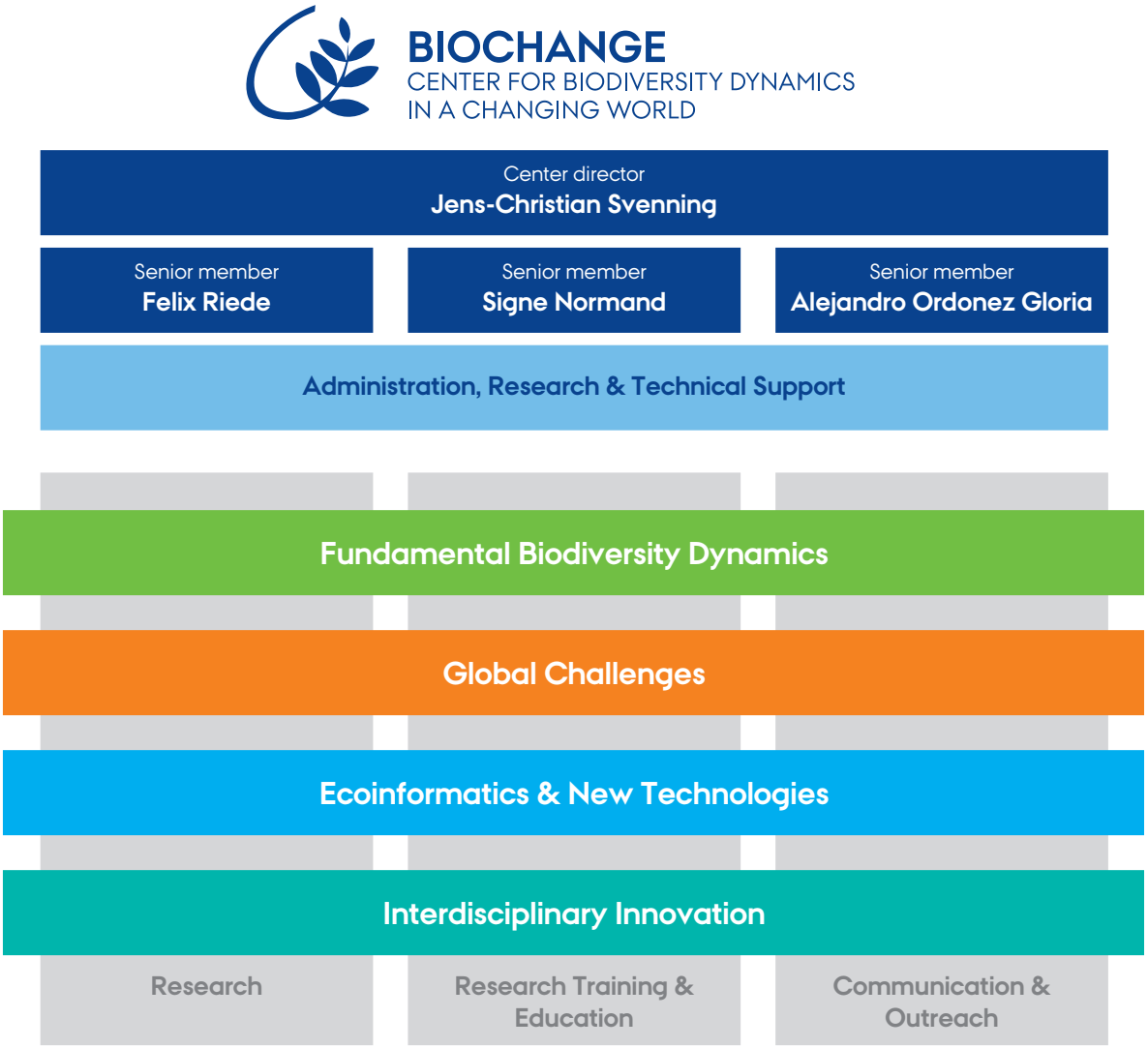
INTERDISCIPLINARY INNOVATION

Our research has focus on big, complex issues, integrating topics such as global change, ecoinformatics, and human-environment relations. This entails a strong need for interdisciplinarity, and our goal with this theme is to explore the potential of novel cross-disciplinary development of perspectives and methods in gaining new ground on important and often complex issues related to biodiversity dynamics in this fast-changing world. We will keep a strategically open agenda to keep exploring novel interdisciplinary possibilities, as we see this as essential for coming up with truly new ideas, new methods, and perspectives needed for breakthroughs on established questions. However, focus areas are:
(1) Enhance the collaboration with computer science to unfold the potential for Big Data studies on biodiversity and the global challenges. (2) Increase our understanding of human dependence on nature via application and integration of theory from a broad range fields, informatics, and remote sensing to study impacts of environment and biodiversity on societal development and human well-being. (3) Develop interdisciplinary research on landscape planning to safeguard biodiversity, ecosystem services, and human well-being in an Anthropocene world with strong human population growth, strong urbanization, and looming massive climate change. This will involve linking fields such as ecology, archaeology, anthropology, environmental history, landscape architecture, and medicine, often using spatial Big Data modelling with remote sensing data in a key role.

ORGANIZATION AND STAFF

ORGANIZATION AND STAFF

BIOCHANGE members at our recent Center retreat at Skanderborg Lake, Denmark in April 2019. Photo: Dennis Pedersen, BIOCHANGE.



ORGANIZATIONAL DIAGRAM

BIOCHANGE is headed by Professor Jens-Christian Svenning and includes three additional senior core members from Aarhus University: Professor MSO Felix Riede, Associate Professor Signe Normand, and Assistant Professor Alejandro Ordonez Gloria. The center is supported by a group of administrative, research and technical staff members. BIOCHANGE is organized around three main functions, namely Research, Research Training and Education, and Communication and Outreach. All activities of the functions in BIOCHANGE are centered on four main research themes: [1] Fundamental Biodiversity Dynamics, [2] Global Challenges, [3] Ecoinformatics & New Technologies, and [4] Interdisciplinary Innovation coordinated by the senior scientists of the Center.

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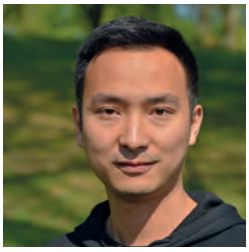
Postdocs



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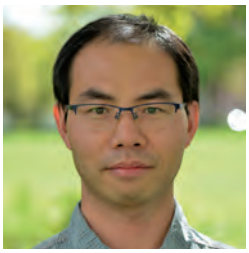

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All photos by Dennis Pedersen, BIOCHANGE.

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PORTRAITS OF SENIOR CORE MEMBERS

Photo: Else Magård.

KEY PAPERS

Engemann, K., C.B. Pedersen, L. Arge, C. Tsirogiannis, P.B. Mortensen, and **J.-C. Svenning**. 2019. Residential green space in childhood is associated with lower risk of psychiatric disorders from adolescence into adulthood. Proceedings of the National Academy of Sciences 116:201807504.

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Sandel, B., L. Arge, B. Dalsgaard, R. G. Davies, K.J. Gaston, W.J. Sutherland, and **J.-C. Svenning**. 2011. The influence of Late Quaternary climate-change velocity on species endemism. Science 334:660-664.

Sandom, C.J., R. Ejrnæs, M.D.D. Hansen, and **J.-C. Svenning**. 2014. High herbivore density associated with vegetation diversity in interglacial ecosystems. Proceedings of the National Academy of Sciences 111:4162-4167.

Svenning, J.-C., P.B.M. Pedersen, C.J. Donlan, R. Ejrnæs, S. Faurby, M. Galetti, D.M. Hansen, B. Sandel, C.J. Sandom, J.W. Terborgh, and F.W.M. Vera. 2016. Science for a wilder Anthropocene: Synthesis and future directions for trophic rewilding research. Proceedings of the National Academy of Sciences 113:898-906.

Watmough, G.R., C.L.J. Marcinko, C. Sullivan, K. Tschirhart, P.K. Mutuo, C.A. Palm, and **J.-C. Svenning**. 2019. Socioecologically informed use of remote sensing data to predict rural household poverty. Proceedings of the National Academy of Sciences 116:1213-1218.

JENS-CHRISTIAN SVENNING

WHO ARE YOU?

My name is Jens-Christian Svenning. I am a broadly based ecologist and biogeographer, with strong interest in biodiversity, global change biology, human-nature interrelations, and the possibilities for sustainable development in the Anthropocene. My work has led to a number of major recognitions, notably a consolidator-phase European Research Council (ERC) Consolidator-phase Starting grant in 2013, the Ministry for Higher Education and Science's Eliteforsk award in 2014, Queen Margrethe II's Science Award in 2016, a Carlsberg Foundation Semper Ardens grant in 2016, and a VILLUM Investigator grant in 2017.

POSITION AND BACKGROUND

I am professor in geospatial ecology, VILLUM Investigator, and director for BIOCHANGE – Center for Biodiversity Dynamics in a Changing World at Department of Bioscience, Aarhus University. I obtained my PhD in 1999 in tropical plant community ecology, based on work on palms in the tropical forests of Ecuador.

MAIN RESEARCH AREAS

I have developed a research agenda on biodiversity dynamics in a changing world focused around four linked themes: [1] Fundamental biodiversity diversity, [2] Global challenges, [3] Ecoinformatics and new technologies, and [4] Interdisciplinary innovation, i.e., the themes I have chosen as the focal themes for BIOCHANGE.

MAIN RESEARCH QUESTIONS

In my prior research, a major achievement has been my contribution to mainstreaming historical contingency and disequilibrium dynamics into ecology and global change biology. Some of the important discoveries and results that I have spearheaded include: (i) evidence for the role of climate stability in shaping Earth's biodiversity patterns and associated functional capacity (in part jointly with BIOCHANGE senior members Signe Normand and Alejandro Ordonez Gloria), (ii) that the massive prehistoric megafauna losses are linked to human expansion and have had strong ecosystem effects, (iii) development of a clear concept and research agenda for rewilding, and (iv) a predictive framework for where climate change is likely to force the emergence of novel ecosystems (jointly with BIOCHANGE senior member Alejandro Ordonez Gloria).

FUTURE PLANS

My future research plans concentrate on developing the four research themes in BIOCHANGE. More specifically, I will have key focus on:

(1) Transient biodiversity dynamics, trophic changes (notably megafauna losses and comebacks and their ecosystem impacts), and novel ecosystems.
(2) Next-generation predictive models in relation to current and future climate change.
(3) The rapidly rising potential in space-based and other remote sensing technologies for extremely high-resolution spatiotemporal monitoring and analyses of ecological dynamics.
(4) Human-nature inter-relations, notably the role of exposure to nature and biodiversity for human well-being and the macroecology of the human species.
(5) Ecosystem and landscape management to safeguard biodiversity and maximize co-benefits (ecosystem services) for society, with emphasis on rewilding as a key approach to ecosystem restoration and its potential to promote sustainable development in the Anthropocene.

FELIX RIEDE

WHO ARE YOU?

My name is Felix Riede; I was born and raised in Germany but have for the last ten years lived in Denmark with my Danish-American wife and our two boys, Alexander (7) and Oskar (3).

POSITION AND BACKGROUND

I received my entire university education in the UK with first a BA from Durham, then an MPhil and PhD from Cambridge, albeit with a period as visiting scholar at KU. Throughout my studies and career, I have been straddling the interface between the human, biological and environmental sciences. After a stint as Junior Research Fellow at Wolfson College and the Leverhulme Centre for Human Evolutionary Studies (Cambridge), I became British Academy Postdoctoral Fellowship at the Centre for the Evolution of Cultural Diversity (UCL). In 2009, I joined Aarhus University, initially as Assistant Professor, then Associate Professor, with intermittent visiting appointments at Harvard (Anthropology) and Cambridge (Geography). After having been Head of Department for a few years, I became Professor MSO in Environmental Humanities and Climate Change Archaeology.

MAIN RESEARCH AREAS

I recently passed on the baton of the Directorship at the Centre for Environmental Humanities to focus on my own research and, not least, on BIOCHANGE. When at Campus Moesgård, I head the Laboratory for Past Disaster Science, funded by two successive *Sapere Aude* grants from the Independent Research Council Denmark. In my group, we investigate how past extreme environmental events – especially volcanic eruptions but also earthquakes, storms and rapid climate

KEY PAPERS

Brewer, J. and **F. Riede**. 2018. Cultural heritage and climate adaptation: a cultural evolutionary perspective for the Anthropocene. World Archaeology 50:1-16.

Jackson, R.C., A.J. Dugmore, and **F. Riede**. 2018. Rediscovering lessons of adaptation from the past. Global Environmental Change 52:58-65.

Riede, F. 2018. Deep pasts - deep futures: a palaeoenvironmental humanities perspective from the Stone Age to the Human Age. Current Swedish Archaeology 26:13-30.

Photo: Dennis Pedersen, BIOCHANGE.

Riede, F. and J.B. Pedersen. 2018. Late glacial human dispersals in Northern Europe and disequilibrium dynamics. Human Ecology 46:621-632.

Riede, F., T.T. Høye, P. Tejsner, D. Veldhuis, and R. Willerslev. 2018. Special section introduction: socioecological disequilibrium in the Circumpolar North. Human Ecology 46:615-620.

change – have impacted human communities in Europe and elsewhere and how this evidence can be brought forward into current debates about climate change, resilience, and vulnerability.

MAIN RESEARCH QUESTIONS

My work is focused on human-environment relations, on biocultural adaptations, and how to study them in human societies, especially those of the past. I am a dedicated interdisciplinarian and I work as much with Neanderthals as with the early human forager groups in northern Europe after the end of the last ice age. I also have an interest in the Anthropocene and how we can approach this, in many ways controversial, epoch, archaeologically. I am keen on bringing sophisticated quantitative and natural science methods to the humanities in general and archaeology in particular.

FUTURE PLANS

Just as my current DFF *Sapere Aude* grant is going into its final third, my recently awarded ERC Consolidator Grant will kick off. Beginning in September 2019, I will be assembling a research group focused on climate change and human adaptations at the transition from ice age conditions to Holocene warmth. In collaboration with Jens-Christian and others at BIOCHANGE, we will be adopting and adapting computational methods from ecoinformatics to the study of the human past in order to define precisely how and what environmental features past humans were adapted to. We will also be conducting fieldwork in order to discover new sites from this period to ground-truth the results of our models.

SIGNE NORMAND

WHO ARE YOU?

I am Signe Normand. I was born in Aarhus and lived the first six years of my life next to the botanical garden and greenhouses in Aarhus. Later, I lived in other parts of Denmark (Grenaa & Ribe), Norway, the US, and Switzerland. I have lived in Aarhus for the last 5 years, and live down town with my Swiss husband and our three children; Liv (10), Sia (8), and Noe (3).

POSITION AND BACKGROUND

My fascination for living organisms, especially plants, started in my early childhood when my grandfather introduced me to the wonders of nature. Later, I went to boarding school focused on biology, and after high school, I moved to Norway for one year where I attended a Folk High School specializing in outdoor life and sustainable use of nature.

I studied Biology at Aarhus University, earning a Bachelor's degree by studying Palms in the Amazon, and afterwards a Master's and PhD degree by studying the distribution and diversity patterns of the European flora. After receiving my PhD degree, I went onto a postdoc position at the Swiss Federal Research Institute for Forest, Snow and Landscape. Since 2014, I have been working at the Section for Ecoinformatics and Biodiversity, and am now Associate Professor in Botanical Macroecology and have established a research group focused on vegetation dynamics as well as the UAS4Ecology Lab, a research facility using the emerging Unmanned Aerial System (UAS) technology to answer questions in ecology. In addition, I am the daily leader of the application initiative in the Danish Drone Infrastructure, and associated with Arctic Research Center and iClimate (Aarhus interdisciplinary Centre for Climate Change), Aarhus University.

MAIN RESEARCH AREAS AND QUESTIONS

I am a macro- and vegetation ecologist dedicated to understand patterns of species' occurrence and biodiversity and to provide methodological progress to bring more realism to models and predictions of vegetation and biodiversity dynamics. I have studied these questions from the tropics to the Arctic, where most of my research effort and fieldwork have been centered in recent years. I mainly utilize remote sensing, range dynamic models, dendro- and trait-based ecology. The goal of my research is to find answers to fundamental questions in ecology, but also to inform nature conservation about the impact of global change on biodiversity. My current research has three main components: (i) Empirical studies to gain insight on the factors and processes determining ecological patterns across space and time; with a special focus on the role of non-equilibrium and transient dynamics as well as scale-dependencies. (ii) Gaining insight on current and future range dynamic through models of species post-glacial migration patterns after the Last Glacial Maximum. (iii) Utilizing the newest sensors mounted on drones in combination with air- and satellite-borne remote sensing for monitoring, understanding, and predicting vegetation and biodiversity dynamics across space and time.

FUTURE PLANS

Several grants have enabled me to build up my independent research group and infrastructure: The VILLUM Young Investigator program, The Carlsberg Foundation Distinguished Associate Professor Fellowships, Aarhus University Research Foundation Associate Professor Starting Grant. Until 2022, I am funded by a Sapere Aude grant from the Danish Council for Independent Research with focus on climate change impacts on Arctic shrub dynamics.

KEY PAPERS

Bjorkman, A.D., I.H. Myers-Smith, S.C. Elmendorf, **S. Normand**, N. Rüger, *et al.* 2018. Plant functional trait change across a warming tundra biome. Nature 562:57-62.

Normand, S., C. Randin, R. Ohlemuller, C. Bay, T.T. Høye, E.D. Kjaer, C. Korner, H. Lischke, L. Maiorano, J. Paulsen, P.E. Pearman, A. Psomas, U.A. Treier, N.E. Zimmermann, and J.-C. Svenning. 2013. A greener Greenland? Climatic potential and long-term constraints on future expansions of trees and shrubs. Philosophical transactions of the Royal Society of London Series B, Biological Sciences 368:20120479.

Normand, S., T.T. Høye, B.C. Forbes, J.J. Bowden, A.L. Davies, B.V. Odgaard, F. Riede, J.-C. Svenning, U.A. Treier, R. Willerslev, and J. Wischnewski. 2017. Legacies of historical human activities in Arctic woody plant dynamics. Annual Review of Environment and Resources 42:541-567.

Steinbauer, M.J., J.-A. Grytnes, G. Jurasinski, A. Kulonen, J. Lenoir, *et al.*, **S. Normand**, *et al.* 2018. Accelerated increase in plant species richness on mountain summits is linked to warming. Nature 556:231-234.

Zurell, D., W. Thuiller, J. Pagel, J.S Cabral, T. Münkemüller, D. Gravel, S. Dullinger, **S. Normand**, K.H. Schiffers, K.A. Moore, and N.E. Zimmermann. 2016. Benchmarking novel approaches for modelling species range dynamics. Global Change Biology 22:2651-2664.

Photo: Urs A. Treier, BIOCHANGE.

ALEJANDRO ORDONEZ GLORIA

WHO ARE YOU?

My name is Alejandro Ordonez Gloria, but most people call me Alejo. I was born and raised in Colombia, but over the last 14 years, I have been moving across multiple countries and continents (the USA, The Netherlands, Australia, and Northern Ireland). Today, my Dutch wife, our baby boy, and I are happy to call Aarhus home.

POSITION AND BACKGROUND

I am an Assistant Professor at the Department of Bioscience at Aarhus University. A biologist by training who received a BSc from the Pontificia Universidad Javeriana (Colombia), and my MSc and PhD at the University of Groningen. In 2011, I became the Climate People and Environment Post-Doctoral researcher at the University of Wisconsin Madison. This position was followed by a 4-year Post-Doctoral appointment (2013-2017) at AU as part of the ERC funded HISTFUNC project lead by Jens-Christian Svenning. In 2017, I became a lecturer in Global Change Biology at Queens University Belfast, but later that year, I moved back to AU as Assistant Professor and became a core member of BIOCHANGE.

MAIN RESEARCH AREAS

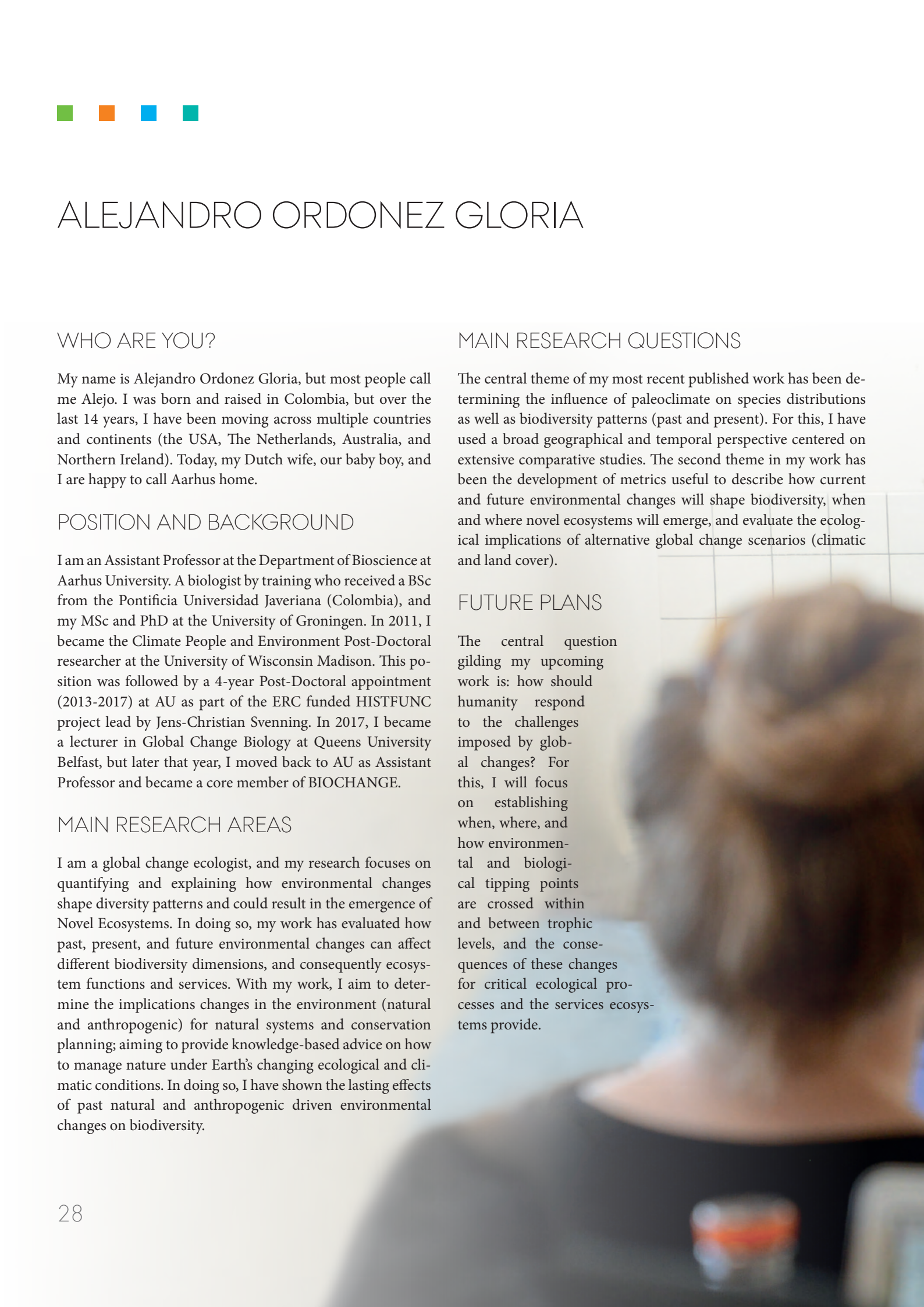
I am a global change ecologist, and my research focuses on quantifying and explaining how environmental changes shape diversity patterns and could result in the emergence of Novel Ecosystems. In doing so, my work has evaluated how past, present, and future environmental changes can affect different biodiversity dimensions, and consequently ecosystem functions and services. With my work, I aim to determine the implications changes in the environment (natural and anthropogenic) for natural systems and conservation planning; aiming to provide knowledge-based advice on how to manage nature under Earth's changing ecological and climatic conditions. In doing so, I have shown the lasting effects of past natural and anthropogenic driven environmental changes on biodiversity.

MAIN RESEARCH QUESTIONS

The central theme of my most recent published work has been determining the influence of paleoclimate on species distributions as well as biodiversity patterns (past and present). For this, I have used a broad geographical and temporal perspective centered on extensive comparative studies. The second theme in my work has been the development of metrics useful to describe how current and future environmental changes will shape biodiversity, when and where novel ecosystems will emerge, and evaluate the ecological implications of alternative global change scenarios (climatic and land cover).

FUTURE PLANS

The central question gilding my upcoming work is: how should humanity respond to the challenges imposed by global changes? For this, I will focus on establishing when, where, and how environmental and biological tipping points are crossed within and between trophic levels, and the consequences of these changes for critical ecological processes and the services ecosystems provide.



KEY PAPERS

Blonder, B., B.J. Enquist, B.J. Graae, J. Kattge, B.S. Maitner, N. Morueta-Holme, **A. Ordonez**, I. Šímová, J. Singarayer, J.-C. Svenning, P.J. Valdes, and C. Violle. 2018. Late Quaternary climate legacies in contemporary plant functional composition. Global Change Biology 24:4827-4840.

Ordonez, A. and J. Williams. 2013. Comparing climatic and biotic velocities for woody taxa distributions over the last 16,000 years in eastern North America. Ecology Letters 16:773-781.

Ordonez, A. and J.-C. Svenning. 2015. Geographic patterns in functional diversity deficits are linked to glacial-interglacial climate stability and accessibility. Global Ecology and Biogeography 24:826-837.

Ordonez, A. and J.-C. Svenning. 2018. Greater tree species richness in eastern North America compared to Europe is coupled to denser, more clustered functional trait space filling, not to trait space expansion. Global Ecology and Biogeography 27:1288-1299.

Ordonez, A., I.J. Wright, and H. Olff. 2010. Functional differences between native and alien species: a global-scale comparison. Functional Ecology 24:1353–1361.

Ordonez, A., J.W. Williams, and J.-C. Svenning. 2016. Mapping climatic mechanisms likely to favour the emergence of novel communities. Nature Climate Change 6:1104-9.

Ordonez, A., S. Martinuzzi, V. Radeloff, and J. Williams. 2014. Combined speeds of climate and land-use change of the conterminous U.S. until 2050. Nature Climate Change 4:811–816.

Photo: Dennis Pedersen, BIOCHANGE.


RESEARCH

RESEARCH HIGHLIGHTS 2018/2019

ERC CONSOLIDATOR GRANT TO FELIX RIEDE

Felix Riede has been awarded 1,907,638 EUR from the prestigious European Research Council Consolidator Grant to start the project CLIOARCH in 2019. Through five linked work packages, the project will explore the application of new technologies and techniques borrowed from ecoinformatics in order to better understand human adaptations to past climate change and events (further reading – CLIOARCH: CLIOdynamic ARCHaeology: Computational approaches to Final Palaeolithic/earliest Mesolithic archaeology and climate change). This grant will contribute to theme [3] Ecoinformatics and New Technologies and theme [4] Interdisciplinary Innovation of BIOCHANGE.

MARIE SKŁODOWSKA-CURIE ITN GRANT TO JENS-CHRISTIAN SVENNING

Jens-Christian Svenning has been awarded 522,844 EUR as part of a larger European Commission Marie Skłodowska-Curie actions, Horizon 2020 Innovative Training Network (c. 4.1 million EUR in total) to investigate how the European natural landscape has developed in the past 10,000 years and how this knowledge can be used in future nature management in Europe (further reading – TERRANOVA: The European Landscape Learning Initiative: Past and Future Environments and Energy Regimes shaping Policy Tools). This grant will contribute to theme [1] Fundamental Biodiversity Dynamics and theme [4] Interdisciplinary Innovation of BIOCHANGE.

Photos: Dennis Pedersen, BIOCHANGE.

AUFF STARTING GRANT TO ALEJANDRO ORDONEZ GLORIA

Alejandro Ordonez Gloria has been awarded 1,900,000 DKK from the Aarhus University Research Foundation Starting Grant to systematically evaluate the links between changes in environmental composition and multiple aspects defining the biological structure of multiple trophic levels within an ecosystem (further reading – BIORATES: Rates of biodiversity change due to human induced global environmental shifts). This grant will contribute to theme [1] Fundamental Biodiversity Dynamics and theme [2] Global Challenges of BIOCHANGE.

HIGHLY CITED

Jens-Christian Svenning has been ranked among Clarivate Analytics top 1% of highly cited researchers in the cross-field category. This list recognizes world-class researchers selected for their exceptional research performance, demonstrated by production of multiple highly cited papers that rank in the top 1% by citations for field and year in Web of Science. Source: Clarivate Analytics.

SPECIAL ISSUES

BIOCHANGE has been directly involved in two special issues this year: (1) Philosophical Transactions of the Royal Society B: Biological Sciences, Vol 373, Issue 1761, 2018. https://doi.org/10.1098/rstb.2017.0432 – Jens-Christian Svenning co-organized this special issue on Trophic Rewilding and co-authored two papers and the editorial. (2) Human Ecology, Vol 46, Issue 5, 2018. https://doi.org/10.1007/s10745-018-0009-8 – Felix Riede and other BIOCHANGE members co-authored the introduction and two additional papers in this special issue on socioecological disequilibrium in the circumpolar north.

PAPER HIGHLIGHTS

ALL THEMES:

Faurby, S., **M. Davis**, **R.Ø. Pedersen**, **S.D. Schowanek**, A. Antonelli, and **J.-C. Svenning**. 2018. PHYLACINE 1.2: the phylogenetic atlas of mammal macroecology. Ecology 99:2626-2626.

THEME 1: FUNDAMENTAL BIODIVERSITY DYNAMICS

Bjorkman, A.D., I.H. Myers-Smith, S.C. Elmendorf, **S. Normand**, N. Rüger, *et al.* 2018. Plant functional trait change across a warming tundra biome. Nature 562:57-62.

Davis, M., S. Faurby, and **J.-C. Svenning**. 2018. Mammal diversity will take millions of years to recover from the current biodiversity crisis. Proceedings of the National Academy of Sciences 115:11262-11267.

Maring, R. and **F. Riede**. 2019. Possible wild boar management during the Ertebølle Period. A carbon and nitrogen isotope analysis of Mesolithic wild boar from Fannerup F, Denmark. Environmental Archaeology 24:15-27.

Ordonez, A. and **J.-C. Svenning**. 2018. Greater tree species richness in eastern North America compared to Europe is coupled to denser, more clustered functional trait space filling, not to trait space expansion. Global Ecology and Biogeography 27:1288-1299.

Pither, J., B.J. Pickles, S.W. Simard, **A. Ordonez**, and J.W. Williams. 2018. Below-ground biotic interactions moderated the post-glacial range dynamics of trees. New Phytologist 220:1148-1160.

Prendin, A.L., M. Carrer, **M. Karami**, J. Hollesen, N.B. Pedersen, M. Pividori, **U.A. Treier**, A. Westergaard-Nielsen, B. Elberling, and **S. Normand**. Accepted. Immediate and carry-over effects of insect outbreaks on vegetation growth in West Greenland assessed from cells to satellite. Journal of Biogeography. (Coupled to theme 3).

THEME 2: GLOBAL CHALLENGES

Jackson, R.C., A.J. Dugmore, and **F. Riede**. 2018. Rediscovering lessons of adaptation from the past. Global Environmental Change 52:58-65.

Jarvie, S., and **J.-C. Svenning**. 2018. Using species distribution modelling to determine opportunities for trophic rewilding under future scenarios of climate change. Philosophical Transactions of the Royal Society B: Biological Sciences 373:20170446.

Riede, F. 2018. Deep pasts - deep futures: a palaeoenvironmental humanities perspective from the Stone Age to the Human Age. Current Swedish Archaeology 26:13-30.

THEME 3: ECOINFORMATICS & NEW TECHNOLOGIES

Buitenwerf, R., B. Sandel, **S. Normand**, A. Mimet, and **J.-C. Svenning**. 2018. Land surface greening suggests vigorous woody regrowth throughout European semi-natural vegetation. Global Change Biology 24:5789-5801. (Coupled to theme 2).

Karami, M., A. Westergaard-Nielsen, **S. Normand**, **U.A. Treier**, B. Elberling, and B.U. Hansen. 2018. A phenology-based approach to the classification of Arctic tundra ecosystems in Greenland. ISPRS Journal of Photogrammetry and Remote Sensing 146:518-529.

Kolyaie, S., **U.A. Treier**, G.R. Watmough, **B. Madsen**, **P.K. Bøcher**, A. Psomas, R. Bösch, and **S. Normand**. 2019. Transferability and the effect of colour calibration during multi-image classification of Arctic vegetation change. Polar Biology. (e-pub ahead of print). (Coupled to theme 2).

Moeslund, J.E., **A. Zlinszky**, R. Ejrnæs, A.K. Brunbjerg, **P.K. Bøcher**, **J.-C. Svenning**, and **S. Normand**. 2019. Light detection and ranging explains diversity of plants, fungi, lichens, and bryophytes across multiple habitats and large geographic extent. Ecological Applications. (e-pub ahead of print).

Watmough, G.R., C.L.J. Marcinko, C. Sullivan, K. Tschirhart, P.K. Mutuo, C.A. Palm, and **J.-C. Svenning**. 2019. Socioecologically informed use of remote sensing data to predict rural household poverty. Proceedings of the National Academy of Sciences 116:1213-1218. (Coupled to theme 4).

THEME 4: INTERDISCIPLINARY INNOVATION

Brewer, J. and **F. Riede**. 2018. Cultural heritage and climate adaptation: a cultural evolutionary perspective for the Anthropocene. World Archaeology 50:1-16.

Engemann, K., C.B. Pedersen, L. Arge, C. Tsirogiannis, P.B. Mortensen, and **J.-C. Svenning**. 2019. Residential green space in childhood is associated with lower risk of psychiatric disorders from adolescence into adulthood. Proceedings of the National Academy of Sciences 116:201807504. (Coupled to theme 3).

Perino, A., H.M. Pereira, L.M. Navarro, N. Fernández, J.M. Bullock, **S. Ceauşu**, A. Cortés-Avizanda, R. van Klink, T. Kuemmerle, A. Lomba, G. Pe'er, T. Plieninger, J.M. Rey Benayas, C.J. Sandom, **J.-C. Svenning**, and H.C. Wheeler. 2019. Rewilding complex ecosystems. Science 364:eaav5570. (Coupled to theme 1).

Riede, F. and **J.B. Pedersen**. 2018. Late glacial human dispersals in Northern Europe and disequilibrium dynamics. Human Ecology 46:621-632.

Riede, F., T.T. Høye, P. Tejsner, D. Veldhuis, and R. Willerslev. 2018. Special section introduction: socioecological disequilibrium in the Circumpolar North. Human Ecology 46:615-620.

MEDIA

Press releases made in relation to the publications of Bjorkman *et al.* 2018, Davis *et al.* 2018, and Engemann *et al.* 2019 were picked up by the press and other media and have resulted in a multitude of feature articles and derived items. Engemann *et al.* with an altmetric score of 2119 has resulted in at least 159 feature articles and 94 derived pieces globally. Davis *et al.* (Altmetric score of 1013) has led to more than 70 feature articles and more than 39 derived feature articles based on a press release to EurekAlert, which was visited > 305,000 times since October 2018. Bjorkman *et al.* (Altmetric score of 516) quickly got much attention throughout the European media scene and has so far resulted in at least 47 feature articles in different media (all metrics have been extracted in May 2019).

VILLUM INVESTIGATOR PROJECT:

BIODIVERSITY DYNAMICS IN A CHANGING WORLD

Principal investigator: Jens-Christian Svenning

The project is funded by VILLUM FONDEN,
with 39,987,212 DKK and runs 2017-2023.

VILLUM FONDEN

Earth is a living planet and what makes it not just a livable, but a wonderful place to live is its rich biodiversity. This natural and biocultural heritage is now under massive pressure from human resource use and associated anthropogenic pressures, with a strong risk that these pressures will become even stronger in the future. To safeguard Earth's biodiversity is one of the most pressing and difficult challenges facing humanity, e.g., as outlined in the global sustainable development goals (SDGs). With the VILLUM Investigator project the ambition is to improve our understanding and predictive capacity of the complex biodiversity dynamics under anthropogenic global change and their consequences for people and society, and based hereon, on developing novel solutions to promote a biodiverse future.

The project has four linked themes, which are the same as for the BIOCHANGE center overall:

[1] Fundamental Biodiversity Dynamics
[2] Global Challenges
[3] Ecoinformatics and New Technologies
[4] Interdisciplinary Innovation

Within these we have key focus on: (1) transient biodiversity dynamics, trophic changes (notably megafauna losses and comebacks), and novel ecosystems, (2) developing next-generation predictive models in relation to current and future climate change, (3) advancing the team's ecoinformatics capabilities and exploiting the rapidly rising potential for extremely high-resolution spatiotemporal analyses, and (4) novel interdisciplinary work. For the latter, the focus will be on: (a) ecological Big Data, (b) human-nature inter-relations (notably the role of exposure to nature and biodiversity for human mental health and well-being), and (c) interdisciplinary landscape planning to safeguard biodiversity, ecosystem services and human well-being in the face of strong current and future human population growth, societal challenges, and climate change.

Since the project started in 2017, we have achieved strong progress, both organizationally and scientifically. Most importantly, the BIOCHANGE center, which was established based around this project, has been established as a vibrant, collaborative and ambitious research community, with a strong set of senior scientists, many postdocs and PhD students, as well as MSc and BSc students and numerous international collaborators working towards addressing the four research themes. Several important studies have already been published, with much more started and well under way.

Further reading:
http://bios.au.dk/om-instituttet/organisation/oekoinformatik-biodiversitet/projects/biochange/research/villum-investigator-project/

KEY PAPERS

Buitenwerf, R., B. Sandel, **S. Normand**, A. Mimet, and **J.-C. Svenning**. 2018. Land surface greening suggests vigorous woody regrowth throughout European semi-natural vegetation. Global Change Biology 24:5789-5801.

Ceauşu, S., R.A. Graves, A.K. Killion, **J.-C. Svenning**, and N.H. Carter. 2019. Governing trade-offs in ecosystem services and disservices to achieve human–wildlife coexistence. Conservation Biology 33:543-553.

Engemann, K., C.B. Pedersen, L. Arge, C. Tsirogiannis, P.B. Mortensen, and **J.-C. Svenning**. 2019. Residential green space in childhood is associated with lower risk of psychiatric disorders from adolescence into adulthood. Proceedings of the National Academy of Sciences 116:201807504.

Svenning, J.-C. 2018. Proactive conservation and restoration of botanical diversity in the Anthropocene's "rambunctious garden". American Journal of Botany 105:963-966.

Watmough, G.R., C.L.J. Marcinko, C. Sullivan, K. Tschirhart, P.K. Mutuo, C.A. Palm, and **J.-C. Svenning**. 2019. Socioecologically informed use of remote sensing data to predict rural household poverty. Proceedings of the National Academy of Sciences 116:1213-1218.

MEGAPAST2FUTURE:

14

MEGAFAUNA ECOSYSTEM ECOLOGY FROM THE DEEP PREHISTORY TO A HUMAN-DOMINATED FUTURE

Principal investigator: Jens-Christian Svenning

Prior to the global expansion of Homo sapiens, ecosystems across the world teemed with large animals (megafauna). Elephants, for example, occurred from Patagonia to the British Isles and the Cape until just 10,000 years ago. Since then, megafaunas have declined dramatically, a decline that continues to the present day, driven by land conversion to agriculture to feed growing human populations and unsustainable hunting. In some regions, however, declines have been replaced by comebacks (e.g., re-expansion of wolves in Europe). At the same time, evidence is emerging that megafaunas may be crucial for ecosystem function and may even affect the Earth's climate and nutrient cycling. Reflecting this, it is increasingly, but controversially, argued that megafaunas should be reintroduced to restore their ecological functions (rewilding). Human impacts are now so pervasive that officially defining a new geological epoch (the Anthropocene, epoch of man) for the present is being considered. Given intensifying human impacts on Earth's environment – with pronounced increases in the human population and strong climate changes likely across the 21st century – we are now at a crossroads for Earth's megafauna. Do we let it become lost, or do we attempt to restore it and its functional importance?

The project focuses on developing a solid, synthetic understanding of megafauna ecosystem ecology and its potential role in developing a sustainable, biodiverse future. To this end, MegaPast2Future aims to develop new theory on the role of megafauna in ecosystems (work package 1), provide a novel understanding of the evolutionary and biogeographic development of the world's megafaunas and their ecosystem importance (work package 2), do field-based testing of key theory and hypotheses (work package 3), and assess and improve the scope for human-megafauna coexistence in the Anthropocene (work package 4). Given the complexity of the problem, the methodology is interdisciplinary, integrating macroecology, theoretical ecology, paleobiology, experimental ecology, geography, economics, and conservation. The project contributes to theme [1] Fundamental Biodiversity Dynamics and theme [4] Interdisciplinary Innovation of BIOCHANGE.

(A) Capybaras, (B) March deer, and (C) collared Tapir at one of the MegaPast2Future field sites in Corrientes, Argentina (further reading about this specific field site under Field Campaigns). Photos: Jens-Christian Svenning (A, C), Dennis Pedersen (B), BIOCHANGE.

The project is funded by the Carlsberg Foundation 'Semper Ardens' research project, with 13,777,082 DKK and runs 2016-2020.
It currently employs five postdocs and three PhD students.

CARLSBERG FOUNDATION

MegaPast2Future

The project will run until end of 2020, but much has already been achieved. Core field sites have been established in Denmark, Argentina, and Kenya, with much fieldwork here already well in progress. In addition, new fieldwork has been started in South Africa, to make use of the unique research possibilities in the country's tradition for megafauna restoration. We have previously (last report period) held a successful international megafauna symposium, a likewise successful megafauna PhD course, and are planning follow-ups for later in 2019 and 2020. Finally, we have been very active in public outreach in relation to this project nationally and internationally. Key studies from this project have already been published (including a MegaPast2Future-led paper in PNAS [and on the cover] in the fall of 2018 and a coauthored review paper on rewilding in Science in spring 2019, resulting from an international working group), with much more started and well under way.

Further reading:
http://bios.au.dk/om-instituttet/organisation/oekoinformatik-biodiversitet/projects/biochange/research/megapast2future/

C

KEY PAPERS

Davis, M., S. Faurby, and **J.-C. Svenning**. 2018. Mammal diversity will take millions of years to recover from the current biodiversity crisis. Proceedings of the National Academy of Science USA 115:11262-11267.

Faurby, S., **M. Davis**, **R.Ø. Pedersen**, **S.D. Schowanek**, A. Antonelli, and **J.-C. Svenning**. 2018. PHYLACINE 1.2: the phylogenetic atlas of mammal macroecology. Ecology 99:2626-2626.

Galetti, M., M. Moleón, P. Jordano, M.M. Pires, P.R. Guimaraes, T. Pape, E. Nichols, D. Hansen, J.M. Olesen, **M. Munk**, J.S. de Mattos, **A.H. Schweiger**, N. Owen-Smith, C.N. Johnson, R.J. Marquis, and **J.-C. Svenning**. 2018. Ecological and evolutionary legacy of megafauna extinctions. Biological Reviews 93:845-862.

Jarvie, S. and **J.-C. Svenning**. 2018. Using species distribution modelling to determine opportunities for trophic rewilding under future scenarios of climate change. Philosophical Transactions of the Royal Society B: Biological Sciences 373:20170446.

Schweiger, A.H., I. Boulangeat, T. Conradi, **M. Davis**, and **J.-C. Svenning**. 2019. The importance of ecological memory for trophic rewilding as an ecosystem restoration approach. Biological Reviews 94:1-15.

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TREECHANGE:

TREE DIVERSITY DYNAMICS UNDER CLIMATE CHANGE

2 3

Principal investigator: Jens-Christian Svenning

The big question that we address in TREECHANGE is: how will tree species diversity react to future global climate change? Forests are among the most important ecosystems on Earth, harboring a substantial proportion of biodiversity and providing vital ecosystem services such as carbon sequestration, climate regulation, erosion protection, and timber and non-timber forest products. The diversity of tree species plays a central role in forest ecosystems and for the subsistence of millions of people in rural communities worldwide. Part of the challenge in understanding drivers of tree diversity is that we do not have a complete picture of the current tree distribution and diversity of tree species worldwide.

To improve our understanding of global tree distributions, we have carried out a large effort to collect, integrate, and quality check data on distributions, traits, and phylogeny for c. 65,000 identified tree species globally, and are now applying advanced modelling approaches to generate estimates of distributions and climate niches and for estimating missing trait values. For species with very few records, we use gap-filling approaches along with information on functional traits and phylogeny to provide insights on species climate niches. As a key outcome, we will use the results to project tree species ranges under different climate change scenarios to evaluate the impacts on tree diversity. Moreover, we are investigating the patterns of the global functional and phylogenetic diversities using the compiled comprehensive dataset, and examining the effects of paleo- and current climate, among other factors, on these spatial patterns. The project contributes to theme [2] Global Challenges and theme [3] Ecoinformatics and New Technologies of BIOCHANGE.

We have achieved good progress, notably we have built a comprehensive, quality-checked database on Earth's tree species, covering c. 500,000 tree species and including c. 37 million species occurrence records as well as large amounts of data on functional traits and phylogeny. We have further published the first paper on the project, in Forest Ecosystems, as well as, linked to our efforts with TREECHANGE, contributed as coauthors to a paper on the global patterns of tree-soil organism mutualisms in Nature (and providing the journal's front-page photo).

Further reading:
http://bios.au.dk/om-instituttet/organisation/oekoinformatik-biodiversitet/projects/biochange/research/treechange/

KEY PAPERS

Serra-Diaz, J.M., B.J. Enquist, B. Maitner, C. Merow, and **J.-C. Svenning**. 2018. Big data of tree species distributions: how big and how good? Forest Ecosystems 4:30.

Steidinger, B.S., T.W. Crowther, J. Liang, M.E. Van Nuland, G.D.A. Werner, *et al.*, **J.-C. Svenning**, *et al.*, and G. consortium. 2019. Climatic controls of decomposition drive the global biogeography of forest-tree symbioses. Nature 569:404-408.

Danish beech in a woodland patch near Aarhus, Denmark.
Photo: Jens-Christian Svenning, BIOCHANGE.

The project is funded by Danish Council for Independent Research | Natural Sciences, with 2,587,678 DKK and runs 2016-2019. It has one postdoc employed, and is done in collaboration with BIOCHANGE alumni Pep Serra Diaz (Associate Professor, AgroParisTech) and other international collaborators.

DANMARKS FRIE FORSKNINGSFOND
INDEPENDENT RESEARCH FUND DENMARK

TERRANOVA:

14

THE EUROPEAN LANDSCAPE LEARNING INITIATIVE: PAST AND FUTURE ENVIRONMENTS AND ENERGY REGIMES SHAPING POLICY TOOLS

Principal investigator: Jens-Christian Svenning

TERRANOVA is a Marie Skłodowska-Curie Innovative Training Network. It aims at improving our long-term understanding of ecosystem and landscape histories, and land-use strategies and impacts in Europe in the Holocene and Anthropocene, and takes special interest in developing the basis for mainstreaming rewilding into European landscape management. Previously identified socio-cultural transitions and the effects of natural forcings will be critically assessed. Regional and continental syntheses will be used to anchor a new generation of landscape and climate change models, which include the effects of past human actions and generate scenarios for landscape management and rewilding. Ultimately, this project aims to contribute research and training to the needed future transition to a low carbon society, addressing the joint current climate and biodiversity crises.

These efforts will be realized through a new interdisciplinary arena created by the TERRANOVA project, constituted by its interdisciplinary and inter-sectoral consortium and 15 new PhD positions. The TERRANOVA consortium consists of eight universities, three NGOs and three companies. The non-academic beneficiaries include IUCN, the world's oldest and largest global environmental organization, and Rewilding Europe, currently working in 13 different European countries and connecting rewilding initiatives in more than 20 European countries, and together with the academic beneficiaries form an unprecedented inter-sectoral consortium for training the next generation of scientists, policy makers, and entrepreneurs.

Two of the PhD projects – on natural ecosystem baselines and on megafauna dynamics – will be localized in BIOCHANGE with Jens-Christian Svenning as the main supervisor and Signe Nor-


A


B

The project is funded by European Commission Marie Skłodowska-Curie actions, Horizon 2020 with 4,090,952.52 EUR totally (with 522,844 EUR to Aarhus University) and runs 2019-2023.

mand as local co-supervisor, with further two PhD projects at other institutions co-supervised by Jens-Christian Svenning. This project contributes to theme [1] Fundamental Biodiversity Dynamics and theme [4] Interdisciplinary Innovation of BIOCHANGE.

Further reading:
http://terranovaproject.eu

Landscapes from three sites in Denmark:
(A) Klosterheden Plantage with beaver dam (Western Jutland),
(B) Skærbæk Plantage (Central Jutland), and
(C) Syvårssøerne (Southern Jutland).
Photos: Jens-Christian Svenning, BIOCHANGE.

CLIOARCH:

3 4

CLIODYNAMIC ARCHAEOLOGY: COMPUTATIONAL APPROACHES TO FINAL PALAEOLITHIC/EARLIEST MESOLITHIC ARCHAEOLOGY AND CLIMATE CHANGE

Principal investigator: Felix Riede

Late Pleistocene/early Holocene Europe is said to be the ideal laboratory for the investigation of human responses to rapidly changing climates and environments, migration, and adaptation. Yet, pinpointing precisely how and why contemporaneous Final Palaeolithic/earliest Mesolithic (15,000-11,000 years BP) foragers migrated, and which environmental or other factors they adapted to – or failed to – has remained remarkably elusive. At the core of CLIOARCH is the radical but, in light of research-historical insights, necessary hypothesis that the current archaeological cultural taxonomy for this iconic period of European prehistory is epistemologically flawed and that operationalisations and interpretations based on this traditional taxonomy – especially those that seek to relate observed changes in material culture and land-use to contemporaneous climatic and environmental changes – are therefore problematic. Hence, novel approaches to crafting the taxonomic building blocks are required, as are novel analyses of human-environment relations in this period. CLIOARCH's premier ambition is to provide operational cultural taxonomies for the Final Palaeolithic/earliest Mesolithic of Europe and to couple these with interdisciplinary cultural evolutionary, quantitative ecological methods and field archaeological investigations beyond the state-of-the-art, so as to better capture such adaptations – almost certainly with major implications for the standard culture-historical narrative relating to this period. In so doing, the project will pioneer a fully transparent and replicable – and eminently transferable – methodology for the study of the impacts of climate change and extreme environmental events in deep history. In turn, such a quantitative understanding of past adaptive dynamics will position archaeology more centrally in contemporary debates about climate change, environmental catastrophe and their cultural dimensions.

Through five linked work packages (WPs), the project will explore the application of new technologies and techniques borrowed from ecoinformatics in order to better understand human adaptations to past climate change and events (Fig. 1). BIOCHANGE Director Jens-Christian Svenning is involved in the project as senior advisor and co-supervisor of one of its PhD students. Indeed, BIOCHANGE is this exciting project's natural second home! This grant will contribute to theme [3] Ecoinformatics and New Technologies and theme [4] Interdisciplinary Innovation of BIOCHANGE.

CLIOARCH is funded by the European Research Council through Consolidator Grant grant agreement 817564 under the Horizon 2020 research and innovation programme with 1,907,638 EUR and will run from 2019-2022.

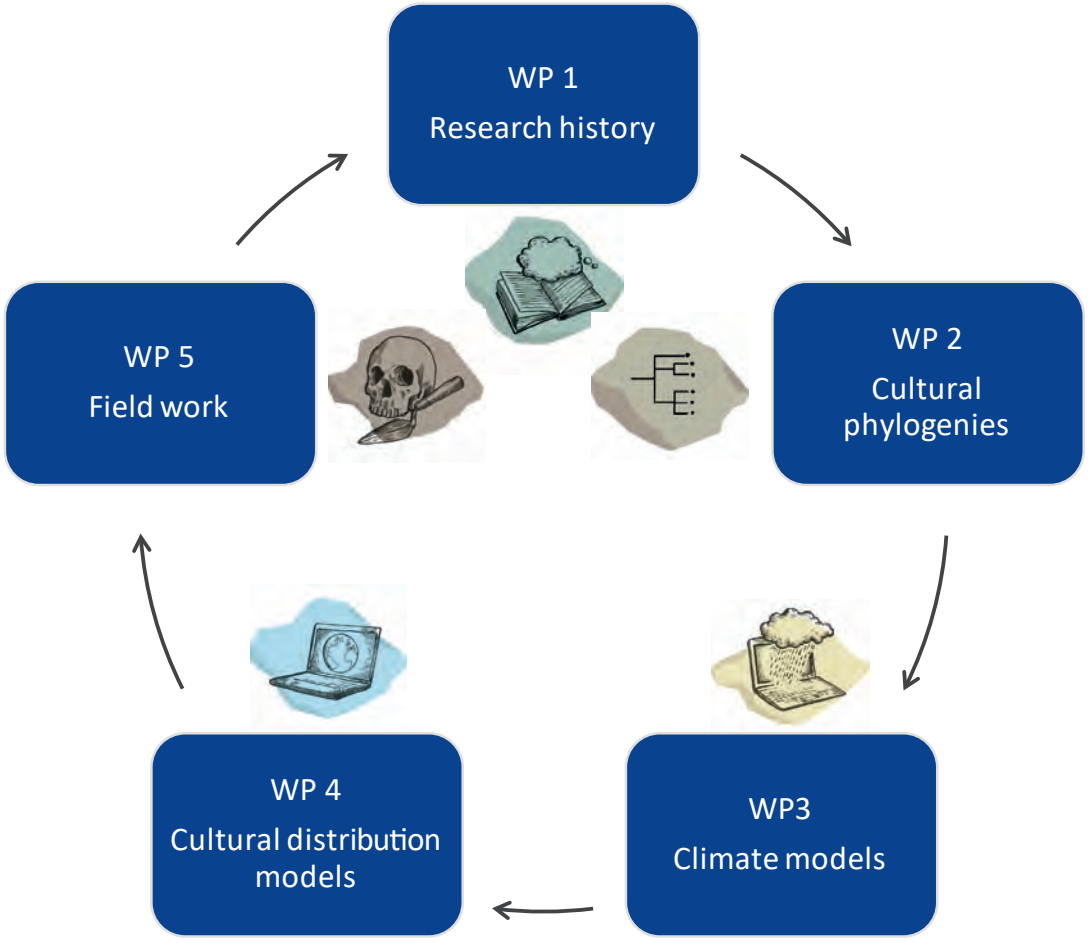


Figure 1. A flow chart of the five constituent work packages (WPs) of CLIOARCH.

LAPADIS PHASE 2:

APOCALYPSE THEN? THE LAACHER SEE VOLCANIC ERUPTION (13,000 YEARS BEFORE PRESENT), DEEP ENVIRONMENTAL HISTORY AND EUROPE'S GEO-CULTURAL HERITAGE

4

Principal investigator: Felix Riede

This project is funded by the Independent Research Council Denmark's Sapere Aude Starting Grant instrument and represents phase two of LAPADIS – the Laboratory for Past Disaster Science. In the project, we conduct ground-breaking research centred on a cataclysmic environmental event that punctuated an early period on Nordic prehistory – the Laacher See volcanic eruption that occurred c. 13,000 years ago in present-day Germany, and its impact on communities in Europe and especially in southern Scandinavia – and on this basis to develop novel outreach engagements that make Europe's geo-cultural heritage work for environmental literacy.

By exploring in parallel and unprecedented detail the cultural and geological dynamics of the Laacher See eruption and its suggested consequences, this project will lead to: (1) a significantly improved understanding of this last major continental European eruption, and (2) allow us to test the dual hypothesis of its regionally varying human impact in Central Europe and southern Scandinavia respectively. This project will furthermore (3) provide a robust historically informed evidence-base for an engagement of deep-time Environmental Humanities with the profound ethical predicaments of present and future climate change and climate catastrophe.

During the last year, we have been focussing on wrapping up various laboratory analyses on an important integrative symposium, and on lining up materials for the exhibition scheduled for the final phase of the project in 2020. During October 2018, an international group of scientists concerned with past disasters – and their relevance in society today – were assembled at Aarhus University. Over two and half days of fruitful and intense discussion, we put together a remarkable array of case studies and perspectives on how interdisciplinary archaeological research can contribute to the understanding not only of past culture change but also to the contemporary quandaries of resilience and vulnerability. The results of this workshop will result in a landmark-edited volume to be published in Berhahn's series Catastrophes in Context.

One of the aims of this project is to explore also how public institutions such as museums can contribute to increased climate change literacy, including literacy about extreme events. To this end, the project's final deliverable is a special exhibition scheduled to take place at Moesgård Museum in the last quarter of 2020. The idea with this exhibition is to use past disasters and what we know about these geologically and in terms of societal impacts as forecast scenarios for future impacts. This builds on the idea of so-called Realistic Disaster Scenarios but extends these with knowledge gained from case studies provided by archaeology and history. The rationale is that the archaeological record serves as a database of completed natural experiments of history that can inform surge capacity tests and scenarios of future societal trajectories (Fig. 1). For the planned exhibition, we use this idea to mirror potential future impacts of re-activated volcanism at the Laacher See volcano in the many results produced by the project. For instance, we will bring together map data on volcanic ashfall as recorded in our geological and archaeological archives with similar data on contemporary population densities and critical infrastructures in Europe to create powerful hazard maps. This project contributes to theme [4] Interdisciplinary Innovation of BIOCHANGE.

Further reading:
http://projects.au.dk/lapadis/

KEY PAPER

Sauer, F., D. Stott, and **F. Riede**. 2018. Search for new final Palaeolithic rock shelter sites in the Federal State of Hesse. Journal of Archaeological Science: Reports 22:168–178.

The project is funded by Danish Council for Independent Research | Natural Sciences with 6,926,238 DKK.

LAPADIS
LABORATORY FOR PAST DISASTER SCIENCE

DANMARKS FRIE FORSKNINGSFOND
INDEPENDENT RESEARCH FUND DENMARK

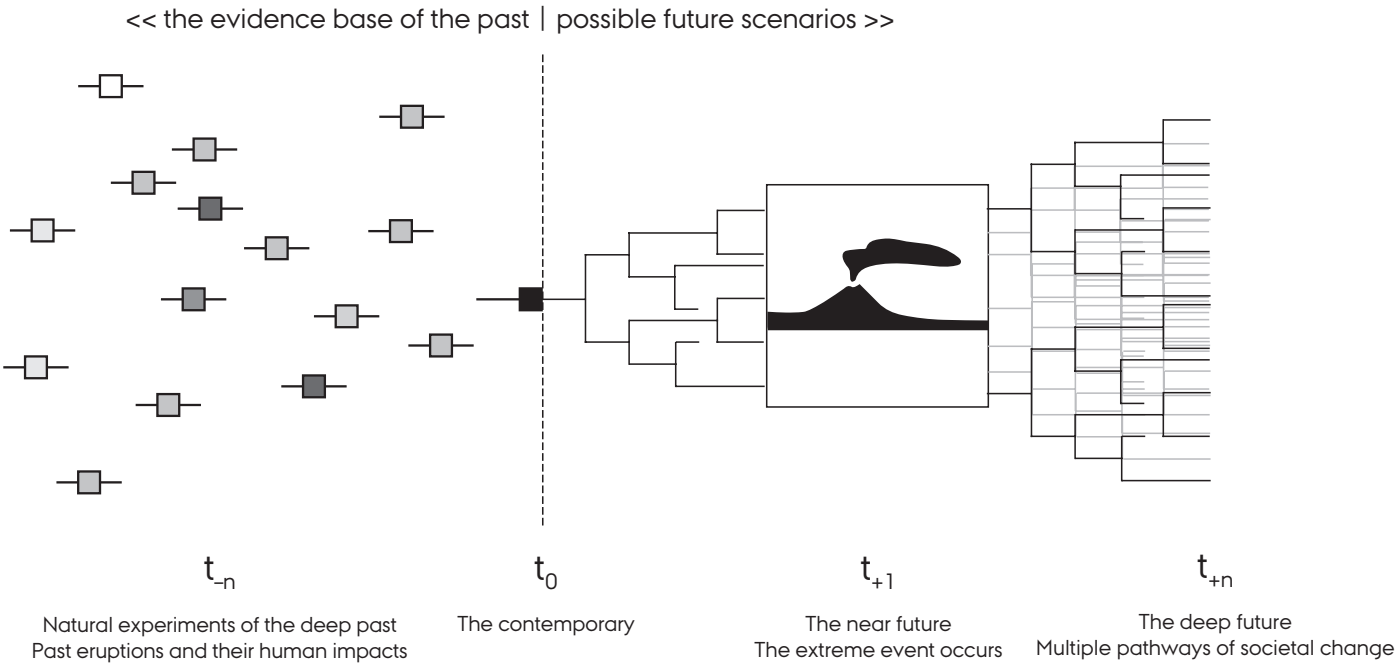


Figure 1. A conceptual schematic for extended Realistic Disaster Scenarios (eRDS). The shaded squares represent archaeological/historical cases – completed natural experiments of history. The line passing through each case square indicates that the archaeological record allows the investigation of both the socio-ecological conditions before and after a given event to be captured. Their variable placement in the left-hand part of the schematic reflects the variable chronological (t_{-n}) and cultural distance from the present (t_0). The stippled line at t_0 divides a known past from a future that can only be prognosticated. From the present, the pathways of societal development can be projected into the future where at t_{+1} an extreme event is projected to occur and to interact with the different socio-ecological near-futures. From this point, manifold but evidence-constrained deep futures (t_{+n}) unfold as a consequence of prior societal trajectories and the impacts of the extreme event in question.

CEH:

CENTRE FOR ENVIRONMENTAL HUMANITIES

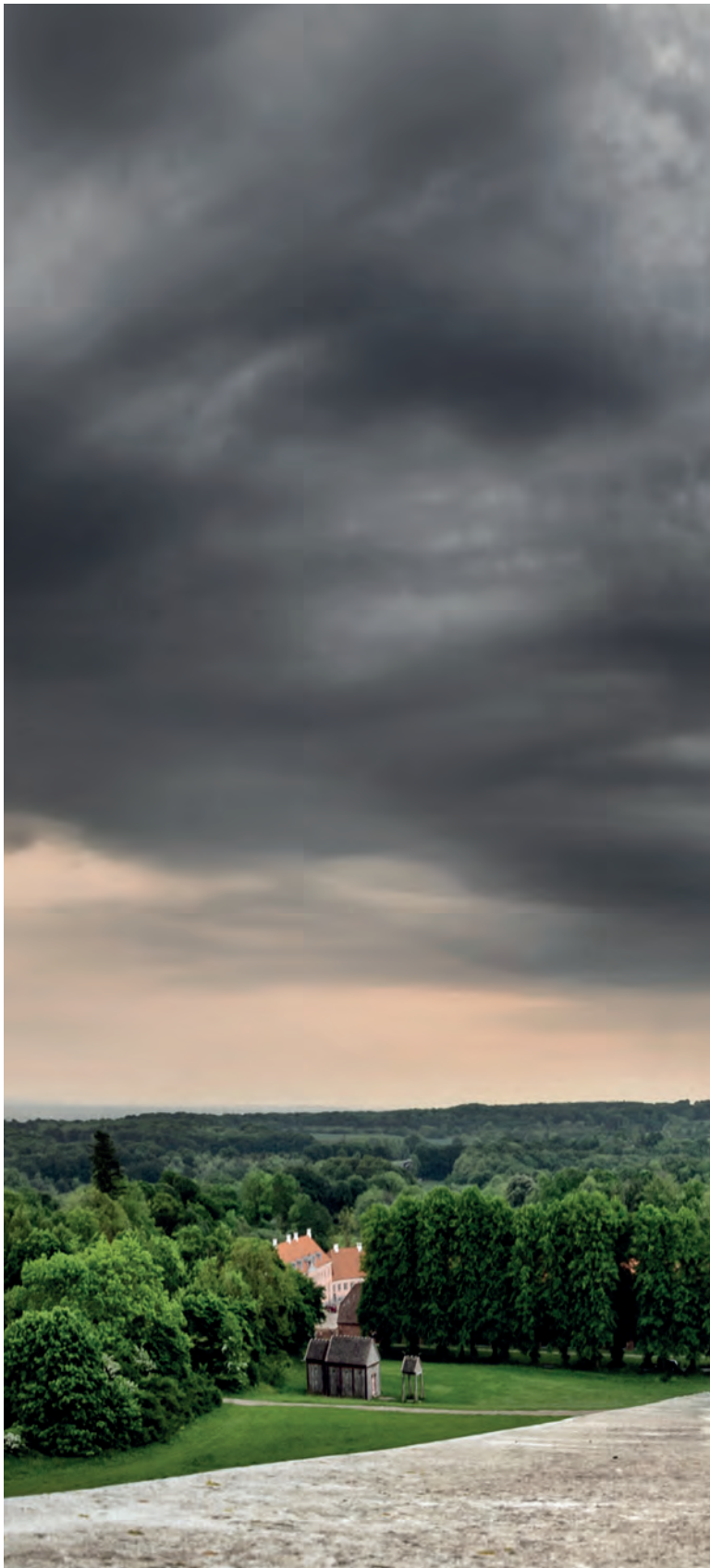
2 4

Principal investigator: Felix Riede

The Aarhus University Centre for Environmental Humanities (CEH) is concerned with re-engaging the environment in disciplines such as history, religion, literature and media, ethics, archaeology, anthropology, education, and artistic practice – all with a specific interest in reflecting on present concerns in a deep historical perspective. In the face of the profound environmental crises that loom large in politics and the popular imagination, exploring the cultural interfaces of different societies and their surroundings, synchronically and diachronically, has attained a new urgency. The AU CEH aims to bring together hitherto isolated Environmental Humanities scholars at Aarhus University, and to provide a major longer-term catalyst for the diverse research conducted under its aegis. The CEH has been seed-funded directly from the School of Culture and Society and currently hosts an International Network Programme (INP) grant from the Danish Agency for Science and Higher Education for developing the Aarhus-Cape Town Environmental Humanities Partnership.

The CEH has hosted a series of workshops with our South African colleagues to design and implement a PhD course focused on water infrastructures and water cultures. While originally planned to be held in Cape Town, the ongoing water crisis there led us to relocate the event to Aarhus. This project contributes to theme [2] Global Challenges and theme [4] Interdisciplinary Innovations of BIOCHANGE.

Further information on this and other CEH activities can be found here: http://ceh.au.dk



KEY PAPER

Jackson, R.C., A.J. Dugmore, and **F. Riede**. 2018. Rediscovering lessons of adaptation from the past. Global Environmental Change 52:58-65.

The project is funded by Danish Agency for Science and Higher Education with 272,197 DKK and Committee for Research and External Cooperation at Aarhus University with 274,135 DKK. Finally, the School for Culture and Society supports with internal funds.

CEH
CENTRE FOR
ENVIRONMENTAL HUMANITIES

Campus Moesgård, a hub of interdisciplinary environmental history and archaeology. Photo: Rógvi N. Johansen, MOMU.

C2C CC:

COAST TO COAST CLIMATE CHALLENGE SUBPROJECT C24: CLIMATE HISTORY | CULTURE HISTORY

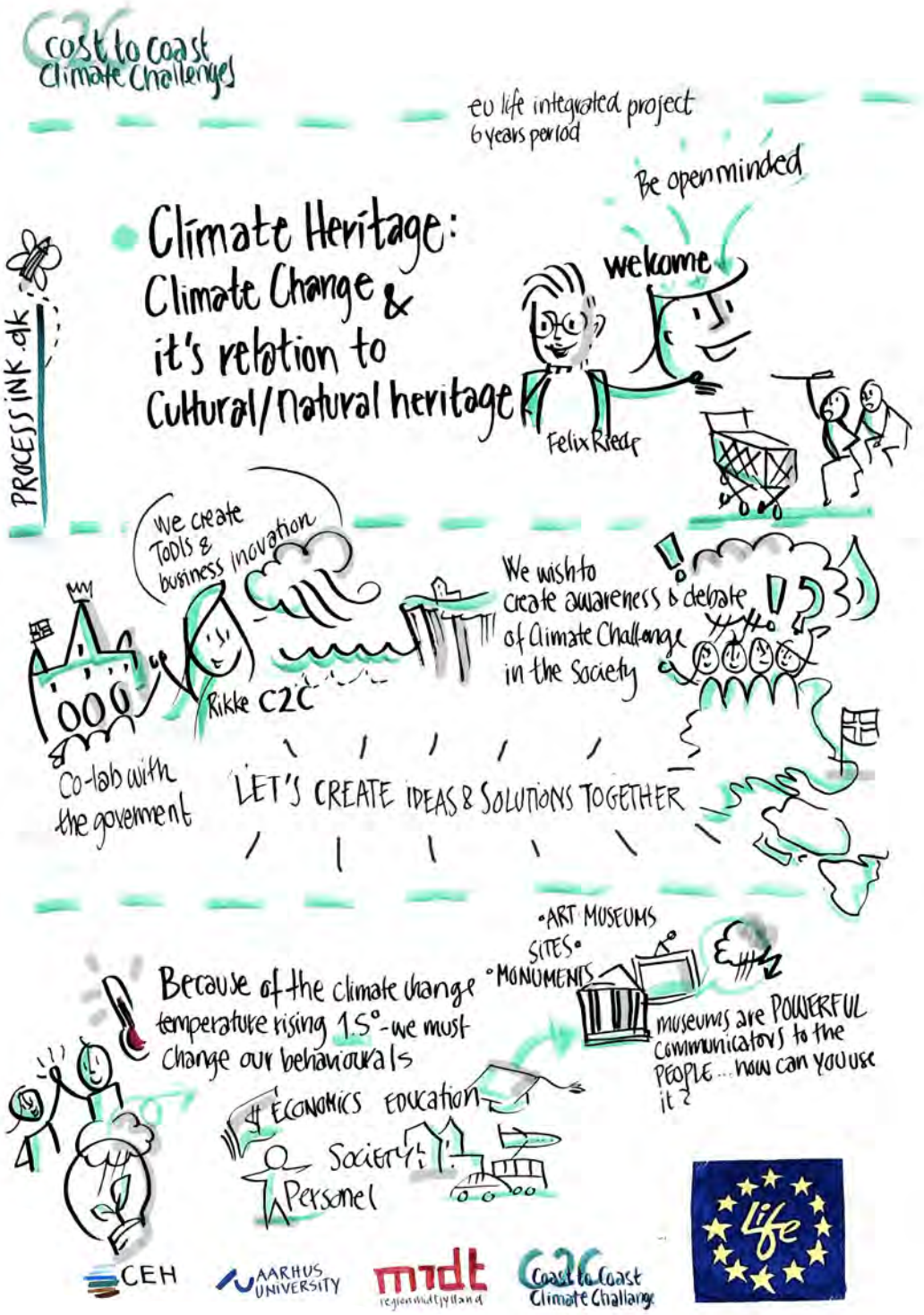
Principal investigator: Felix Riede

As part of a large EU Life funded project anchored in the Region of Central Denmark, this aims to provide a historically informed and evidence-based dissemination platform for C2C Climate Challenge that facilitates citizen-near adaptation and long-term behavioral change. The project couples existing environmental and cultural historical datasets together in order to provide evidence-based snapshots of past environmental conditions and human responses. With a focus on hydrological changes in inland (river, lake) and coastal contexts, C24 connects directly with other C2C CC projects and makes use of existing dissemination platforms (e.g. the Klimatorium and AquaGlobe) in order to showcase the overall project nationally. At the same time, this project reaches out to a wider international network through workshops and participation in international conferences. Finally, the project will add value to C2C CC overall by translating climate history into components useable also in sustainable growth via tourism. The popular outreach portal danmarkshistorien.dk is co-opted in this project to present coupled cultural and climate history to the Danish-speaking public. Our collection of expert contributions can be seen here: http://danmarkshistorien.dk/leksikon-og-kilder/vis/materiale/miljoehistorie-hvad-er-det/. We are also in the final stages of designing a small exhibition on environmental history in the Skanderborg area. This will go on display at the AquaGlobe. This project contributes to theme [2] Global Challenges, and theme [4] Interdisciplinary Innovations of BIOCHANGE.

KEY PAPER

Brewer, J. and **F. Riede**. 2018. Cultural heritage and climate adaptation: a cultural evolutionary perspective for the Anthropocene. World Archaeology 50:1-16.

The project is supported by the EU LIFE-program with approximately 52 million DKK and has a total budget of c. 90 million DKK.
It currently employs one research assistant.



A graphic summary of our part of the C2C CC project that aims to bring cultural history and natural history together in thinking climate adaption across sectors.

Drawing by Rikke Cilja, Processink.

HumanColonisation:

PATTERNS AND PROCESSES OF DISPERSAL, CULTURAL CHANGE AND DEMOGRAPHIC COLLAPSE IN THE EARLIEST HUMAN COLONIZATION OF PALAEARCTIC SOUTHERN SCANDINAVIA

14

Principal investigator: Felix Riede

This project focuses on the first presence of modern humans in southern Scandinavia during the Late Glacial (14,500-14,000 years ago), linked to the so-called Hamburgian culture. A reindeer specialized hunter-gatherer culture, generally understood as reflecting a culture-historical epoch with an unbroken use of the recently deglaciated landscape.

The Hamburgian culture is traditionally divided into an earlier, more eastern 'classic' and a later, more north-western 'Havelte' phase, and ends abruptly at around 14,000 years ago. Rather than differing substantially in their lithic repertoire or their subsistence economy, however, the two phases of the Hamburgian culture diverge only in their diagnostic projectile point forms. A chronological as well as spatial overlap is also observed, making the basis for, and meaning of, this division of phases somewhat problematic. Currently, no robust answer for this clear yet curious division exists.

The project proposed here therefore seeks novel explanations for the shift from 'classic' to 'Havelte' and the latter's sudden disappearance. The hypothesis of the project is that (i) the change from 'classic' to 'Havelte' was driven by a dispersal process linked to individual decision making, and that (ii) the disappearance of the 'Havelte' phase and with it the entire Hamburgian culture, can plausibly be linked to a demographic collapse. The project aims to address these questions by:

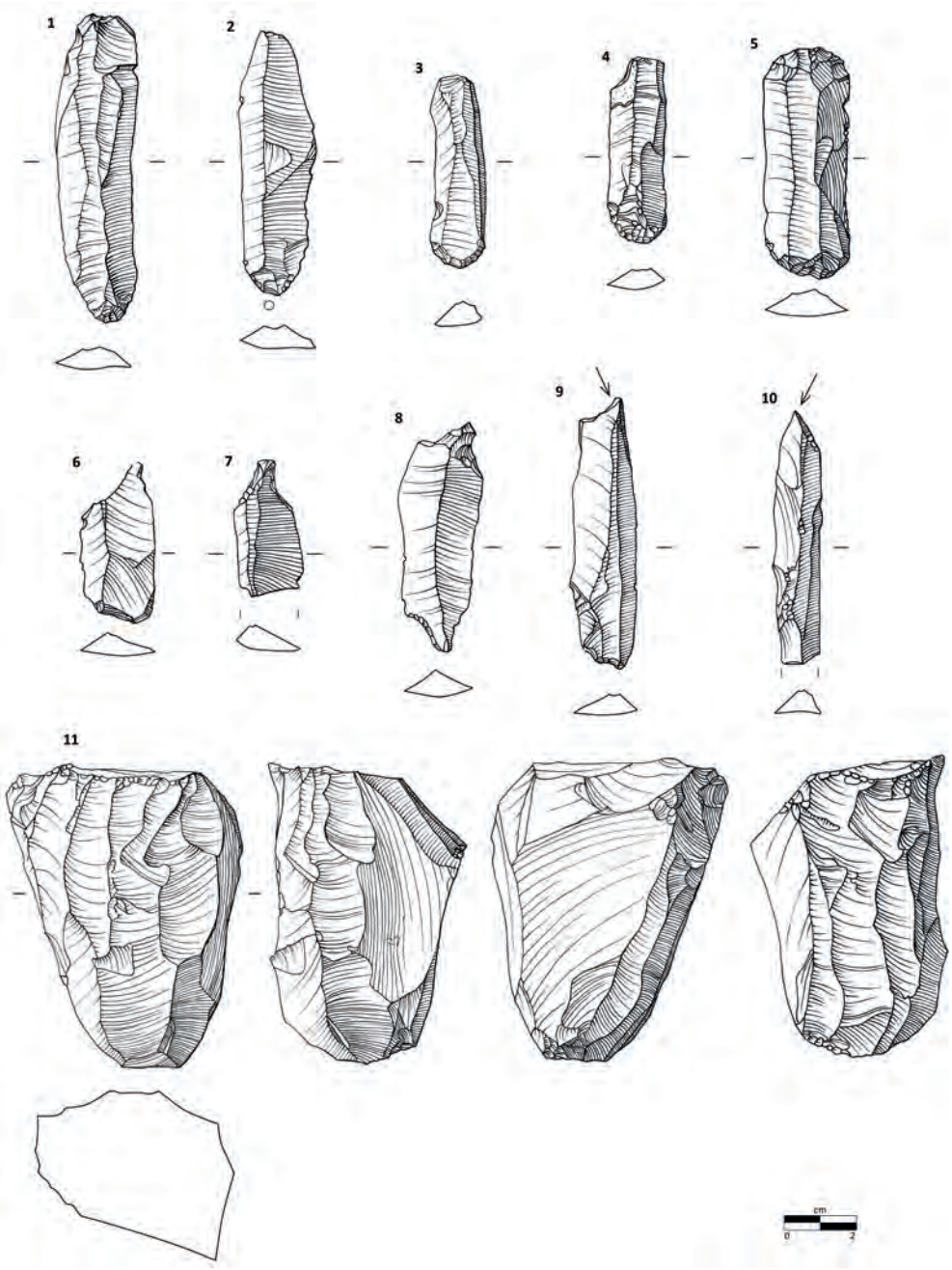
- Using a mixed-method approach to identify the artefactual signatures of individuals in order to quantify and hence qualify the technological and morphological variability inherent in the Hamburgian culture;
- Deploying ethnographic data on hunter-gatherer demographic collapse as part of quantitative models that reconstruct past population dynamics;
- Using climate datasets of the Last Glacial Maximum with the archaeological data of the Hamburgian culture, in order to evaluate the relationship between the archaeological record and climate conditions in time and space and by doing so, construct distribution models for the Hamburgian culture.

The aim of the project is therefore to generate new empirical data through these multi-scalar analytical tracks. If the hypothesis is correct, we will need to significantly re-think how we conceptualize Palaeolithic 'cultures' in general, how we see hunter-gatherers adapting to climate change and how vulnerable such groups are to changing climates. This particular and iconic episode of the 'first immigration' of people into what is today Denmark may need to be substantially revised. The first papers arising from this project are being published. This project contributes to theme [1] Fundamental Biodiversity Dynamics and theme [4] Interdisciplinary Innovations of BIOCHANGE.

KEY PAPER

Riede, F. and **J.B. Pedersen**. 2018. Late glacial human dispersals in Northern Europe and disequilibrium dynamics. Human Ecology 46:621-632.

The project currently employs one PhD student supported by an AU Arts Faculty PhD Fellowship supervised by Felix Riede and co-supervised by Associate Professor Signe Normand from BIOCHANGE.



Stone tools from the site of Jels 3' in southern Jutland: blades (1-2), blade end scrapers (3-5), single and double Zinkens (6-8), burins on blade (9-10) and single faced dual platform blade core (11). The area around the Jels Lakes was one of the bridgeheads for the earliest human colonization of southern Scandinavia.

Drawings: Louise Hilmar, MOMU.

BIOSENS:

SENSING BIODIVERSITY CHANGE AND ITS DRIVERS

1 3

Principal investigator: Signe Normand

The newest sensor technology mounted on drones (Unmanned Aerial System, UAS) provides novel opportunities for assessing how biodiversity and its drivers change at ultra-high spectral (wavelengths in nanometres), structural (dense 3D point clouds), spatial (millimeter to meters), and temporal (days to years) resolution. In particular, combining measurements of highly differentiated spectrometric signals and detecting the range of emitted laser light pulses, show great potential for simultaneously assessing the functional, structural, and taxonomic components of biodiversity, as well as its environmental drivers (e.g. hydrology, topography, nutrient status). BIOSENS is one of the first projects worldwide that combines the newest hyperspectral and LiDAR sensor technology for UAS with a detailed assessment of temporal and spatial changes in local diversity and ecological parameters. Since 2017, repeated droneflights have been conducted across a controlled grassland experiment (in Bern, Switzerland), with controlled levels of plant diversity, as well as across a natural grassland with substantial variation in plant diversity, vegetation structure, function, and ecological factors (Rewilding area, Mols, Denmark). Simultaneously, highly detailed and spatially explicit information on plant diversity and structure have been measured with traditional ecological methods and hand-held hyper-spectral sensors.

Using the LiDAR data collected across the Rewilding area, Mols, Denmark, we have been able to recognize and map specific shrub species in 3D. We especially targeted the classification of *Cytisus scoparius*, because of the particular concern in landscape management (Fig. 1), and we successfully estimated biomass changes between autumn 2017 and spring 2018. The next steps are to understand the drivers of these changes.

With the grassland experiment in Switzerland, we have a unique opportunity to test different UAS set-ups in a controlled environment (Fig. 2). Thus, we are currently evaluating the accuracy of plot-scale biomass estimates from non-destructive LiDAR measurements, and how vegetation can be assessed using structural features. Furthermore, we will use hyperspectral measurements from 20 different grassland species to analyze the impact from manipulative treatments (nitrogen additions and pathogen exclusion) on the performance of recognizing taxonomic and functional diversity. This project contributes to theme [1] Fundamental Biodiversity Dynamics and theme [3] Ecoinformatics and New Technologies of BIOCHANGE.

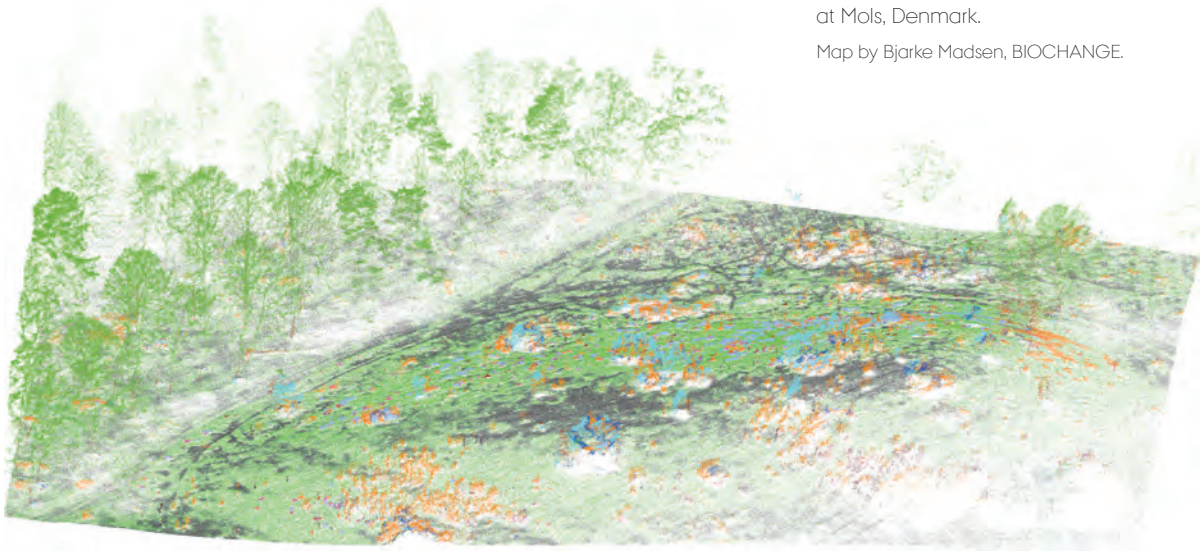


Figure 1. Classification of *Cytisus scoparius* landscape at Mols, Denmark.
Map by Bjarke Madsen, BIOCHANGE.

The project is funded by the Carlsberg Foundation Distinguished Associate Professor Fellowships from 2017-2020. It currently employs one PhD student.

CARLSBERG FOUNDATION

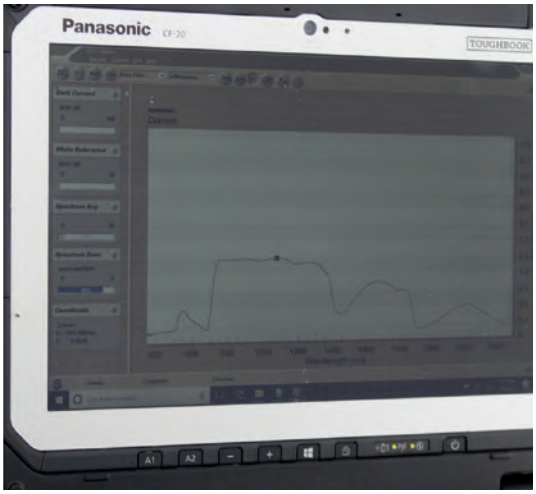


Figure 2. Impressions from fieldwork in Bern (catching spectral measurements of *Crepis biennis* and *Centaurea jacea*).
Photos: Urs A. Treier, BIOCHANGE.

KEY PAPER

Moeslund, J.E., **A. Zlinszky**, R. Ejrnæs, A.K. Brunbjerg, **P.K. Bøcher**, **J.-C. Svenning**, and **S. Normand**. 2019. Light detection and ranging explains diversity of plants, fungi, lichens, and bryophytes across multiple habitats and large geographic extent. Ecological Applications. (e-pub ahead of print).

DRONE ECOLOGY:

THE MISSING LINK FOR CROSS-SCALE INTEGRATION IN ECOLOGY

1 3

Principal investigator: Signe Normand

How and why the fate of individuals, populations, and species vary across space and time is a fundamental question in ecology. Currently, a prominent gap exists in our knowledge on the local dynamics of individuals, their drivers, and how they scale to the dynamics of species distributions across space (centimeters to biomes) and time (years to millennia). Closing the scale gap is essential for understanding vegetation dynamics under global change and their related biodiversity, ecosystem, and societal consequences. The aim of this project is two-fold: (1) investigating the degree to which drone-based remote sensing contribute to closing the scale-gap and add distinctive insight on vegetation dynamics by analyzing a unique data set of ground-based observations of vegetation composition and drone-imagery sampled across Greenland, and (2) establishing and consolidating the infrastructure and competences needed for mastering unique and innovative applications of drone-based remote sensing to answer questions in ecology. The project substantially contributed to establishment of the UAS4Ecology Lab, a research facility using Unmanned Aerial System (UAS) technology in combination with novel sensor technology (see BIOSENS) to address ecological questions.

With climate warming, shrub cover is expected to expand upward in elevation. Detecting vegetation change with imagery requires that models are transferrable across time and space. To quantify the likelihood with which we can detect vegetation change in the future, we assessed the transferability of vegetation classification across 108 plots randomly stratified across altitudes (Kolyaie *et al.* in press). We find good transferability of Arctic shrub cover classification, which is promising for vegetation monitoring using image classification of ultra-high spatial resolution imagery acquired with hand-held cameras or from drones.

Quantification of shrub cover and land-cover classification are essential for monitoring and change detection purposes, as well as upscaling of various ecosystem processes. In Karami *et al.* (2018), we combined Landsat 8 data with drone-based and field-based observations collected across Greenland and were able to produce a land-cover classification map with a resolution of 30 m across Greenland.

Shrub dynamics is periodically affected by insect outbreaks. Linking information from wood anatomy to satellites we have mapped the spatiotemporal extent of outbreaks in Western Greenland (see key paper under sDYN). This project contributes to theme [1] Fundamental Biodiversity Dynamics and theme [3] Ecoinformatics and New Technologies of BIOCHANGE.

KEY PAPERS

Karami, M., A. Westergaard-Nielsen, **S. Normand**, **U.A. Treier**, B. Elberling, and B.U. Hansen. 2018. A phenology-based approach to the classification of Arctic tundra ecosystems in Greenland. ISPRS Journal of Photogrammetry and Remote Sensing 146:518-529.

Kolyaie, S., **U.A. Treier**, G.R. Watmough, **B. Madsen**, **P.K. Bøcher**, A. Psomas, R. Bösch, and **S. Normand**. 2019. Transferability and the effect of colour calibration during multi-image classification of Arctic vegetation change. Polar Biology. (e-pub ahead of print).

Wüest, R.O., N.E. Zimmermann, D. Zurell, J. Alexander, S.A. Fritz, C. Hof, H. Kreft, **S. Normand**, J.S. Cabral, E. Szekely, W. Thuiller, M. Wikelski, and D.N. Karger. Accepted. Macroecology in the age of big data – where to go from here? Journal of Biogeography.

The project is funded by the Aarhus University Research Foundation Starting Grant from 2016-2020. It currently employs one PhD student and one research assistant.

Photo: Bjarke Madsen, BIOCHANGE.

sDYN:

CROSS-SCALE INTEGRATION OF ARCTIC SHRUB DYNAMICS

1 2 3

Principal investigator: Signe Normand

Collection of shrub individuals for dendroecological analyses at one of the sDYN field sites in Greenland in 2018.
Photo: Urs A. Treier, BIOCHANGE.

The project is funded by the Sapere Aude Research leader grant, Danish Council for Independent Research from 2018-2022. One postdoc and two PhD students are currently employed in this project, which closely collaborates with several national and international collaborators as well as BIOCHANGE associate, postdoc Angela Luisa Prendin.

DANMARKS FRIE FORSKNINGSFOND
INDEPENDENT RESEARCH FUND DENMARK

Climate warming is expected to have pronounced effects on the functioning of Arctic ecosystems. However, evidence show substantial variation in the response of woody plants to recent warming across sites. sDYN will provide new insight on Artic shrub dynamics and their variation across space and time by a novel integration of satellite- and drone-based remote sensing, functional traits, dendroecology, and dynamic modelling. The empirical basis for this integration is a unique data set on growth, recruitment, cover, and functional traits collected simultaneously with drone-based surveys at multiple sites across large-scale climatic gradients in Greenland, a large randomly stratified sample of vegetation cover across Greenland, and new cross- and landscape scale mapping of shrub dynamics, and their geophysical drivers (further reading about this specific field site under Field Campaigns). sDYN is expected to provide the scientific basis for an improved understanding and prediction of ongoing and future vegetation dynamics in the Arctic. This project contributes to theme [1] Fundamental Biodiversity Dynamics, theme [2] Global Challenges, and theme [3] Ecoinformatics and New Technologies of BIOCHANGE.

KEY PAPER

Prendin, A.L., M. Carrer, **M. Karami**, J. Hollesen, N.B. Pedersen, M. Pividori, **U.A. Treier**, A. Westergaard-Nielsen, B. Elberling, and **S. Normand**. Accepted. Immediate and carry-over effects of insect outbreaks on vegetation growth in West Greenland assessed from cells to satellite. Journal of Biogeography.

BIORATES:

RATES OF BIODIVERSITY CHANGE DUE TO HUMAN INDUCED GLOBAL ENVIRONMENTAL SHIFTS

1 2

Principal investigator: Alejandro Ordonez Gloria

Earths environmental and biological setup is changing due to human activities, a transformation that is leaving lasting impacts on ecosystems processes and services. These changes would result in the emergence of novel ecosystems when the environmental and biological step transformations cross a tipping point. While much work has focused on establishing the most likely causes for the recorded biological reorganization of ecosystems over the last decades, we have limited knowledge of how these responses take place and the rates at which they occur. BIORATES aims to provide the first systematic evaluation of the links between changes in environmental composition and multiple aspects defining the biological structure of an ecosystem. By doing this, BIORATES will establish the anthropogenic and ecological factors that have the most substantial influence in determining shifts in different levels of biological organization (Fig 1). This project will contribute to theme [1] Fundamental Biodiversity Dynamics and theme [2] Global Challenges of BIOCHANGE.

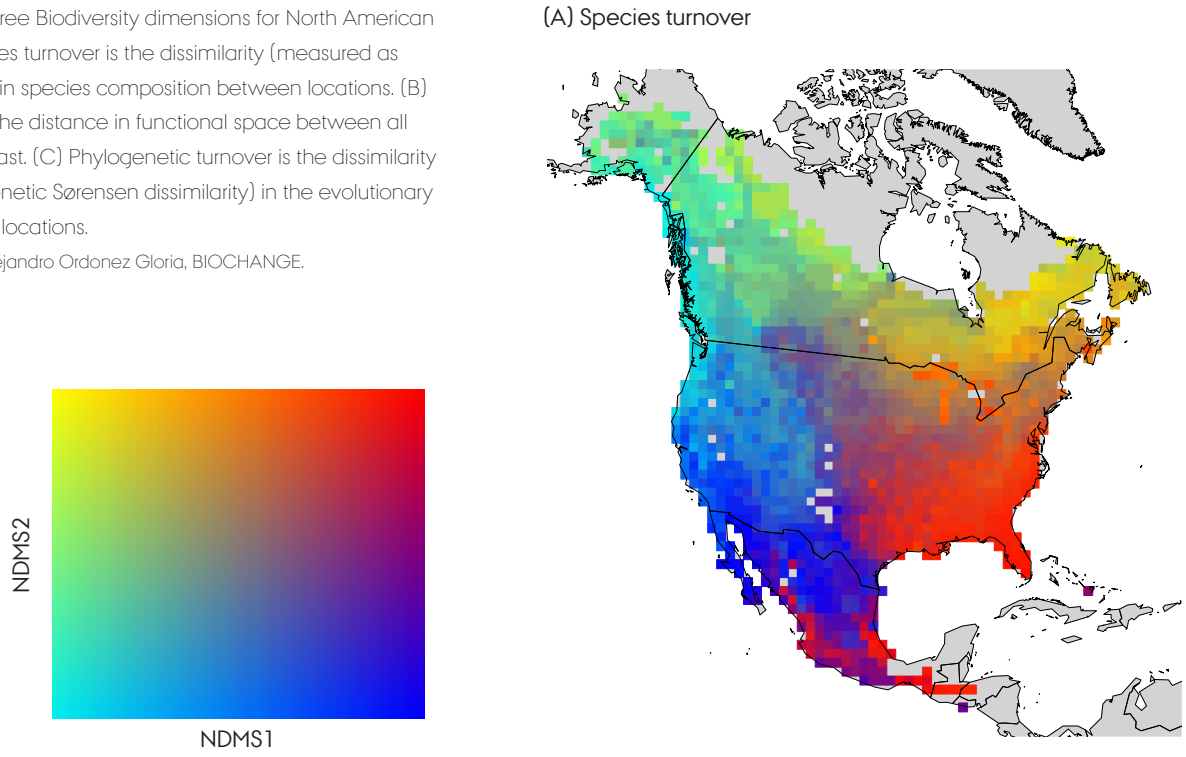
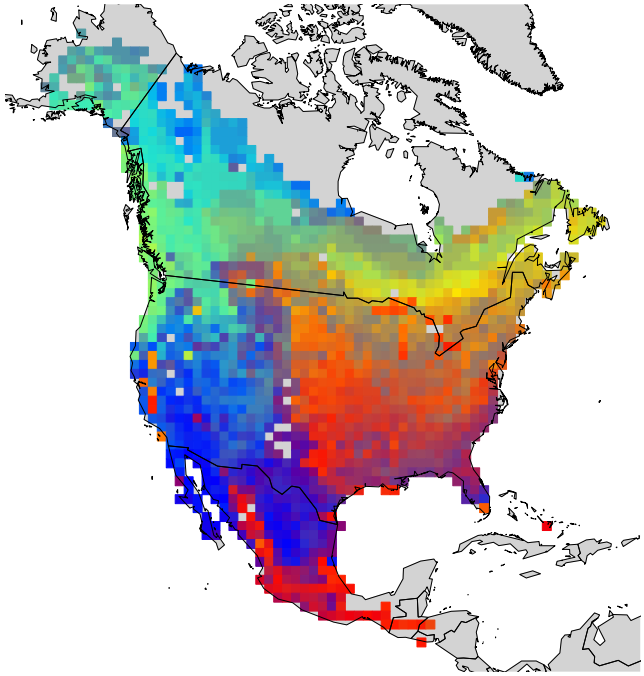


Figure 1. Turnover in three Biodiversity dimensions for North American tree species. (A) Species turnover is the dissimilarity (measured as Sørensen dissimilarity) in species composition between locations. (B) Functional turnover is the distance in functional space between all pairwise species contrast. (C) Phylogenetic turnover is the dissimilarity (measured as Phylogenetic Sørensen dissimilarity) in the evolutionary composition between locations.
Maps: Wubing Xu and Alejandro Ordonez Gloria, BIOCHANGE.

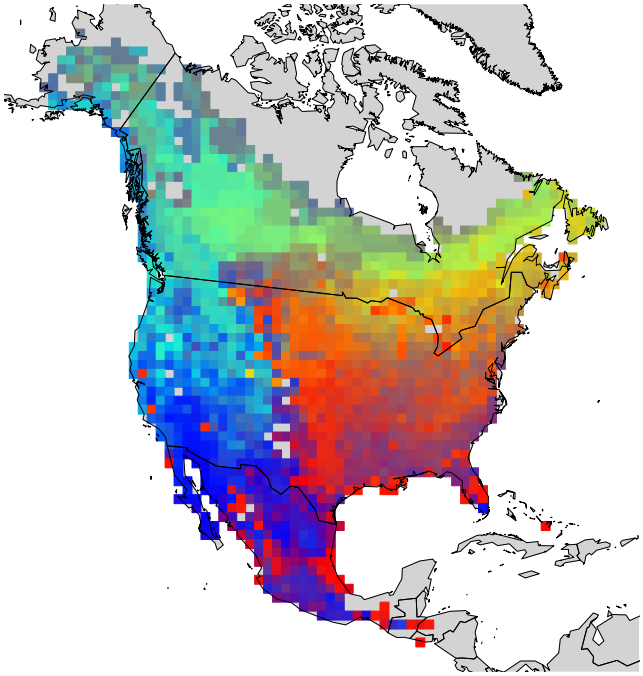
The project is funded by the Aarhus University Research Foundation with 1,900,000 DKK and runs from 2018-2020. It currently employs one postdoc.

AARHUS UNIVERSITETS FORSKNINGSFOND
AARHUS UNIVERSITY RESEARCH FOUNDATION

(B) Functional turnover



(C) Phylogenetic turnover



MMSDI:

MAASAI MARA SCIENCE AND DEVELOPMENT INITIATIVE

1 2 4

Chair: Jens-Christian Svenning

The Greater Mara Ecosystem in Kenya is facing a multitude of interconnected, complex challenges, which can be divided into four main categories: (1) land use and climate challenges, (2) ecosystem challenges, (3) political and economic challenges, and (4) human and cultural challenges. The Maasai Mara Science and Development Initiative (MMSDI) is an African-European cooperation between University of Nairobi, Aarhus University, Kenya Wildlife Trust, Karen Blixen Camp Trust, and the local Mararianta Community in Maasai Mara, Kenya, initiated to address these through interdisciplinary research and development activities. Therefore, the MMSDI operates as a multi-stakeholder platform with representatives from academics, business, organizations and local citizens as members of the core structure of the initiative. The overall aim of the partnership is to develop initiatives with a clear goal: to contribute to conserving the Greater Mara ecosystem with its rich wildlife and culture through interdisciplinary research and development initiatives. It is the hope that intense knowledge exchange with the many stakeholders of the Maasai Mara will give valuable inputs to the research about core challenges and research questions and provide data to the research projects. In return, research outputs can support decision makers in developing sustainable solutions.

The initiative was founded in 2014 as a response to the urgent need for action in the area. It is funded by the individual members conducting research in the area supported by the Karen Blixen Camp in Mara North. Center director Jens-Christian is chair of MMSDI and several members of BIOCHANGE are involved in the initiative. This project contributes to theme [1] Fundamental Biodiversity Dynamics, theme [2] Global Challenges, and theme [4] Interdisciplinary Innovations of BIOCHANGE.

Further reading:
http://maasaimarascience.org/

MMSDI meeting for the Aarhus group in August 2018.

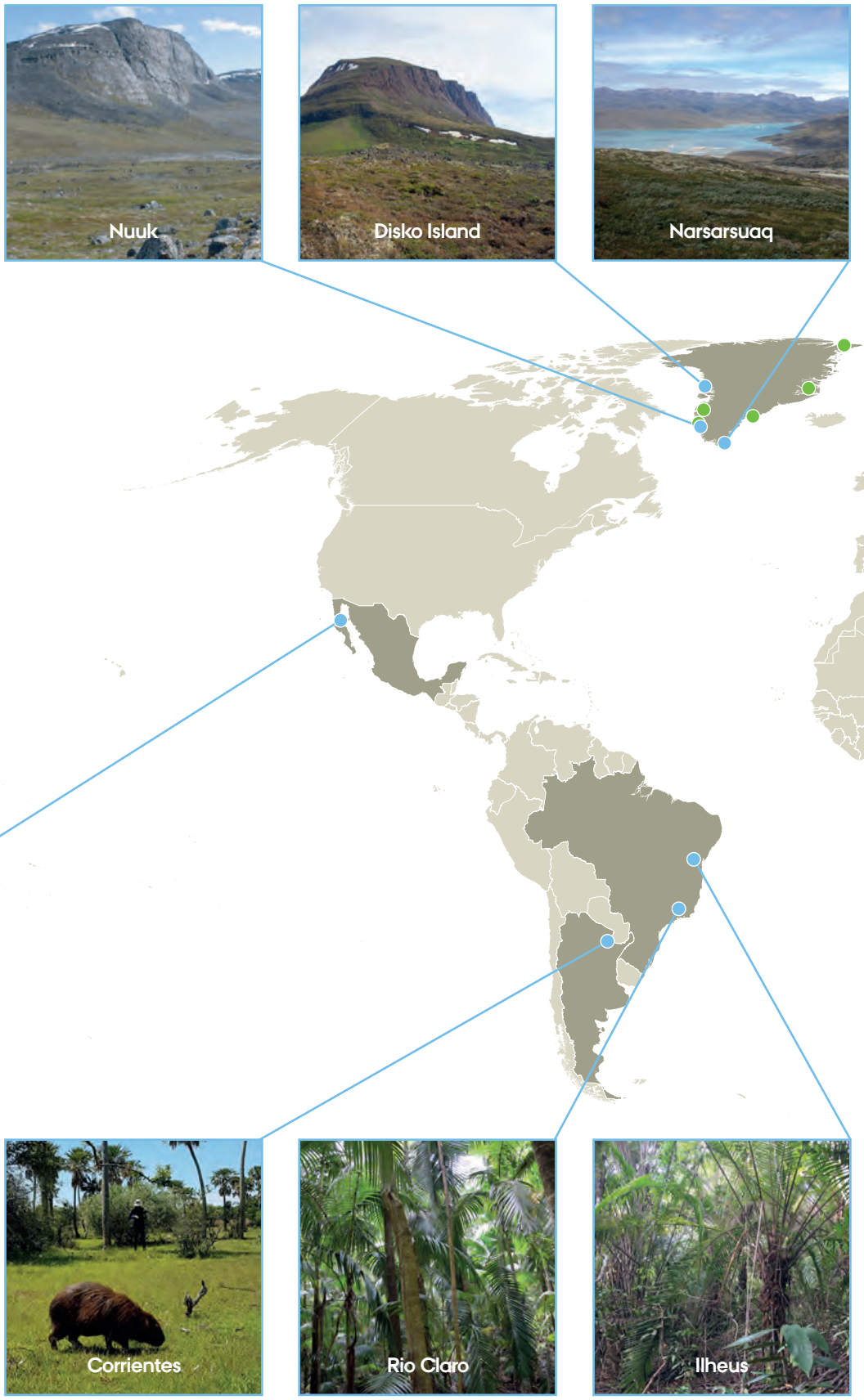
Photo: Anne Blach Overgaard, BIOCHANGE.

Maasai Mara
Science and Development Initiative

Representatives from MMSDI (from left BIOCHANGE members Peder Klith Bøcher, Jens-Christian Svenning, and Anne Blach Overgaard, and Jesper Stagegaard, Director at Ree Park, Denmark) at the conference, Partnerships for a sustainable future – the 17 UN Sustainable Development Goals, held at Aarhus University, Denmark in February 2019.
Photo: Sebastian Ottl.

Participants and lecturers at a recent advanced GIS course provided by BIOCHANGE for local NGOs, stakeholders and researchers in Maasai Mara held at Karen Blixen Camp May 2019, Mara North Conservancy, Maasai Mara, Kenya.
Photo: Peder Klith Bøcher, BIOCHANGE.

FIELD CAMPAIGNS



Map of the distribution of current (●) and past (●) field sites across the World. BIOCHANGE conducts research in many parts of the World spanning the Arctic to the Tropics. On the following pages, we describe a select of current field campaigns conducted in 2018-2019.

Insert photos by Vincent Fehr, Ditte Arp Jensen, Normand-Treier, Bjarke Madsen, Simon Schowanek, Florian Rudolf Sauer, Anne Blach Overgaard, and Jens-Christian Svenning, BIOCHANGE.


Geding-Kasted
Mols
Northern Hessia
Bern
Ticino
Muling
Tianmu
Hluhluwi-iMfzolozi Park
Kruger National Part
Maasai Mara
Zhaojia

MAASAI MARA – A WORLD-FAMOUS NATURAL HERITAGE SITE UNDER PRESSURE

MAASAI MARA, KENYA

The Maasai Mara in Kenya is one of the World's most famous natural areas, due its rich savanna wildlife including its million-plus migration of wildebeests and zebras. However, the Mara savanna ecosystem is under increasing pressure. Wildlife numbers are declining, and local pastoralist populations are strongly growing and undergoing strong societal changes. The traditional pastoral lifestyle is changing and private land subdivided into smaller plots, which are often fenced and hinders the movement of larger animals and competing with increasing numbers of livestock.

Figure 1. Measuring vegetation structure in Maasai Mara National Reserve in 2018.
Photo: Michael Munk, BIOCHANGE.

Our research aim is to better understand the Mara ecosystem dynamics, including the roles of its wild megafauna, and the Maasai and their livestock in shaping biodiversity, ecosystem structure, processes, and services, such as fire spread, carbon sequestration, water infiltration, evaporation, erosion control, and the availability and quality of grass, with the aim of providing a scientific basis for a future ecologically sustainable management of this key natural heritage site. Two large field campaigns have been conducted in Maasai Mara since the start of BIOCHANGE, in November 2017 and February 2018 (Fig. 1). The main aim has been to build a baseline for time series studies and calibrate satellite remote sensing data for classification studies with collected ground validation data. These data have been used in two studies. The first has been submitted and reveals widespread and accelerating land degradation within the Maasai Mara since 1985. Initial results from the second study show very promising land cover maps, with substantially more de-

Figure 2. (A) BIOCHANGE research vehicle kindly provided by Karen Blixen Camp, Mara North Conservancy, Kenya. (B) A typical fence marking private land plots in Maasai Mara.
Photos: Michael Munk, BIOCHANGE.

tail than has been possible previously. During May 2019, another team of BIOCHANGE researchers conducted a trip to Maasai Mara to acquire ground truthing data. The objectives of this field trip was to establish a profound sampling database of GPS-tagged photos to be used for ground truthing of satellite-based land-cover classification and satellite-based registration of fences (Fig 2). The fieldwork aimed at sampling as many GPS tagged photos of the terrain as possible across Maasai Mara National Reserve, Mara North Conservancy, Pardamat Conservation Area, and Olare Motorogi Conservancy. Overall, more than 3,000 GPS tagged photos were acquired (Fig. 3).

A second aim of the various field trips has been to establish contacts with local stakeholders, expand the collaboration with scientists and managers in the local community, and promote interdisciplinary research relevant for region-specific conservation. A stakeholder meeting with local reserve managers, NGO's and Kenyan scientists in February 2018 identified the scope for local capacity building in the form of GIS training. In May 2019, Peder Bøcher (GIS specialist) and Wang Li (Postdoc in remote sensing) hosted a 1-week GIS course in Mara North Conservancy for 22 participants from local stakeholders (see Research Training and Education).

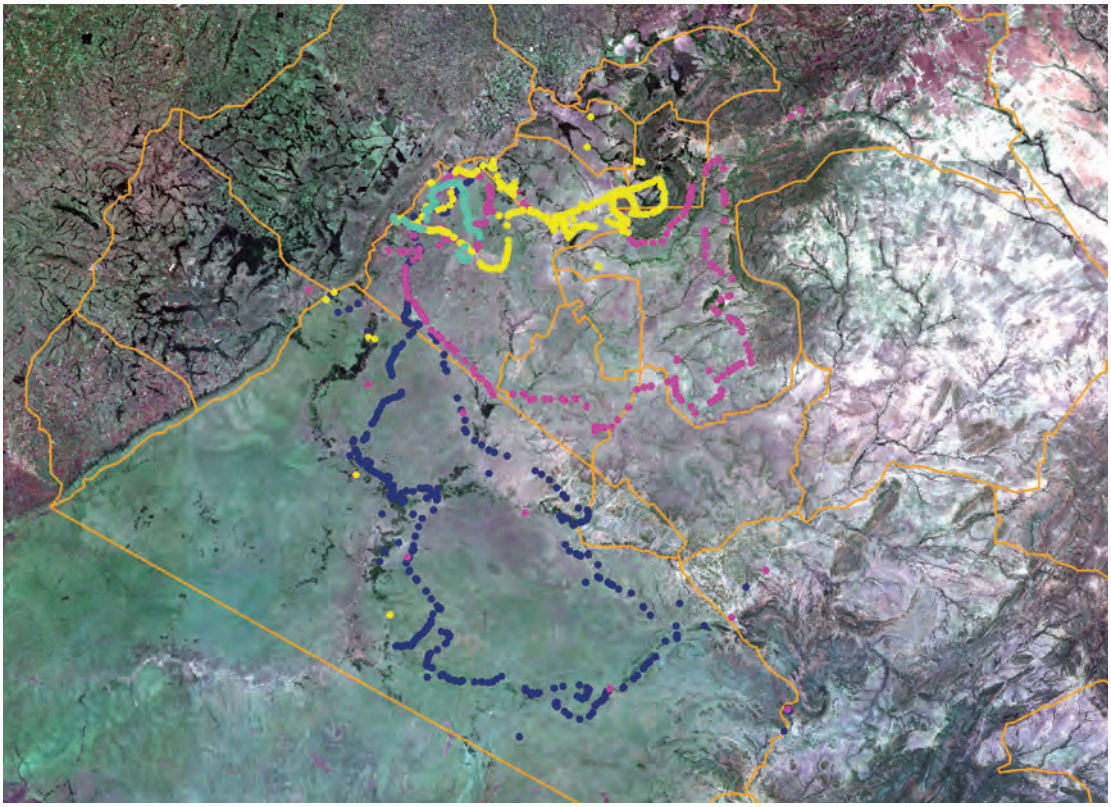


Figure 3. Map of the distribution of GPS-tagged photos of the terrain across several conservancies in MAasai Mara, Kenya.
Map by Peder Klith Bøcher, BIOCHANGE.

TROPHIC REWILDING IN THE GLOBAL SOUTH

CORRIENTES, ARGENTINA

Trophic rewilding is a new idea for ecological restoration, and is centered around restoring the top-down trophic processes via re-establishment of missing species (typically megafauna) to promote self-regulating biodiverse ecosystems. In this project, we focus on a key understudied biome, namely the South America savannah region. South America formerly harbored a very rich megafauna, but was depleted of most of it as humans colonized the continent at the end of the Pleistocene (± 12,000 years ago), with further losses continuing up through history to the present day. Surviving species persist only at low densities, often in small refugia or on unproductive land. The loss of megafauna resulted in the loss of ecological functions. However, the large-scale ecological consequences of losing megafauna remain understudied, hampering planning, restoration and management toward a biodiverse future. At our field-sites in Argentina's Corrientes province, we work toward filling these knowledge gaps.

A particularly important unanswered question is to what extent the loss of megafauna has changed vegetation structure, as vegetation forms the backbone of terrestrial ecosystems. The ratio and spatial distribution of e.g. forest, savanna, and grassland has large consequences for overall biodiversity and for ecosystem functioning, e.g. carbon sequestration and fire frequency.


A


B


C

Figure 1. (A) Capybara, (B) vegetation sampling within exclosure plot, and (C) herbivore exclosure.

Photos: Dennis Pedersen (A, C), and Jens-Christian Svenning (B), BIOCHANGE.

Figure 2. (A) Traditional vegetation plot to measure vegetation structure and composition. (B) Terrestrial laser scanning of vegetation structure.

Photos: Dennis Pedersen, BIOCHANGE.

One of our field sites, Rincon del Socorro, is a private reserve (part of Thompkins Conservation: http://www.tompkinsconservation.org/home.htm) with an active rewilding program where locally extinct species such as lowland tapir, pampas deer, and collared peccary are reintroduced. The other Mburucuyá National Park is more of a passive rewilding site, i.e., with passive recovery and no active reintroductions, with both localities being former ranches. To assess impacts of increasing megafauna density we characterize vegetation structure using a combination of traditional vegetation plots and novel terrestrial laser scanning methods. We have established an experiment where we measure herbivore impact on vegetation by excluding megafauna such as capybaras from small fenced areas (Fig. 1). To gain a better understanding of the (potential) impact of different herbivore species, we quantify diet composition using DNA meta-barcoding on fecal material from all major herbivores in the system.

In fall 2018, a major field expedition with six people from BIOCHANGE collected data for four studies incl.: laser scanning of vegetation to quantify vegetation structure, the first re-measurement of the herbivore exclosures (that were set up during the previous field campaign 6 months prior), collecting 246 herbivore dung samples, used to quantify diets of different species during both the dry and wet season, and finally we mapped the distribution of capybara, one of the main herbivores in the ecosystem, throughout our five study reserves in the region (Fig. 2). In May 2019, a second re-measurement of vegetation growth, structure and composition in the herbivore exclosures was conducted.

MEGAFAUNA REWILDING IMPACTS IN SOUTH AFRICAN SAVANNAS

ASSOCIATION OF PRIVATE GAME RESERVES, KRUGER NATIONAL PARK, AND HLUHLUWI-IMFZOLOZI PARK, SOUTH AFRICA

In 2018/2019, we have initiated field campaigns in South Africa to assess the effects of restoring highly diverse megafaunas (megafauna-based rewilding), focused on Kruger National Park and associated private game reserves in the Lowveld region as well as Hluhluwi-iMfzolozi Park in central KwaZulu-Natal.

There is increasing focus on restoring historically depleted large-herbivore assemblages as a means to facilitate self-managing biodiverse ecosystems (i.e. trophic rewilding). At the same time, our knowledge of the ecological and biodiversity effects of such megafauna restoration is limited. Our project addresses this knowledge gap through field-based studies in South African savanna, making use of the numerous nature reserves in the region with varied levels of restored megafaunas. Specifically, our research investigates how elephant and white rhino indirectly influence flora and fauna communities through herbivory and habitat modification. These species are mega-herbivores (weighing at least 1000 kg), a functional group of especially high ecological importance and formerly widespread across most continental areas, but now highly depleted. The research aims to assess the ecological effects of restoring these mega-herbivores, e-g., on fire regimes, on smaller herbivores and their ecological effects, and on wildlife diversity.

A landscape-scale field survey was conducted in 2019 to determine if grass and woody vegetation composition and structure, ground wood density and connectivity and tree hollow size, density and location varied within the wider Kruger National Park region. The field survey data will be supplemented by long-term flora and fauna datasets (1994 – 2018) and satellite imagery to determine historical fauna densities and grass biomass. In addition to the landscape-scale survey, a small-scale experiment was set-up at ten sites to determine how meso-herbivore grazing pressure and behavior (assessed using wildlife trail cameras) varied with landscape openness and grass cover across the wet – dry season transition. A second small-scale experiment was also set-up at twelve sites to determine how the density and occupancy of hollow dwelling fauna (e.g. birds; assessed using audio sound recorders) varied between areas with high and low tree hollow densities.

Where elephants remain, they regularly attain high local densities, often leading to large impacts on the woody vegetation and intense discussions about whether the number of elephants has become too high. This so-called elephant problem has sparked lots of research. Despite this, we still have a limited understanding of which woody plant species perform well and which do not in the presence of elephants. Our research tries to develop a more mechanistic understanding of how woody plants defend themselves against elephants by identifying the various ways they deal with elephant damage.

During recent fieldwork (spring 2019), we measured tree functional traits (such as: thorn size, wood density, leaf strength), the selection preferences of elephants, and the tree demographic trends in Hluhluwi-iMfzolozi park in collaboration with Umeå University, Nelson Mandela University, and Ezemvelo KZN Wildlife. Using this data, we will analyze whether knowing the ecological characteristics of a tree can help us predict which species survive in the face of elephant impact. By unravelling the mechanism by which trees sustain elephant impact, we hope we can help mitigate the "elephant problem" in areas where elephants remain or become restored as well as shed light on the vegetation changes that happened when proboscidean mega-herbivores went extinct elsewhere.

Impressions from our two field sites in South Africa. (A) Landscape across the Hluhluwi-iMfzolozi Park, (B) elephant in Kruger National Park, (C) camera trap used to determine meso-herbivore grazing pressure and behavior, and (D) hollow tree where density and occupancy of hollow dwelling fauna are measured. Photos: Simon Schowanek (A, B) and Christopher Edward Gordon (C, D), BIOCHANGE.

FIELD CAMPAIGNS


A


B


C


D

PALMS AS GENERATORS OF NOVEL ECOSYSTEMS

BRAZIL, MEXICO, SWITZERLAND

Figure 1. In Southern Brazil the Australian Alexander palm is building monodominant stands in subtropical rainforest. Photo: Vincent Fehr, BIOCHANGE.

Human activities are increasingly generating novel ecosystems without historical precedent, notably by moving species around the world. While the increasing emergence of novel ecosystems is widely recognized, our understanding of their ecological properties and capacity for sustaining biodiversity remain rudimentary. Here, we address this key question, focusing on palms due to the ecological and societal importance. The fact that palms are of high value for humans (e.g. as ornamental plants or by providing food, building material, handcrafts, fuel and medicine) has led to an expanded distribution of many palm species into regions far away from their natural habitat, with some species being recognized as naturalized or even invasive. Palms are often keystone species in ecosystems where they occur naturally, interacting with the local biota e.g. through mutualistic relationships. Due to their distinctive architecture, palms shape the vegetation structure in a particular way. Based on these reasons, we expect that non-native palms may strongly affect composition, interactions and functioning of ecosystems, finally resulting in novel ecosystems.

Here, we aim to uncover ecosystem effects of non-native palms by focusing on four non-native invasive palm species in four dif-

Figure 2. The Middle Eastern date palm is dominant in San Ignacio, a desert oasis in Baja California, Mexico.
Photo: Vincent Fehr, BIOCHANGE.

Figure 3. A window trap to collect flying arthropods in a forest patch in Southern Switzerland invaded by the Chinese windmill palm.
Photo: Vincent Fehr, BIOCHANGE.

ferent biomes around the world. This entails extensive fieldwork in three different countries: Switzerland (Chinese windmill palm), Brazil (two sites: Alexander palm, Fig. 1, and African oil palm) and Mexico (Date palm, Fig. 2). Due to the key roles of palms, we examined a broad range of ecosystem components and variables (e.g. richness of plants, arthropods and soil inhabiting cryptic groups, vegetation structure, light regime, litter accumulation and air temperature), which we hypothesize may respond to the presence of non-native palms in invaded plots and uninvaded control plots.

Between March 2018 and February 2019, we successfully conducted fieldwork at all four study sites. We applied novel sampling techniques such as a handheld 3D laser scanner to measure vegetation structure. We also collected soil samples to analyze the presence of soil-inhabiting cryptic groups (e.g. fungi and other microorganisms) by extracting environmental DNA of the samples. In the next months, we will analyze the data. We will also start processing the soil samples (DNA extraction, PCR) and developing metrics for the laser scanner data (point clouds) to describe the vegetation structure.

In Southern Switzerland, we are running a case study focusing on the effects of the non-native, invasive Chinese windmill palm on the diversity, abundance and biomass of various guilds of arthropods and on the process of litter decomposition. Studying how non-native plants affect the arthropod community is crucial to understand the effects of plant invasions on higher trophic levels as a huge number of organisms depend on arthropods as prey. Additionally, key ecosystem processes like leaf litter decomposition and pollination are also directly influenced by arthropods.

The arthropods are collected between May and August 2019 using various sampling methods (e.g. pitfall and window traps, Fig. 3). We will monitor the process of litter decomposition under site-specific conditions by accounting for the weight loss of leaf-litter material in litterbags. The litterbags have been installed in February 2019 and they will be collected by the end of July 2019.

TROPHIC REWILDING IN A DANISH NATIONAL PARK

MOLS AND GEDING-KASTED MOSE, DENMARK

The Natural History Museum Aarhus initiated trophic rewilding in 2016 by introducing 13 Exmoor horses and 13 Galloway cattle on 120 hectares at the Mols Laboratory, one of the most biodiverse and varied landscapes in Mols Bjerge National Park and a biodiversity hot spot for Denmark (Fig. 1). The large herbivores is regulated only by culling of individuals that fall below a set of welfare thresholds based on their body condition and behavior. By spring 2019, the two populations have grown to 65 individuals in total.

The ecosystem is expected to be affected especially by direct feeding and trampling effects on the vegetation by the cattle and horses, but also by their dispersal of nutrients and propagules via their movement and defecation activities. For arthropods, a range of direct and indirect effects are expected as changes in vegetation composition, vegetation structure, resources and abiotic environments can have dramatic impacts on invertebrate communities.

In 2017, an exclosure experiment was set up by BIOCHANGE researchers and Natural History Museum Aarhus to investigate and monitor how biodiversity dynamics are affected by rewilding with large herbivores. The experiment compares rewilding to four different alternative scenarios: (1) mowing, (2) only summer grazing (the typical grazing management approach in Denmark), (3) only winter grazing (to assess the specific role of having large herbivores in the system in the stressful winter period, where they may forage on less ideal food sources, such as woody plant parts), and (4) leaving the area to free succession without the impacts by large herbivores (Fig. 2).

Camera traps aimed at arthropod activity and density together with a temperature logger at 45 cm above ground, were set up in 2018 at two of the five treatments, shooting photos in more than 179 days through the season. Other arthropod traps were active in spring, summer and autumn.

Figure 1. Galloway cattle at the Mols Laboratory. Photo: Oskar L.P. Hansen, BIOCHANGE.

Annual vegetation surveys and drone campaigns have been conducted across the area to map and understand different elements of plant diversity. The drones have been equipped with basic RGB cameras, advanced multispectral and LiDAR sensors, which potentially will provide new perspectives in the way we monitor vegetation. In 2018/2019, three BSc and one MSc students have been involved in projects relating to the ecological dynamics in the Mols rewilding experiment, including horse and cattle behavior and space use as well as vegetation and arthropod dynamics.

Similar work has been initiated in Geding-Kasted Mose (Fig. 3), a relatively small rewilding site on the western edge of Aarhus. Here Galloway cattle, Konik horses and water buffalo have been introduced in the summer of 2016. During fall 2018 and spring 2019, four BSc students collected data on herbivore movements, habitat use, behavior and diet, and conducted vegetation surveys to quantify the impact of grazing on vegetation structure and plant diversity.

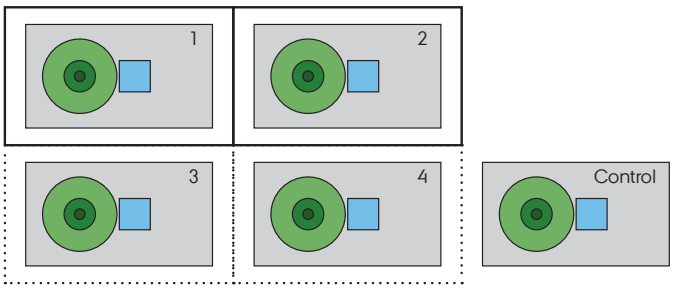


Figure 2. Schematic representation (not to scale) of our experimental rewilding block design at Mols consisting of one control plot (no treatment), and four sub-plots where four alternative rewilding scenarios will be tested: In permanent exclosures (black solid line): (1) mowing and (2) free succession (no herbivory from large animals); In seasonal exclosures (dotted line): (3) summer grazing only, and (4) winter grazing only. Green concentric circles denotes plot sizes used for vegetation sampling across scales. Blue rectangles indicate areas where arthropod traps are positioned within each sub-plot.

Modified after drawing by Simon Schowanek, BIOCHANGE.

Figure 3. Konik horses and water buffalos at Geding-Kasted Mose, Aarhus.
Photo: Jens-Christian Svenning, BIOCHANGE.

SEARCHING FOR ROCK SHELTER SITES TO TEST THE HUMAN IMPACTS OF THE LATE PLEISTOCENE LAACHER SEE ERUPTION

NORTHERN HESSIA, GERMANY

Associated with the 'Apocalypse Then?' project, our on-going field campaign in the Federal State of Hesse in Central Germany aims to find new archaeological sites that preserve volcanic ash of the Laacher See volcanic eruption c. 13,000 years ago and layers containing archaeological finds above and/or below the ash. The goal is to investigate the influence of the cataclysmic event on human lifeways in the medial zone of the eruption. To locate these sites, we have built a predictive model that draws on our data on the ash spread across Europe (Fig. 1), digital elevation data and a legacy database of potential rock shelter locations. Previously, the legacy database contained more than 700 entries, which were evaluated regarding their archaeological potential based on our model (Fig. 2). Using the predictions, two surveys were conducted in November 2017 and March 2018 during which 80 different locations were visited. In 2018, three of these sites were selected for fieldwork.

Figure 1. The currently known distribution of volcanic ash from the Laacher See eruption.
Map: Florian Rudolf Sauer, BIOCHANGE.

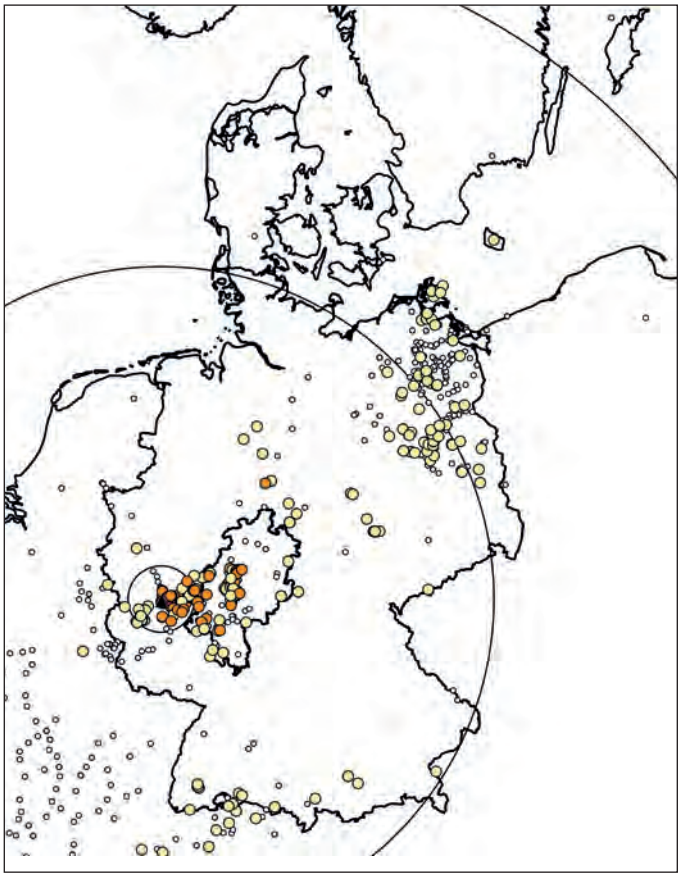
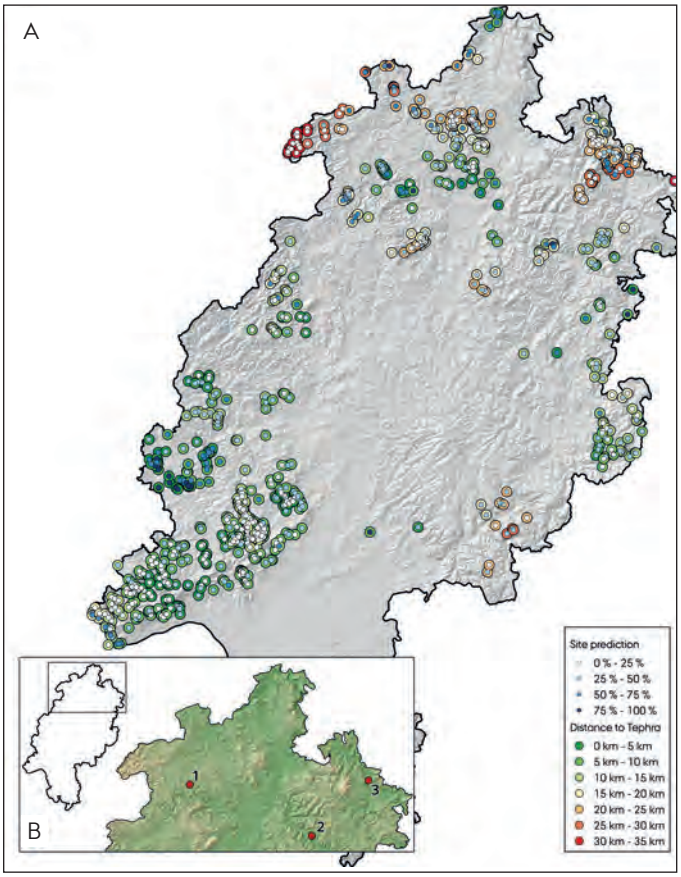


Figure 2. (A) Predictions on the rock shelter database of the Federal State of Hesse combined with the distance to the next known tephra outcrop. (B) Sites selected for fieldworks (1: Alraft 1 & 2, 2: Wetterstein, 3: Baumbach).
Map: Florian Rudolf Sauer, BIOCHANGE.



Despite our best efforts, none of the tested sites revealed preserved layers of ash or layers dating to the late ice age at all. Contrary to our expectations, sediment preservation was not adequate. At one site, Wetterstein, we did encounter interesting archaeological remains dating as far back as the Neolithic, a period that is associated with pottery and a range of other new tool forms and signals the arrival of agricultural populations and lifestyles in Europe (Fig. 3).

Locating sites that preserve intact layers of this age is difficult – but we are not giving up. For the coming campaign in 2019, the sites of Ellerstein and Kupferbach-Dammühle have been selected. Permission as in place for the autumn of 2019, and especially the Ellerstein site looks promising (Fig. 4). We look forward to continuing this pioneering search.

Figure 3. Finds of Neolithic pottery from the Wetterstein site. Photo: Felix Riede, BIOCHANGE.

Figure 4. The Ellerstein site as surveyed in late 2017. Photo: Felix Riede, BIOCHANGE.

SHRUB DYNAMICS AND MICROCLIMATIC VARIATION ACROSS AN ARCTIC LANDSCAPE

DISKO ISLAND, GREENLAND

Insight on ongoing and future shrub dynamics is essential for assessing related climate feedbacks and their impact on biodiversity. Microclimate is expected to profoundly affect shrub community composition and diversity, growth, recruitment, and their functional trait variation. However, shrubs communities also affect microclimate. The overall aim of the field campaign on Disko Island for 8 weeks during summer of 2019 is to understand how local patterns of shrub diversity and microclimate interacts and scale across the landscape. The field campaign consists of four components: (1) Landscape scale mapping of microclimate, vegetation productivity, cover, spectral diversity, structural heterogeneity, and terrain features with RGB, multispectral, and thermal sensors, as well as site-wise area mapping with UAS-LiDAR (c. 100×100m). (2) The degree to which soil moisture and micro-climatic variation explain variation in plant species richness, intra-specific trait variation, wood-plant growth, and recruitment. We aim at minimum 100 plots distributed randomly stratified across the landscape. Climate and soil moisture loggers as well as the drone imagery will be used for the landscape scale mapping, and for regional climate down-scaling. (3) Assessment of the relationship between plant-species richness and geodiversity (i.e., the variation in geological structure etc.) (4) Understanding the magnitude of dark-diversity in Arctic plant communities.

Photos: Urs A. Treier, BIOCHANGE.

RESEARCH TRAINING AND EDUCATION

RESEARCH TRAINING

One of the objectives of BIOCHANGE is to be a platform for excellent research training. In collaboration with Section for Ecoinformatics and Biodiversity (ECOINF), Department of Bioscience and Graduate School of Science and Technology (GSST), BIOCHANGE offers advanced research training for PhD students, aimed at those at the center and section, but open to and attended by students also from Aarhus University more broadly, as well as from other universities from Denmark and beyond. Two PhD courses have been conducted in the past year on Remote sensing, and on LiDAR for Ecology. In addition, BIOCHANGE has recently hosted an advanced GIS course for NGOs, local stakeholders and researchers in Maasai Mara, Kenya.

BIOCHANGE and ECOINF host weekly journal clubs for all postdocs and PhD students in the group as well as periodical discussion groups on specific research topics organized by BIOCHANGE postdocs. All PhD students are offered to participate in international workshops and conferences and are on research exchange stays abroad at international institutions during their PhD program in accordance with the rules and regulations of GSST. BIOCHANGE PhD students are actively involved in BSc and MSc courses at Aarhus University, as teaching assistants, or do other outreach work in special cases.

PHD AND OTHER ADVANCED COURSES

PhD course on Airborne LiDAR for ecology

The objective of the course was to teach the participants the theoretical knowledge and practical skills necessary to use LiDAR to produce data relevant for ecological mapping and analysis. Topics covered was: (1) The physical basis and functioning of LiDAR systems, (2) The advantages and limitations of LiDAR for ecological applications, (3) Terrain modelling and analysis with LiDAR for ecological studies, (4) Visualization and interpretation of LiDAR datasets, (5) Quantifying vegetation structure from point clouds, (6) Using radiometric and waveform information for vegetation mapping, (7) Biodiversity modelling from LiDAR data, (8) Vegetation classification with LiDAR on raster and point cloud basis, and (9) Planning and execution of LiDAR campaigns for ecology (including airborne and UAV platforms). The course took place at Aarhus University in September 2018. The course was organized by BIOCHANGE senior core member Signe Normand and led by BIOCHANGE alumni Postdoc András Zlinszky. Additional lectures included: Prof. Norbert Pfeifer and Lukas Winiwarter from GEO TU Vienna, and Postdoc Jesper E. Moeslund from Aarhus University with help from BIOCHANGE member Urs A. Treier.

Photo: Signe Normand, BIOCHANGE.

PhD course on High-resolution satellite- and drone-based remote sensing in Environmental Sciences

The objective of the course was to give the participants the tools and insight needed to get started with using high-resolution remote sensing data to answer questions of relevance for environmental sciences. Specifically, the course introduced the students to: (1) Image processing in the ENVI software, (2) Pixel-based classification methods in ENVI, (3) Image segmentation and object-based classification approaches in the eCognition software, (4) Change detection techniques, (5) Unmanned aerial image processing and data handling methods, and (6) Data download and handling in Google Earth Engine. The course alternated between lectures, where the students were introduced to different methods, and exercises, where the students applied the methods to various image data sets. The course was led by Interdisciplinary lecturer Gary Watmough from The University of Edinburgh (BIOCHANGE alumni), BIOCHANGE member Urs A. Treier, and organized by BIOCHANGE senior core member Signe Normand. The course took place at Aarhus University in November 2018.

Photo: Urs A. Treier, BIOCHANGE.

Advanced GIS course for NGOs, local stakeholders and researchers in Maasai Mara, Kenya

In May 2019, BIOCHANGE hosted a 1-week advanced GIS course aimed at NGOs, local stakeholders, and researchers in Maasai Mara, Kenya. The participants (22 in total) represented the following organizations: Mara Elephant Project, Save the Elephants, Lions Guardians, Kenya Wildlife Trust – Mara Predator Conservation Program, Lion Guardians, Nairobi University, Maasai Mara University, Enonkishu Stakeholders Company, Mara North Conservancy, and Karen Blixen Camp. The objective of the course was to elevate the participants' GIS skills relevant for their field of work. The course was carried out as a residential course at Karen Blixen Camp, Mara North Conservancy in Maasai Mara, Kenya. Over the very busy week, they covered the following subjects: (1) Extended vector and raster analysis, (2) Handling and analysis of GPS and animal movement data, (3) LiDAR data analysis with specific focus on terrain analysis, (4) Thorough introduction to remote sensing, and (5) LiDAR data analysis with specific focus on vegetation structure analysis. BIOCHANGE member Peder Klith Bøcher (GIS specialist) planned and led the course with the help from BIOCHANGE postdoc Wang Li (postdoc in remote sensing), and Dr. Irene Amoke from Kenya Wildlife Trust. Dr. Jake Wall from Mara Elephant Project provided a ½-day course on animal movement analysis.

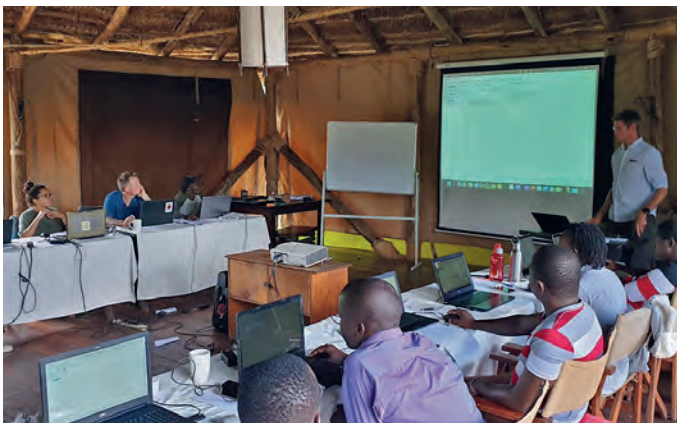


Photo: Peder Klith Bøcher, BIOCHANGE.

JOURNAL CLUB

BIOCHANGE hosts a weekly journal club jointly with ECOINF. The journal club is open to all ECOINF & BIOCHANGE post-docs and PhD students (including visitors). The journal club is led by Center Director Jens-Christian Svenning jointly with 1-3 early-career scientists, which circulates among group members (this year: BIOCHANGE postdocs Scott Jarvie, Susanne Vogel, and Wenyong Guo). Each person takes a turn presenting an important, exciting or thought-provoking recent paper (preferably published in the last two months of a meeting) from his or her field (in a broad sense). The aims of the journal club are to create an active and stimulating environment in which ideas and methods are discussed, as well to improve communication skills and critical sense towards scientific works, and to broadening the attendants' perspective on different topics beyond their specific field of study. General thematic areas covered are: Ecology/Conservation/Restoration/Remote sensing/Geography/Human ecology. In the journal club, we aim to create interactive discussions about the papers from different points of view of all the participants. The group discusses the scientific value of the paper, methodological procedures, work impact on its specific field, and implication for the projects of the group.

Photo: Michael Munk, BIOCHANGE.

DISCUSSION GROUPS

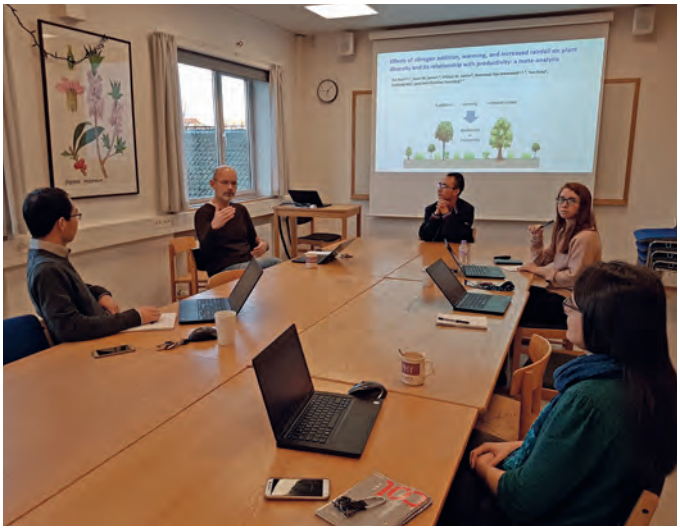


Photo: Anne Blach Overgaard, BIOCHANGE.

Different discussion groups have covered the following overall topics in the past year:

- Remote Sensing
- Socio-ecological systems
- Megafauna

EDUCATIONAL ACTIVITIES

Photo: Bjarke Madsen, BIOCHANGE.

The senior members of BIOCHANGE are responsible for and involved in the teaching of several BSc and MSc courses and in the supervision of project- BSc and MSc students.

BSc AND MSc COURSES

- Biogeography & Macroecology (Aarhus University, 10 ECTS)
- Danish Flora and Vegetation (Aarhus University, 10 ECTS)
- Geographic Information Systems (GIS) (Aarhus University, 5 ECTS)
- Statistical and Geospatial Modelling (Aarhus University, 10 ECTS)
- Geospatial Ecology (Sino-Danish Center for Education and Research (SDC), jointly with Graduate University of Chinese Academy of Sciences (GUCAS), 3.75 ECTS)
- Cultural-Historical Overview (Aarhus University, 10 ECTS)
- Prehistoric archaeology 1: Stone Age (Aarhus University, 10 ECTS)
- Natural science in archaeology 1 (Aarhus University, 15 ECTS)
- Natural science in archaeology 2 (Aarhus University, 10 ECTS)
- Archaeological data analysis (Aarhus University, 20 ECTS)

BSc AND MSc STUDENTS

BSc

- Anja Lisby (BSc)
  Supervisors: Alejandro Ordonez Gloria and Adam M. Reitzel (University of North Carolina at Charlotte)
- Anne T. Holst (BSc)
  Supervisors: Jens-Christian Svenning, Claus Rasmussen (Aarhus University) and Oskar L. P. Hansen
- Astrid Andersen (BSc)
  Supervisor: Signe Normand
- Astrid Holm Andersen (BSc)
  Supervisors: Jens-Christian Svenning and Peder Klith Bøcher
- Birgitte Hyldahl Ptak (BSc)
  Supervisor: Signe Normand
- Cecilie Kristensen (BSc)
  Supervisor: Signe Normand
- Clarissa Gernow (BSc)
  Supervisor: Signe Normand
- Jens Peter Paulsen (BSc)
  Supervisor: Jens-Christian Svenning
- Johannes N. Udsen (BSc)
  Supervisors: Jens-Christian Svenning and Peder Klith Bøcher
- Kathrine Andreasen (BSc)
  Supervisor: Felix Riede
- Lea Bach Sloth (BSc)
  Supervisors: Jens-Christian Svenning and Robert Buitenwerf
- Line Ochelka (BSc)
  Supervisors: Jens-Christian Svenning and Robert Buitenwerf
- Malene S. Pejstrup (BSc)
  Supervisors: Jens-Christian Svenning and Robert Buitenwerf
- Mathilde Mikkeline Holst Stoltze (BSc)
  Supervisor: Signe Normand
- Mathilde Skjoldager (BSc)
  Supervisor: Signe Normand
- Nanna R. Svendsen (BSc)
  Supervisors: Jens-Christian Svenning and Robert Buitenwerf
- Signe S. Bay (BSc)
  Supervisors: Jens-Christian Svenning and Robert Buitenwerf
- Thomas Hansen (BSc)
  Supervisors: Jens-Christian Svenning and Christopher Gordon
- Tine E. Andersen (BSc)
  Supervisors: Jens-Christian Svenning and Robert Buitenwerf

MSc

- David Houborg (MSc)
  Supervisors: Jens-Christian Svenning and Robert Buitenwerf
- Elisabeth B. Slæggerup (MSc)
  Supervisors: Signe Normand and Urs A. Treier
- Fenja Marie Winther (MSc)
  Supervisors: Jens-Christian Svenning and Maya Pasgaard (ECOINF)
- Julie K.M. Drud (MSc)
  Supervisors: Jens-Christian Svenning and Robert Buitenwerf
- Jonas Andersen (MSc)
  Supervisor: Jens-Christian Svenning
- Katrine Hvid Andersen (MSc)
  Supervisors: Anders Barfod (ECOINF) and Signe Normand
- Kåre Würtz (MSc)
  Supervisors: Jens-Christian Svenning and Oskar L.P. Hansen & Kent Olsen (Natural History Museum)
- Lars Christian Aage (MSc)
  Supervisors: Signe Normand and Anders Barfod (ECOINF)
- Marie Mønsted (MSc)
  Supervisors: Jens-Christian Svenning and Anne Blach Overgaard
- Markus Mellerup (MSc)
  Supervisors: Jens-Christian Svenning and Robert Buitenwerf
- Mette Grøn (Sino-Danish Center for Education and Research & Copenhagen University) (MSc)
  Supervisors: Jens-Christian Svenning and Peder Klith Bøcher
- Nana Bouvin Christiansen (MSc)
  Supervisor: Signe Normand

Photo: Bjarke Madsen, BIOCHANGE.

COMMUNICATION AND OUTREACH

COMMUNICATION AND OUTREACH

INVITED AND CONTRIBUTED TALKS

September 2018
Jens-Christian Svenning: Introduktion og biodiversitet i det antropocæne. Folkeuniversitetet, Aarhus, Denmark.

Signe Normand: Arktis i det antropocæne. Folkeuniversitetet, Aarhus, Denmark.

Jens-Christian Svenning: Afternoon talk on science communication and networking through social media. AIAS, Aarhus University, Aarhus, Denmark.

Alejandro Ordonez Gloria: Facing the Anthropocene challenge: how species and vegetation databanks can help addressing the ecological problems of a non-analogue future. International Symposium on Mapping Asia Plants, Chinese Academy of Science Institute of Botany (Beijing), China.

October 2018
Felix Riede: Antropocænepokens katastrofer – store og små. Folkeuniversitetet, Aarhus, Denmark.

Jens-Christian Svenning: Uddøden. Folkeuniversitetet, Emdrup, Denmark.

Signe Normand: Modelling species range dynamics: challenges and ways forward. Conference on Past Plant Diversity, Morocco.

November 2018
Felix Riede: Offentlige foredrag i naturvidenskab: Vulkaner og samfund gennem tiderne. Søauditorierne, Aarhus University, Aarhus, Denmark.

Felix Riede: The purpose of the future university. Aarhus University, Aarhus, Denmark.

Jens-Christian Svenning: Om biodiversitetens formindskelse. Bæredygtig Udvikling, UNESCO-ASP-netværksmøde, Aarhus University, Aarhus, Denmark.

Jens-Christian Svenning: A deep-time perspective on Anthropocene woodlands. Woodlands of the Anthropocene: A conference, Aarhus University, Aarhus, Denmark.

Alejandro Ordonez Gloria: Rising novelty in ecosystems and climates: Metrics to understand a no-analogue future. Shanghai Normal Univiversity, China.

December 2018
Signe Normand: Climate-growth variation across the entire ice-free part of Greenland. Center for Permafrost, Copenhagen, Denmark.

Signe Normand: Remote sensing for cross-scale integration of spatiotemporal ecosystem dynamics, Seminar in Next Generation Monitoring – it's about time. Department of Bioscience, Aarhus University, Aarhus, Denmark.

Jens-Christian Svenning: Palæoøkologisk perspektiv på store planteæderes rolle i økosystemer. Workshop om store dyrs rolle i økosystemer, Aarhus University, Aarhus, Denmark.

Jens-Christian Svenning: Humans & biodiversity in the Anthropocene. Urban Atmopsheres workshop, Aarhus School of Architecture, Aarhus, Denmark.

Signe Normand: Biodiversitet i Arktis i en foranderlig verden. Statens Naturhistoriske Museum, Copenhagen, Denmark.

January 2019
Alejandro Ordonez Gloria: Rising novelty in ecosystems and climates: Metrics to understand a no-analogue future. International Biogeography Society 9th Biennial Conference, Malaga, Spain.

Jens-Christian Svenning: A biogeographic perspective on trophic rewilding. International Biogeography Society 9th Biennial Conference, Malaga, Spain.

Jens-Christian Svenning: Trophic rewilding – background, opportunities and challenges for megafauna-based restoration in the Anthropocene. The past is a foreign country: how much can the fossil record actually inform conservation? Discussion Meeting, Royal Society, London, England.

Jens-Christian Svenning: En forskningsbaseret fremtidsvision for Danmarks natur. Biodiversitetssymposiet, Aarhus University, Aarhus, Denmark.

Signe Normand: LiDAR bidrager til at forstå variation i biodiversitet på tværs af trofiske niveauer/ LiDAR explains variation in diversity across trophic levels. Biodiversitets symposiet, Aarhus University, Aarhus, Denmark.

Signe Normand: Cross-scale integration for improved understanding of vegetation & biodiversity dynamics. Tovetorp workshop, Stockholm University, Stockholm, Sweden.

Felix Riede: Moments of crisis – volcanic eruptions, environmental impacts and societal change in the northern past. Edinburgh University, Edinburgh, Scotland.

February 2019

Jens-Christian Svenning: Trophic rewilding – background, opportunities and challenges for megafauna-based restoration in the Anthropocene. Netherlands Annual Ecology Meeting (NAEM), Lunteren, The Netherlands.

Jens-Christian Svenning: The long-term base-line for nature in Denmark. Dansk Flora & Vegetation, Department of Bioscience, Aarhus University, Aarhus, Denmark.

March 2019

Signe Normand: Cross-scale integration for improved understanding of biodiversity dynamics. BACI final meeting. Jena, Germany.

Jens-Christian Svenning: Vild natur med store vilde dyr i Danmark – hvorfor og hvordan? Folkeuniversitetet, Nysted, Denmark.

Jens-Christian Svenning: Biodiversitet og SDG15. VL gruppe 44, Aarhus, Denmark.

April 2019

Jens-Christian Svenning: Trophic rewilding – background, opportunities and challenges for megafauna-based ecosystem restoration in the Anthropocene. Institute of Botany, Chinese Academy of Sciences, Beijing, China.

Jens-Christian Svenning: Late-Quatenary megafauna extinction – a global perspective with special attention to islands and the island rule. Island Biogeography and Biodiversity Conservation Workshop, Thousand Island Lake Field Station, Zhejiang University, China.

Peder Klith Bøcher: The use of GIS and remote sensing for studying fragmentation. Island Biogeography and Biodiversity Conservation Workshop, Institute of Botany, Chinese Academy of Sciences, Beijing, China.

Jens-Christian Svenning: Vildere natur i Danmark – Hvorfor, hvordan og hvor? Forskningens Døgn, Aarhus University, Aarhus, Denmark.

Jens-Christian Svenning: Trophic rewilding – Megafauna-based restoration in the Anthropocene. Department of Biology, University of Southern Denmark, Odense, Denmark.

May 2019
Signe Normand: Disturbance and vegetation dynamics in Arctic ecosystems. Workshop on Disturbance and recovery dynamics, Goslar, Germany.

Jens-Christian Svenning: Naturværdier i et bystrategisk perspektiv. Et bæredygtigt Østjylland, Dansk Byplanlaboratorium, Horsens, Denmark.

Alejandro Ordonez Gloria: Rising Novelty in Ecosystems and Climates: looking to the past to address the challenges of a human-dominated world. Colombia Pontificia Universidad Javeriana, Columbia.

Jens-Christian Svenning: Trophic rewilding – background, opportunities and challenges for megafauna-based restoration in the Anthropocene. Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zurich, Switzerland.

MEDIA | DEBATES | NEWS

Below is a selection of examples of media appearances, participation in debates and feature articles by BIOCHANGE senior core members and associates/postdocs/PhD students. BIOCHANGE members have contributed input to many feature articles based on BIOCHANGE research outputs in the last year. As mentioned in the research highlights, four BIOCHANGE papers have resulted in more than 290 international feature articles and at least 145 derived articles as well. For all BIOCHANGE research in total these numbers are even higher. We have only included a fraction of this output below.

September 2018
Signe Normand and Anne Bjorkman: New plants on the block: Taller species are taking over in a warming Arctic (press release). EurekAlert. September 26, 2018

Signe Normand and Anne Bjorkman: Højere plantearter flytter ind i et varmere Arktis (press release). AU – Science and Technology. September 26, 2018

Signe Normand and Anne Bjorkman: Taller plants moving into Arctic because of climate change (press release). EurekAlert. September 26, 2018

Jens-Christian Svenning: Could Pablo Escobar's Escaped Hippos Help the Environment? National Geographic. September 27, 2018

Signe Normand and Anne Bjorkman: Taller plants moving into warmer Arctic. BBC News. September 27, 2018

Jens-Christian Svenning: Colombian drug lord Pablo Escobar's escaped 'cocaine hippos' could be STERILISED because they are breeding like crazy – but some experts say they may be helping the environment. Daily Mail. September 28, 2018

Signe Normand and Anne Bjorkman: Klimaforandringer giver arktiske planter vokseværk. DR. September 29, 2018

October 2018

Vincent Fehr: Descoberta maior palmeira real no antigo Horto de RC. Rio Claro newspaper, Brazil. October 7, 2018

Vincent Fehr: Maior palmeira imperial do mundo é moradora da Feena em Rio Claro. TV Rio Claro, Brazil. October 7, 2018

Jens-Christian Svenning and Matt Davis: Mammals cannot evolve fast enough to escape current extinction crisis. EurekAlert. October 15, 2018

Jens-Christian Svenning and Matt Davis: Vi udrydder pattedyr med rekordhast: Naturen er syv millioner år om at komme sig. DR.dk. October 17, 2018

Jens-Christian Svenning and Matt Davis: Så lang tid tager det evolutionen at rydde op efter mennesker. Jyllands-Posten. October 17, 2018

Jens-Christian Svenning and Matt Davis: Udryddelse af vilde dyr overhaler naturens evolution. Kristeligt Folkeblad. October 18, 2018

Jens-Christian Svenning: Rewilding landscapes can help to solve more than one problem. EurekAlert. October 23, 2018

Jens-Christian Svenning: 'Rewilding' landscapes with rhinos and reindeer could prevent fires and keep Arctic cool. Science Magazine. October 23, 2018

Jens-Christian Svenning and Matt Davis: De store dør: Velkommen til de små dyrs verden. Århus Stiftidende. October 27, 2018

Jens-Christian Svenning and Matt Davis: De store dør: Velkommen til de små dyrs verden. Vejle Amts Folkeblad. October 27, 2019

Jens-Christian Svenning: Forskere: Verdens sidste vilde natur er ved at forsvinde. Dr.dk. October 31, 2018

November 2018

Jens-Christian Svenning: Can vanishing wildlife evolve back? Current Biology Magazine 28. November 19, 2018

Jens-Christian Svenning: Hvad er rewilding? Bloom Festival – aftertalk. November 29, 2018

December 2018

Jens-Christian Svenning: As the mammal tree of life suffers hits, should we prioritize which species to save? Mongabay. December 6, 2018

Jens-Christian Svenning: Vilde Klimaplaner. Weekendavisen. December 7, 2018

Jens-Christian Svenning: Rewilding: Hvor langt skal vi tilbage for at genoprette Danmarks oprindelige fauna, og hvem hører egentlig hjemme i dagens danske natur? Verdens skove Nyheder. December 17, 2018

Jens-Christian Svenning: Naturens hjælper eller en plage? Bæveren deler vandene. Dr.dk. December 18, 2018

Jens-Christian Svenning: Naturens hjælper eller en plage? Bæveren deler vandene. TV Avisen DR. December 18, 2018

January 2019

Jens-Christian Svenning: Satellite images reveal global poverty. AU – Science and Technology. January 3, 2019

Jens-Christian Svenning: Satellite images reveal global poverty. EurekAlert. January 7, 2019

Jens-Christian Svenning: Satellitbilleder fortæller mere, end du tror: Afslører fattige områder. DR. January 7, 2019

February 2019

Jens-Christian Svenning and Kristine Engemann: Being surrounded by green space in childhood may improve mental health of adults (press release). EurekAlert. February 25, 2019

Jens-Christian Svenning and Kristine Engemann: Being surrounded by green space in childhood may improve mental health of adults (press release). AU – Science and Technology. February 25, 2019

Jens-Christian Svenning and Kristine Engemann: Greener childhood associated with happier adulthood. NPR. February 25, 2019

Jens-Christian Svenning and Kristine Engemann: Green space good for your child's mental health. U.S. News. February 25, 2019

Jens-Christian Svenning and Kristine Engemann: The growing evidence that living near green space helps kids grow up to be happier. Quartz. February 26, 2019

Jens-Christian Svenning and Kristine Engemann: Klar tendens overrasker forsker: Grønne omgivelser allerede i barndommen er godt for psyken. Politiken. February 26, 2019

Jens-Christian Svenning and Kristine Engemann: Undgå at dit barn får psykiske lidelser: Forskere har fundet løsningen. TV2 Østjylland. February 26, 2019

Jens-Christian Svenning and Kristine Engemann: Aarhusiansk undersøgelse: Børn, der klatrer i træer, har færre psykiske lidelser. Jyllands-Posten. February 26, 2019

Kristine Engemann: Wo Kinder am gesündesten aufwachsen. Die Welt. February 26, 2019

Jens-Christian Svenning and Kristine Engemann: Grønne omgivelser i din barndom gavner måske psyken hele livet. B.T. February 26, 2019

March 2019

Felix Riede: Mild Boars. Archaeology Magazine. March 1, 2019

Jens-Christian Svenning: STAY CURIOUS. Youtube. March 29, 2019

Kristine Engemann: Study finds access to nature in childhood helpts mental health. Landscape News. March 27, 2019

April 2019

Ashley Pearcy Buitenwerf, Jens-Christian Svenning, and Scott Jarvie: Is rewilding viable under climate change? Current Conservation. April 16, 2019

Jens-Christian Svenning and Kristine Engemann: Ökad psykisk hälsa med naturnära barndom. Psykologtidningen. April 16, 2019

Jens-Christian Svenning: Sådan gør man naturen vild og uafhængig (press release). AU – Science and Technology. April 25, 2019

May 2019

Jens-Christian Svenning: A documentary on rewilding by ARTE. ARTE, a European Television Channel. May 11, 2019

Jens-Christian Svenning: Et bæredygtigt Østjylland. Dansk Byplanlaboratorium. May 14, 2019

Kristine Engemann and Jens-Christian Svenning: Green space is good for mental health, Landsat helps establish. NASA Landsat Science. May 22, 2019

Jens-Christian Svenning: Laboratorium – Uddannelse for fremtiden (debate). Naturmødet, Hirtshals. May 23, 2019

Jens-Christian Svenning: Professorpanelet (debate). Bloom Festival, Søndermarken. May 26, 2019

Jens-Christian Svenning: Kødæderne mod planteæderne (debate). Bloom Festival, Søndermarken. May 26, 2019

OTHER OUTREACH ACTIVITIES

This year, one of our major outreach projects has been our collaboration with *Videnskabsklubben* (The Science Club) on developing an entire teaching program titled 'Biodiversity'. *Videnskabsklubben* is an organization enabling children in grades 4–6 to study science in their leisure time. The children are taught and inspired by mentors from grades 7–9 and upper-secondary schools, who create an alternative teaching environment with no adults.

Signe Normand (member of the Young Academy in Denmark) conceived the idea for the teaching program in 2018, an idea, which was developed further by a team of BIOCHANGE researchers and the non-profit organization ROD, and pitched for *Videnskabsklubben* in April 2018 with a successful result. BIOCHANGE represented by Signe Normand (PI), Nina Tofte Hansen (owner of ROD, and employed as project manager on the program), Urs A. Treier, Peder Klith Bøcher, Anne Blach Overgaard, and Jens-Christian Svenning have subsequently collaborated with *Videnskabsklubben* on developing the entire teaching program with the headline Biodiversity. We have worked hard on designing a teaching program that is both exciting, eye opening and intellectually challenging for the children. As part of the program, we have developed games, experiments and outdoor activities, which will help the students getting around central aspects of understanding biodiversity. It has been an exciting challenge for us to translate the latest scientific findings on complex issues like trophic cascades and rewilding into something meaningful for a 12-year old "mini researcher". We are proud of the results, which will be rolled out in schools and upper-secondary schools all over Denmark from fall 2019. For more information on the project, please see: https://www.videnskabsklubben.dk/ (in Danish only).

Photos: Anne Blach Overgaard, BIOCHANGE.

EVENTS

CENTER RETREAT

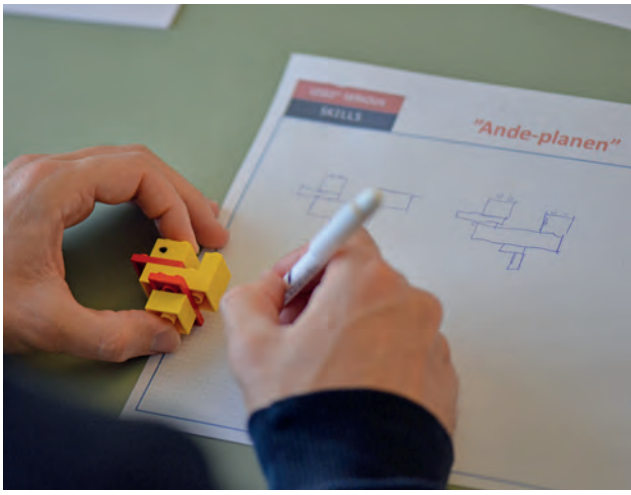
Impressions from our two-day center retreat in Skanderborg, Denmark in April 2019.

Photos: Dennis Pedersen and Anne Blach Overgaard, BIOCHANGE.

On April 29 and 30, 2019, BIOCHANGE hosted its first center retreat at Skanderborg Lake, Denmark. The main aims of the retreat were to get the BIOCHANGE community together in a different setting to provide a platform for team building (with a scientific content) and capacity building through knowledge exchange and skills sharing through a mix of plenary talks, workshops, walk 'n' talks, and activities in smaller groups and of course free time to have fun and interact.

On day one, we wanted to provide insight into the BIOCHANGE vision and objectives, and research themes through talks by our four core members, as we have had a big turnover of early career scientists since our last gathering in April 2018. We also wanted to give people an opportunity to see how everyone is positioned in the center and how the individual research projects fit into the general framework of BIOCHANGE. We did this through an interactive network analysis and a LEGO Serious Play workshop. The network analysis was based on the ranking of different research-related keywords by each person. Everyone was split into various different groups in five rounds, one for each of the BIOCHANGE themes, and one based on shared skills in the group. None of the groups were alike, indicating that we each share research focus and skills sets with many different people in BIOCHANGE and not only with people in our immediate research teams. Adding to this exercise, we introduced LEGO Serious Play in an interactive workshop, which had several aims. Each person built their own research with LEGO bricks and was subsequently asked to use the LEGO build as a visual aid to talk about their research to six other people and relate their research to the four BIOCHANGE themes. We did this in three rounds (with new people) in a scientific speed dating setting. As a final task, everyone had to place connections to other people at their final table to open up for further interactions and/or collaborations amongst the BIOCHANGE members across research teams. As a nice break between indoor activities, teams of four were sent on walk 'n' talks into the forest in the lovely spring weather to talk about what motivates them scientifically and to reflect on the BIOCHANGE objectives presented earlier in the day.

The second day of the retreat focused on capacity building and skills sharing. Ashley Pearcy Buitenwerf opened the day by giving a plenary and interactive introduction to public speaking. This was followed by three concurrent workshops hosted by BIOCHANGE members (Ashley Pearcy Buitenwerf, Scott Jarvie, Peder Klith Bøcher, Kai Yue, Wang Li, Robert Buitenwerf, Michael Munk, Emilio Berti, Susanne Vogel, and Sophie Monsarrat) on dissemination, more public speaking, creating maps in R, meta-analysis dos and don'ts, intro to Google Earth Engine, introduction to the power of photographs, introduction to Linux, and to the potential of Raspberry Pis.


"Ande-planen"


Follow BIOCHANGE on


Rise to these global challenges is a priority...
Business as usual is NOT AN OPTION
without compromising the ability of future generations to meet their own needs.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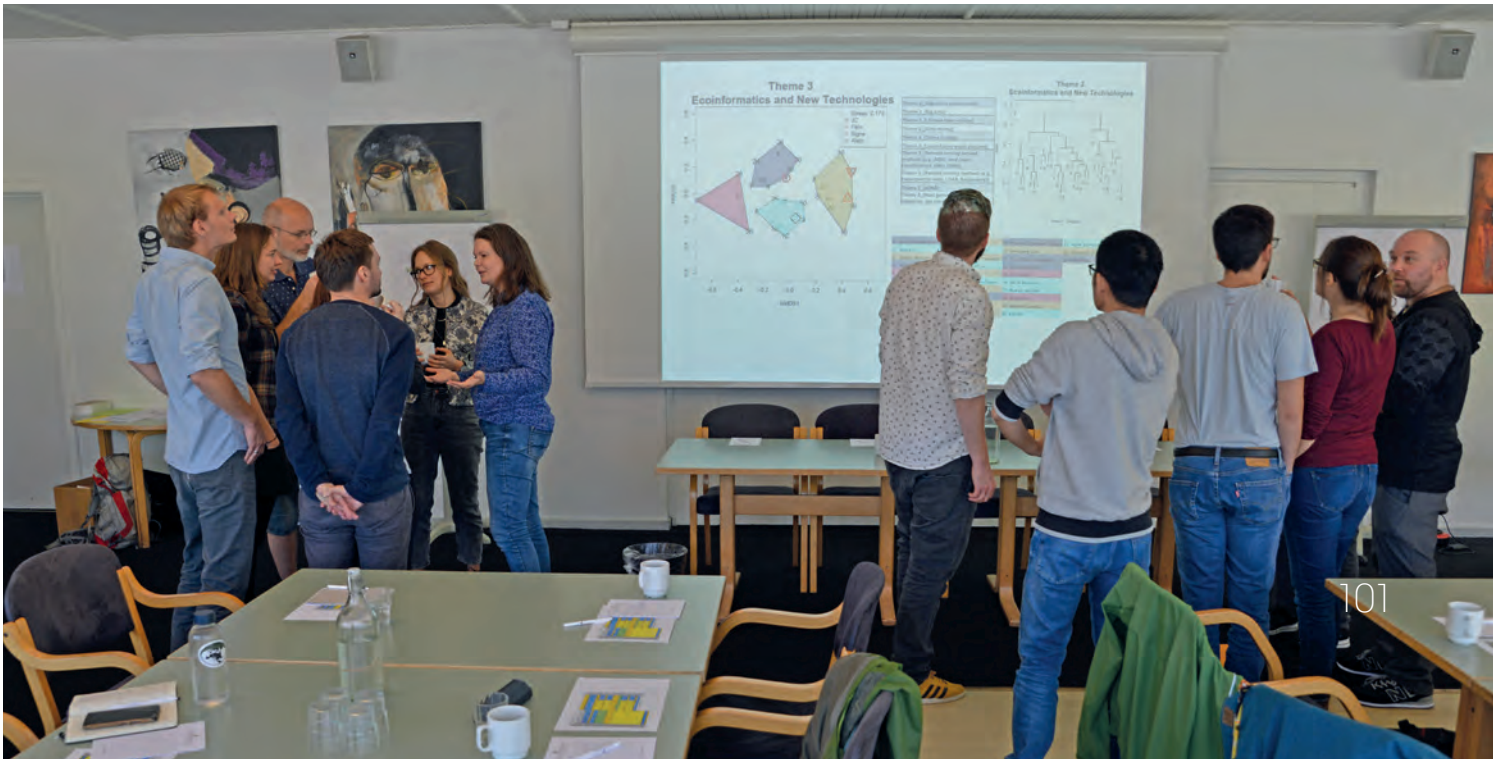
BIOCHANGE
INTERDISCIPLINARY INNOVATION


Theme 3
Ecoinformatics and New Technologies

BIOCHANGE AT THE PARTNERSHIPS FOR A SUSTAINABLE FUTURE – THE 17 UN SUSTAINABLE DEVELOPMENT GOALS CONFERENCE

On February 4, 2019, Jens-Christian Svenning, Peder Klith Bøcher and Anne Blach Overgaard from BIOCHANGE in collaboration with Pernille Kallehave (Dept. of Management), Jesper Stagegaard (Director at Ree Park), and Sebastian Ottl (postdoc, Dept. of Management) participated in AU's conference on "Partnerships for a sustainable future" at the Main Hall at Aarhus University as representatives of the Maasai Mara Science and Development Initiative (MMSDI) (further reading: MMSDI under Research; http://maasaimarascience.org/). MMSDI is an African-European interdisciplinary network of researchers, NGO's, local communities and Ree Park aiming to contribute to solutions to the many challenges of the Maasai Mara. At the conference, we presented the ongoing research in Maasai Mara being conducted at AU with partners from the MMSDI network. Some impressions are shown below.

Photos: Anne Blach Overgaard, BIOCHANGE.

PHD DEFENSES AND QUALIFYING EXAMS

In September and December 2018, we celebrated two successful PhD defenses in the BIOCHANGE Center.

On September 24, 2018, BIOCHANGE Alumni PhD student Pil Birkefelt Møller Pedersen, supervised by BIOCHANGE Director Professor Jens-Christian Svenning, Senior Researcher Rasmus Ejrnæs (Aarhus University), and Assistant Professor Brody Sandel (Santa Clara University, USA), defended her thesis: Ecological consequences and opportunities of rewilding in a European anthropogenic context. Members of the assessment committee consisted of Associate Professor Patrick Jansen (Wageningen University and Research, The Netherlands), Associate Professor Carl-Gustav Thulin (Swedish University of Agricultural Sciences, Sweden), and Chair Associate Professor Signe Normand (Aarhus University).

On December 19, 2018, BIOCHANGE Alumni PhD student Rasmus Østergaard Pedersen, supervised by BIOCHANGE Director, Professor Jens-Christian Svenning and Søren Faurby (University of Gothenburg, Sweden), defended his thesis: How mammals shape the world. Members of the assessment committee consisted of Associate Professor Christian Smit (University of Groningen, The Netherlands), Professor Richard Sibly (University of Reading, UK), and Chair Associate Professor Signe Normand (Aarhus University).

Photos: Anne Blach Overgaard, BIOCHANGE.

In 2018/2019, we have celebrated seven successfully defended qualifying exams by BIOCHANGE PhD students:

Emilio Berti – August 9, 2018
Michael Munk – August 9, 2018
Ditte Arp Jensen – September 20, 2018
Bjarke Madsen – November 12, 2018
Oskar Liset Pryds Hansen – November 15, 2018
Julia Carolina Mata – February 28, 2019
Vincent Fehr – May 13, 2019

PUBLICATIONS

Below BIOCHANGE-related publications published in 2018 and to May 2019 are listed. We have highlighted BIOCHANGE members or associates in bold font. Author lists abbreviated for publications with more than five authors.

Araujo, A.C., *et al.* 2018. Spatial distance and climate determine modularity in a cross-biomes plant–hummingbird interaction network in Brazil. Journal of Biogeography 45:1846-1858. (**J.-C. Svenning**).

Bakker, E.S. and **J.-C. Svenning**. 2018. Trophic rewilding: impact on ecosystems under global change. Philosophical Transactions of the Royal Society B: Biological Sciences 373:20170432.

Bjorkman, A.D., *et al.* 2019. Status and trends in Arctic vegetation: Evidence from experimental warming and long-term monitoring. Ambio. (e-pub ahead of print). (**S. Normand**).

Bjorkman, A.D., *et al.* 2018. Plant functional trait change across a warming tundra biome. Nature 562:57-62. (**S. Normand, A. Blach-Overgaard, U.A. Treier**).

Bjorkman, A.D., *et al.* 2018. Tundra Trait Team: A database of plant traits spanning the tundra biome. Global Ecology and Biogeography 27:1402-1411. (**S. Normand, U.A. Treier**).

Blonder, B., *et al.* 2018. Late Quaternary climate legacies in contemporary plant functional composition. Global Change Biology 24:4827-4840. (**J.-C. Svenning**).

Blong, R.J., **F. Riede**, and Q. Chen. 2018. A fuzzy logic methodology for assessing the resilience of past communities to tephra fall: A Laacher See eruption 13,000 year BP case. Volcanica 1:63-84.

Boulangeat, I., **J.-C. Svenning**, T. Daufresne, M. Leblond, and D. Gravel. 2018. The transient response of ecosystems to climate change is amplified by trophic interactions. Oikos 127:1822-1833.

Brewer, J. and **F. Riede**. 2018. Cultural heritage and climate adaptation: a cultural evolutionary perspective for the Anthropocene. World Archaeology 50:1-16.

Brucet, S., *et al.* 2018. Size diversity and species diversity relationships in fish assemblages of Western Palearctic lakes. Ecography 41:1064-1076. (**J.-C. Svenning**).

Bruelheide, H., *et al.* 2018. Global trait–environment relationships of plant communities. Nature Ecology & Evolution 2:1906-1917. (**A.D. Bjorkman, J.-C. Svenning**).

Buitenwerf, R., B. Sandel, **S. Normand**, A. Mimet, and **J.-C. Svenning**. 2018. Land surface greening suggests vigorous woody regrowth throughout European semi-natural vegetation. Global Change Biology 24:5789-5801.

Bull, J.W., R. Ejrnæs, D.W. Macdonald, **J.-C. Svenning**, and C.J. Sandom. 2019. Fences can support restoration in human-dominated ecosystems when rewilding with large predators. Restoration Ecology 27:198-209.

Castro-Insua, A., C. Gómez-Rodríguez, **J.-C. Svenning**, and A. Baselga. 2018. A new macroecological pattern: The latitudinal gradient in species range shape. Global Ecology and Biogeography 27:357-367.

Ceauşu, S., R.A. Graves, A.K. Killion, **J.-C. Svenning**, and N.H. Carter. 2019. Governing trade-offs in ecosystem services and disservices to achieve human–wildlife coexistence. Conservation Biology 33:543-553.

Chalmandrier, L., *et al.* 2018. Comparing spatial diversification and meta-population models in the Indo-Australian Archipelago. Royal Society Open Science 5:171366. (**J.-C. Svenning**).

Chen, Y., *et al.* 2018. Drivers of macrofungi community structure differ between soil and rotten-wood substrates in a temperate mountain forest in China. Frontiers in Microbiology 9:37. (**J.-C. Svenning**).

Chen, Y., *et al.* 2018. Macrofungal species distributions depend on habitat partitioning of topography, light, and vegetation in a temperate mountain forest. Scientific Reports 8:13589. (**J.-C. Svenning**).

Damgaard, C., B.K. Ehlers, J.C.G. Ransijn, I.K. Schmidt, and **J.-C. Svenning**. 2018. Insights on plant interaction between dominating species from patterns of plant association: expected covariance of pin-point cover measurements of two species. Environmental and Ecological Statistics 25:221-235.

Davis, M., S. Faurby, and **J.-C. Svenning**. 2018. Mammal diversity will take millions of years to recover from the current biodiversity crisis. Proceedings of the National Academy of Sciences 115:11262-11267.

Droissart, V., *et al.* 2018. Beyond trees: biogeographical regionalization of tropical Africa. Journal of Biogeography 45:1153-1167. (**A. Blach-Overgaard, J.-C. Svenning**).

Echeverría-Londoño, S., *et al.* 2018. Plant functional diversity and the biogeography of biomes in North and South America. Frontiers in Ecology and Evolution 6:219. (**J.-C. Svenning**).

Engemann, K., *et al.* 2018. Childhood exposure to green space – a novel risk-decreasing mechanism for schizophrenia? Schizophrenia Research 199:142-148. (**J.-C. Svenning**).

Engemann, K., *et al.* 2019. Residential green space in childhood is associated with lower risk of psychiatric disorders from adolescence into adulthood. Proceedings of the National Academy of Sciences 116:201807504. (**J.-C. Svenning**).

Faurby, S., *et al.* 2018. PHYLACINE 1.2: The phylogenetic atlas of mammal macroecology. Ecology 99:2626-2626. (**M. Davis, R.Ø. Pedersen, S.D. Schowanek, J.-C. Svenning**).

Fløjgaard, C., *et al.* 2018. Are ungulates in forests concerns or key species for conservation and biodiversity? Reply to Boulanger *et al.* (DOI: 10.1111/gcb.13899). Global Change Biology 24:869-871. (**J.-C. Svenning**).

Galetti, M., *et al.* 2018. Ecological and evolutionary legacy of megafauna extinctions. Biological Reviews 93:845-862. (**M. Munk, A.H. Schweiger, J.-C. Svenning**).

Gaucherel, C., C. Tramier, V. Devictor, **J.-C. Svenning**, and C. Hély. 2018. Where and at which scales does the latitudinal diversity gradient fail? Journal of Biogeography 45:1905-1916.

Gaüzère, P., L.L. Iversen, J.-Y. Barnagaud, **J.-C. Svenning**, and B. Blonder. 2018. Empirical predictability of community responses to climate change. Frontiers in Ecology and Evolution 6:186.

Genes, L., **J.-C. Svenning**, A.S. Pires, and F.A.S. Fernandez. 2019. Why we should let rewilding be wild and biodiverse. Biodiversity and Conservation 5:1285-1289.

Girardello, M., *et al.* 2019. Global synergies and trade-offs between multiple dimensions of biodiversity and ecosystem services. Scientific Reports 9:5636. (**J.-C. Svenning**).

Graae, B.J., *et al.* 2018. Stay or go – how topographic complexity influences alpine plant population and community responses to climate change. Perspectives in Plant Ecology, Evolution and Systematics 30:41-50. (**J.-C. Svenning**).

Guadilla-Sáez, S., M. Pardo-de-Santayana, V. Reyes-García, and **J.-C. Svenning**. 2019. Biodiversity conservation effectiveness provided by a protection status in temperate forest commons of north Spain. Forest Ecology and Management 433:656-666.

Jackson, R.C., A.J. Dugmore, and **F. Riede**. 2018. Rediscovering lessons of adaptation from the past. Global Environmental Change 52:58-65.

Jarvie, S. and **J.-C. Svenning**. 2018. Using species distribution modelling to determine opportunities for trophic rewilding under future scenarios of climate change. Philosophical Transactions of the Royal Society B: Biological Sciences 373:20170446.

Jiménez-Alfaro, B., *et al.* 2018. History and environment shape species pools and community diversity in European beech forests. Nature Ecology & Evolution 2:483-490. (**J.-C. Svenning**).

Kambach, S., *et al.* 2019. Of niches and distributions: range size increases with niche breadth both globally and regionally but regional estimates poorly relate to global estimates. Ecography 42:467-477. (**J.-C. Svenning**).

Karami, M., *et al.* 2018. A phenology-based approach to the classification of Arctic tundra ecosystems in Greenland. ISPRS Journal of Photogrammetry and Remote Sensing 146:518-529. (**S. Normand**, **U.A. Treier**).

Kirchheimer, B., *et al.* 2018. Reconstructing geographical parthenogenesis: effects of niche differentiation and reproductive mode on Holocene range expansion of an alpine plant. Ecology Letters 21:392-401. (**J.-C. Svenning**).

Koc, D.E., **J.-C. Svenning**, and M. Avci. 2018. Climate change impacts on the potential distribution of Taxus baccata L. in the Eastern Mediterranean and the Bolkar Mountains (Turkey) from Last Glacial Maximum to the future. Eurasian Journal of Forest Science 6:69-82.

Kolyaie, S., *et al.* 2019. Transferability and the effect of colour calibration during multi-image classification of Arctic vegetation change. Polar Biology. (e-pub ahead of print). (**U.A. Treier, B. Madsen**, **P.K. Bøcher, S. Normand**).

Kozma, R., M. Lillie, B.M. Benito, **J.-C. Svenning**, and J. Höglund. 2018. Past and potential future population dynamics of three grouse species using ecological and whole genome coalescent modeling. Ecology and Evolution 8:6671-6681.

Liang, C., *et al.* 2018. Bird species richness is associated with phylogenetic relatedness, plant species richness, and altitudinal range in Inner Mongolia. Ecology and Evolution 8:53-58. (**J.-C. Svenning**).

Liang, C., *et al.* 2019. Taxonomic, phylogenetic and functional homogenization of bird communities due to land use change. Biological Conservation 236:37-43. (**J.-C. Svenning**).

Ma, T., R. Li, **J.-C. Svenning**, and X. Song. 2018. Linear spectral unmixing using endmember coexistence rules and spatial correlation. International Journal of Remote Sensing 39:3512-3536.

Maitner, B.S., *et al.* 2018. The bien r package: a tool to access the Botanical Information and Ecology Network (BIEN) database. Methods in Ecology and Evolution 9:373-379. (**J.-C. Svenning**).

Maring, R. and **F. Riede**. 2019. Possible wild boar management during the Ertebølle Period. A carbon and nitrogen isotope analysis of Mesolithic wild boar from Fannerup F, Denmark. Environmental Archaeology 24:15-27.

Maruyama, P.K., *et al.* 2018. Functional diversity mediates macroecological variation in plant–hummingbird interaction networks. Global Ecology and Biogeography 27:1186-1199. (**J.-C. Svenning**).

Mezquida, E.T., **J.-C. Svenning**, R.W. Summers, and C.W. Benkman. 2018. Higher spring temperatures increase food scarcity and limit the current and future distributions of crossbills. Diversity and Distributions 24:473-484.

Moeslund, J.E., *et al.* 2019. Light detection and ranging explains diversity of plants, fungi, lichens, and bryophytes across multiple habitats and large geographic extent. Ecological Applications. (e-pub ahead of print). (**A. Zlinszky, P.K. Bøcher**, **J.-C. Svenning, S. Normand**).

Morueta-Holme, N. and **J. C. Svenning**. 2018. Geography of plants in the New World: Humboldt's relevance in the age of big data. Annals of the Missouri Botanical Garden 103:315-329.

Müller, A., **P.K. Bøcher**, C. Fischer, and **J.-C. Svenning**. 2018. 'Wild' in the city context: do relative wild areas offer opportunities for urban biodiversity? Landscape and Urban Planning 170:256-265.

Muscarella, R., *et al.* 2018. Soil fertility and flood regime are correlated with phylogenetic structure of Amazonian palm communities. Annals of Botany 123: 641-655. (**J.-C. Svenning**).

Muscarella, R., J. Messier, R. Condit, S.P. Hubbell, and **J.-C. Svenning**. 2018. Effects of biotic interactions on tropical tree performance depend on abiotic conditions. Ecology 99:2740-2750.

Nielsen, T.K. and **F. Riede**. 2018. On research history and Neanderthal occupation at its Northern margins. European Journal of Archaeology 21:506-527.

Nordvig, M. and **F. Riede**. 2018. Are there echoes of the AD 536 event in the Viking Ragnarok myth? A critical appraisal. Environment and History 24:303-324.

Nüchel, J., **P.K. Bøcher**, and **J.-C. Svenning**. 2019. Topographic slope steepness and anthropogenic pressure interact to shape the distribution of tree cover in China. Applied Geography 103:40-55.

Nüchel, J., **P.K. Bøcher**, W. Xiao, A.-X. Zhu, and **J.-C. Svenning**. 2018. Snub-nosed monkeys (Rhinopithecus): potential distribution and its implication for conservation. Biodiversity and Conservation 27:1517-1538.

Oddershede, A., C. Violle, A. Baattrup-Pedersen, **J.-C. Svenning**, and C. Damgaard. 2018. Early dynamics in plant community trait responses to a novel, more extreme hydrological gradient. Journal of Plant Ecology 12:327-335.

Odgaard, M.V., T. Dalgaard, **P.K. Bøcher**, and **J.-C. Svenning**. 2018. Site-specific modulators control how geophysical and socio-technical drivers shape land use and land cover. Geo: Geography and Environment 5:e00060.

Onstein, R.E., *et al.* 2018. To adapt or go extinct? The fate of megafaunal palm fruits under past global change. Proceedings of the Royal Society B: Biological Sciences 285:20180882. (**J.-C. Svenning**).

Ordonez, A. and **J.-C. Svenning**. 2018. Greater tree species richness in eastern North America compared to Europe is coupled to denser, more clustered functional trait space filling, not to trait space expansion. Global Ecology and Biogeography 27:1288-1299.

Pedersen, J.B., L. Ivanovaite, and **F. Riede**. 2018. Bill Finlayson and Graeme Warren, eds. The diversity of Hunter-Gatherer pasts (Oxford & Philadelphia: Oxbow Books, 2017, 204 pp., 21 b/w illustr., 8 tables, pbk, ISBN 978-1-78570-588-5). European Journal of Archaeology 21:665-668.

Perino, A., *et al.* 2019. Rewilding complex ecosystems. Science 364:eaav5570. (**S. Ceauşu, J.-C. Svenning**).

Philippsen, B., *et al.* 2019. Eight new late Pleistocene/early Holocene AMS dates from the Southeastern Baltic. Radiocarbon 61:615-627. (**F. Sauer**, **F. Riede**).

Pither, J., B.J. Pickles, S.W. Simard, **A. Ordonez**, and J.W. Williams. 2018. Below-ground biotic interactions moderated the postglacial range dynamics of trees. New Phytologist 220:1148-1160.

Prendin, A.L., *et al.* Accepted. Immediate and carry-over effects of insect outbreaks on vegetation growth in West Greenland assessed from cells to satellite. Journal of Biogeography. (**U.A. Treier, S. Normand**).

Qiu, Y., *et al.* 2019. The resolution-dependent role of landscape attributes in shaping macro-scale biodiversity patterns. Global Ecology and Biogeography 28:767-778. (**J.-C. Svenning**).

Radchuk, V., *et al.* 2019. The dimensionality of stability depends on disturbance type. Ecology Letters 22:674-684. (**J.-C. Svenning**).

Rao, M., *et al.* 2018. Environmental and evolutionary drivers of diversity patterns in the tea family (Theaceae s.s.) across China. Ecology and Evolution 8:11663-11676. (**M.J. Steinbauer, J.-C. Svenning**).

Riede, F. 2018. Da himlen faldt ned. Skalk 3:3–8.

Riede, F. 2018. Deep pasts - deep futures: a palaeoenvironmental humanities perspective from the Stone Age to the Human Age. Current Swedish Archaeology 26:13-30.

Riede, F. 2019. Doing palaeo-social volcanology: developing a framework for systematically investigating the impacts of past volcanic eruptions on human societies using archaeological datasets. Quaternary International 499:266-277.

Riede, F. 2019. Environmental determinism and archaeology. Red flag, red herring. Archaeological Dialogues 26:17-19.

Riede, F. 2019. Niche construction theory and human biocultural evolution. Pages 337-358 in A.M. Prentiss, ed. Handbook of evolutionary research in archaeology. Springer International Publishing, Cham.

Riede, F. and **J.B. Pedersen**. 2018. Late glacial human dispersals in Northern Europe and disequilibrium dynamics. Human Ecology 46:621-632.

Riede, F., **F. Sauer**, and **C. Hoggard**. 2018. Rockshelters and the impact of the Laacher See eruption on Late Pleistocene foragers. Antiquity 92:e2.

Riede, F., **C. Hoggard**, and S. Shennan. 2019. Reconciling material cultures in archaeology with genetic data requires robust cultural evolutionary taxonomies. Palgrave Communications 5:55.

Riede, F., T.T. Høye, P. Tejsner, D. Veldhuis, and R. Willerslev. 2018. Special section introduction: socioecological disequilibrium in the Circumpolar North. Human Ecology 46:615-620.

Riede, F., *et al.* 2019. Laacher See-vulkanudbruddet og effekten på klimaet. Kvant 30:19–23. (**A. Zernack**).

Robinson, E. and **F. Riede**. 2018. Cultural and palaeoenvironmental changes in late glacial to middle Holocene Europe: gradual or sudden? Quaternary International 465:159-161.

Root-Bernstein, M. and **J.-C. Svenning**. 2018. Human paths have positive impacts on plant richness and diversity: a meta-analysis. Ecology and Evolution 8:11111-11121.

Sandom, C.J., *et al.* 2018. Learning from the past to prepare for the future: felids face continued threat from declining prey. Ecography 41:140-152. (**J.-C. Svenning**).

Sauer, F. and **F. Riede**. 2019. A critical reassessment of cultural taxonomies in the Central European late Palaeolithic. Journal of Archaeological Method and Theory 26:155-184.

Sauer, F., D. Stott, and **F. Riede**. 2018. Search for new final Palaeolithic rock shelter sites in the Federal State of Hesse. Journal of Archaeological Science: Reports 22:168-178.

Scarlett, J.P. and **F. Riede**. 2019. The dark geocultural heritage of volcanoes: combining cultural and geoheritage perspectives for mutual benefit. Geoheritage. (e-pub ahead of print).

Schweiger, A.H., I. Boulangeat, T. Conradi, **M. Davis**, and **J.-C. Svenning**. 2019. The importance of ecological memory for trophic rewilding as an ecosystem restoration approach. Biological Reviews 94:1-15.

Schweiger, A.H. and **J.-C. Svenning**. 2018. Down-sizing of dung beetle assemblages over the last 53 000 years is consistent with a dominant effect of megafauna losses. Oikos 127:1243-1250.

Serra-Diaz, J.M., B.J. Enquist, B. Maitner, C. Merow, and **J.-C. Svenning**. 2018. Big data of tree species distributions: how big and how good? Forest Ecosystems 4:30.

Serra-Diaz, J. M. and J. Franklin. 2019. What's hot in conservation biogeography in a changing climate? Going beyond species range dynamics. Diversity and Distributions 25:492-498.

Serra-Diaz, J.M., *et al.* 2018. Disequilibrium of fire-prone forests sets the stage for a rapid decline in conifer dominance during the 21st century. Scientific Reports 8:6749.

Šímová, I., *et al.* 2018. Spatial patterns and climate relationships of major plant traits in the New World differ between woody and herbaceous species. Journal of Biogeography 45:895-916. (**J.-C. Svenning, K. Engemann**).

Steidinger, B.S., *et al.* 2019. Climatic controls of decomposition drive the global biogeography of forest-tree symbioses. Nature 569:404-408. (**J.M. Serra-Diaz, J.-C. Svenning**).

Steinbauer, M.J., *et al.* 2018. Accelerated increase in plant species richness on mountain summits is linked to warming. Nature 556:231-234. (**A.D. Bjorkman, S. Normand, J.-C. Svenning**).

Stewart, L., C.E. Simonsen, **J.-C. Svenning**, N.M. Schmidt, and L. Pellissier. 2018. Forecasted homogenization of high Arctic vegetation communities under climate change. Journal of Biogeography 45:2576-2587.

Svenning, J.-C. 2018. Proactive conservation and restoration of botanical diversity in the Anthropocene's "rambunctious garden". American Journal of Botany 105:963-966.

Svenning, J.-C., **M. Munk**, and **A.H. Schweiger**. 2019. Trophic rewilding: ecological restoration of top-down trophic interactions to promote self-regulating biodiverse ecosystems. Pages 73-98 in J.T. du Toit, N. Pettorelli, and S.M. Durant, eds. Rewilding. Cambridge University Press, Cambridge.

Teng, S.N., C. Xu, B. Sandel, **J.-C. Svenning**, and R. Freckleton. 2018. Effects of intrinsic sources of spatial autocorrelation on spatial regression modelling. Methods in Ecology and Evolution 9:363-372.

Thers, H., **P.K. Bøcher**, and **J.-C. Svenning**. 2019. Using LiDAR to assess the development of structural diversity in forests undergoing passive rewilding in temperate Northern Europe. PeerJ 6:e6219.

Thomas, H.J.D., *et al.* 2019. Traditional plant functional groups explain variation in economic but not size-related traits across the tundra biome. Global Ecology and Biogeography 28:78-95. (**A.D. Bjorkman, S. Normand, U.A. Treier**).

Torres, A., *et al.* 2018. Measuring rewilding progress. Philosophical Transactions of the Royal Society B: Biological Sciences 373:20170433. (**J.-C. Svenning**).

Van Meerbeek, K. and **J.-C. Svenning**. 2018. Causing confusion in the debate about the transition toward a more plant-based diet. Proceedings of the National Academy of Sciences 115:E1701-E1702.

Večeřa, M., *et al.* 2019. Alpha diversity of vascular plants in European forests. Journal of Biogeography. (e-pub ahead of print). (**J.-C. Svenning**).

Veldhuis, D., P. Tejsner, **F. Riede**, T.T. Høye, and R. Willerslev. 2018. Arctic disequilibrium: shifting human-environmental systems. Cross-Cultural Research 53:243-251.

Walsh, M.J., S. O'Neill, **F. Riede**, and R. Willerslev. 2018. A soul by any other name: The name-soul concept in Circumpolar perspective. Cross-Cultural Research 53:312-349.

Watmough, G.R., *et al.* 2019. Socioecologically informed use of remote sensing data to predict rural household poverty. Proceedings of the National Academy of Sciences 116:1213-1218. (**J.-C. Svenning**).

Wheeler, H.C., T.T. Høye, and **J.-C. Svenning**. 2018. Wildlife species benefitting from a greener Arctic are most sensitive to shrub cover at leading range edges. Global Change Biology 24:212-223.

Wüest, R.O., *et al.* Accepted. Macroecology in the age of big data – where to go from here? Journal of Biogeography. (**S. Normand**).

Xu, W., *et al.* 2018. Plant geographical range size and climate stability in China: Growth form matters. Global Ecology and Biogeography 27:506-517. (**J.-C. Svenning**).

Yue, K., *et al.* 2019. Responses of nitrogen concentrations and pools to multiple environmental change drivers: A meta-analysis across terrestrial ecosystems. Global Ecology and Biogeography 28:690-724. (**K. Van Meerbeek, J.-C. Svenning**).

Zhang, J., *et al.* 2018. Trophic interactions among vertebrate guilds and plants shape global patterns in species diversity. Proceedings of the Royal Society B: Biological Sciences 285:20180949. (**J.-C. Svenning**).

BIOCHANGE
CENTER FOR BIODIVERSITY DYNAMICS
IN A CHANGING WORLD

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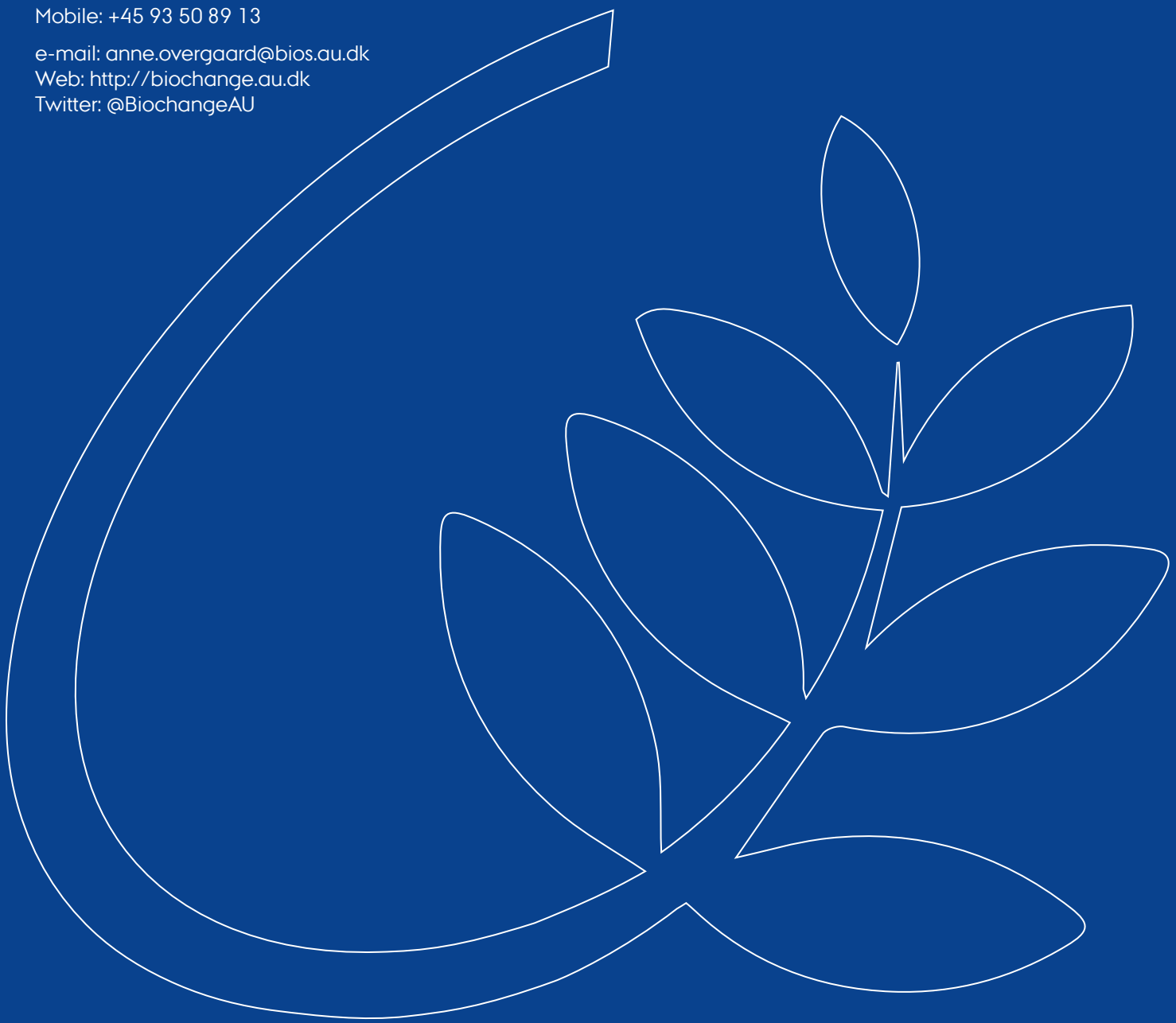

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