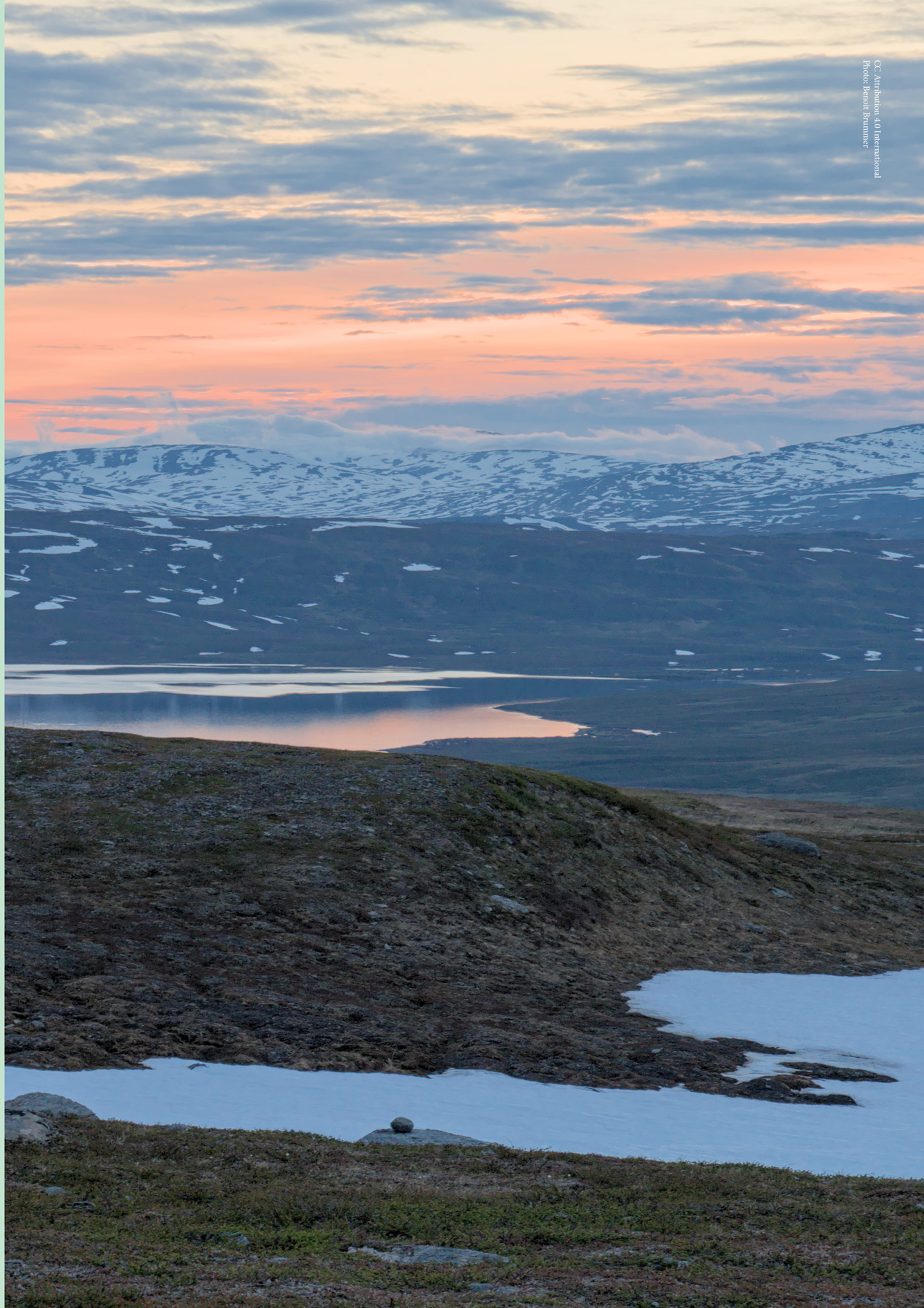
UNIVERSITY
OF OSLO

Centre for Biogeochemistry in the Anthropocene

Annual Report 2024



We study interactions and feedbacks between climate, carbon cycling and ecosystems at northern latitudes.



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Photo: Benoit Brummer

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CBA's economy in short



Photo: Getty Images

Mission

We study interactions and feedbacks between climate, carbon cycling and ecosystem at northern latitudes.

We assess and predict links from atmosphere to terrestrial and aquatic systems for carbon and other key elements, and feedbacks to climate by greenhouse gas productions in ecosystems. This is crucial for improving Earth system models, and ultimately predicting and countering anthropogenic climate change.

We educate the next generation of climate scientists in the fields of bioscience, chemistry and geoscience. We engage the public to implement strategies that help society and ecosystems reverse or adapt to climate and environmental changes.

Vision

Our shared vision is to:

- Develop and deploy basic science and novel approaches to understand biogeochemical cycles in a changing anthropogenic world.
- Educate students and raise awareness in society at large about the links between climate and ecosystem processes, for a better future.

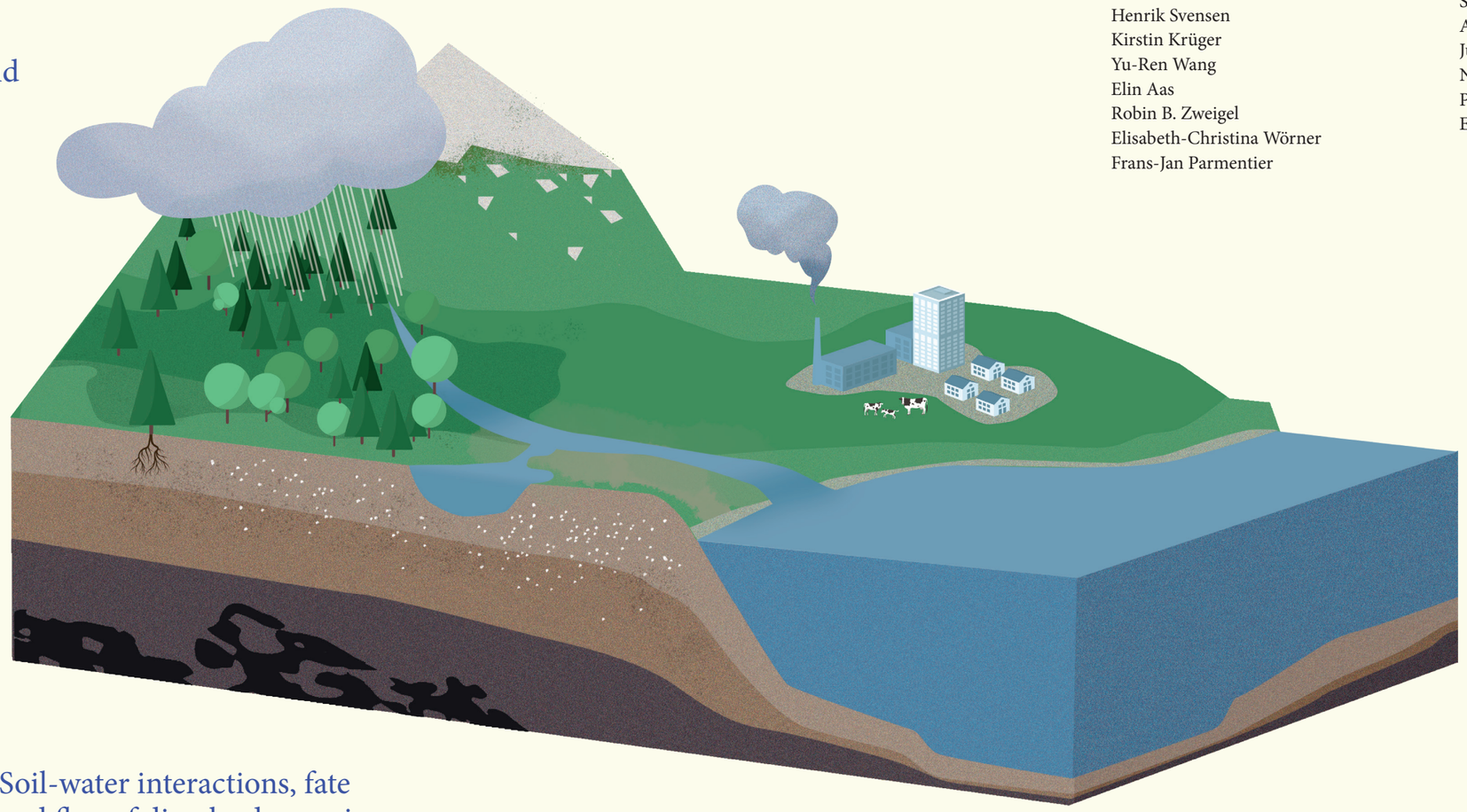
Values

We want to achieve excellence through:

- Scientific rigorousness and openness
- Ethical practices in all areas of our endeavor
- Scientific accountability
- Respect, professionalism and dedication
- Sense of responsibility to transfer knowledge to the public
- Sharing of best practices and working as a team

CBA research topics

Faculty staff, postdocs and PhDs



Weathering processes and soil characterization

Helge Hellevang
Mats Rouven Ippach
Rolf Vogt

Microbial genomics and metabolism

Alexander Eiler
Jing Wei
Laurent Fontaine
Eira Carlsen
Franck Lejzerowicz
Siyan Li
Peter Dörsch
Inger Skrede

Atmospheric chemistry

Armin Wisthaler
Tomas Mikoviny
Baptiste Languille
Felix M. Piel
Wojciech Wojnowski
Anjitha S. K. Geetha
Alexander Håland
Claus J. Nielsen
Niels Højmark Andersen

Soil-water interactions, fate and flux of dissolved organic matter and key elements

Heleen de Wit
Nicolas V. Parra
Jacqueline Knutson
Camille Crapart
Yu Yu
Francois Clayer
Xiang Lu
Thomas Rohrlack

ECODISTURB

Christina Nadeau
Dag O. Hessen
Manjana Milkoreit

Climatic change and feedbacks

Terje K. Berntsen
Trude Storelvmo
Frode Stordal
Lena M. Tallaksen
Anders Bryn
Yeliz Yilmaz
Henrik Svensen
Kirstin Krüger
Yu-Ren Wang
Elin Aas
Robin B. Zweigel
Elisabeth-Christina Wörner
Frans-Jan Parmentier

CLIPT lab

Alexander Eiler
Christine Riis-Pedersen

Permafrost dynamics, thaw, age, fate and flux of "old carbon"

Sebastian Westermann
Anfisa Pismeniuk
Frans-Jan Parmentier
Jon Petter Omtvedt
Siyan Li
Alexander Eiler
Juditha Aga
Norbert Pirk
Peter Dörsch
Eira Carlsen

Contaminants and carbon in coastal ecosystems

Katrine Borgå
Tom Andersen
Dag O. Hessen
Jan David Heuschele
Sabrina Schultze
Alexander Eiler
Franck Lejzerowicz
Isolde Puts

Freshwater and coastal ecosystem responses

Dag O. Hessen
Tom Andersen
Alexander Eiler
Thomos Rohrlack
Aleksandr Berezovski

Management structure

The CBA is a joint operation between the Department of Biosciences, Geosciences, and Chemistry. The interdisciplinary nature of the centre's work is reflected in both the leader group and the board.

The leader group



Alexander Eiler
Professor in biology and centre leader



Sebastian Westermann
Professor in geosciences and centre leader



Dag O. Hessen
Professor in biology



Eira Carlsen
ECR representative



Terje Koren Berntsen
Professor in geosciences



Emma Wall
Centre coordinator



Armin Wisthaler
Professor of atmospheric chemistry, Department of Chemistry

The board



Bjørn Jamtveit
Vice Dean (Prodekan) of Research



Roger Simm
Head of Department of Biosciences



Bernd Etzelmüller
Head of Department of Geosciences



Stian Svelle
Head of Department of Chemistry

The scientific advisory group



Tim Lenton
University of Exeter, Global Systems Institute



Vigdis Vandvik
Bjerknes Centre for Climate Research, University of Bergen



Marten Scheffer
Wageningen University & Research

CBA Status and Highlights 2024

Sebastian Westermann and Alexander Eiler
Centre co-leaders

2024 External Evaluation: A Mandate for Excellence

This year, the CBA underwent a comprehensive evaluation by an esteemed external panel consisting of Prof. Gesine Mollenhauer (Alfred Wegener Institute), Prof. Tom Battin (EPFL), and Prof. Hjalmar Laudon (SLU).

We are proud to report that the panel assessed the research conducted at CBA as "very good to excellent," with several individual projects identified as "outstanding".

Strengthening Our Distributed Community

Our collaboration and communication have grown significantly stronger over the past year. In 2024, we held several half-day meetings and an annual meeting connected to the Evaluation Panel´s site visit, engaging in deep discussions about our future trajectory. It was inspiring to see the active participation of researchers at all career stages, shaping the vision of our Centre in a truly bottom-up approach.

Empowering the Next Generation

A standout highlight from the evaluation was the praise for our Early Career Researchers (ECRs). The panel noted that ECRs strongly identify with the Centre, valuing the interdisciplinary interactions and the team-building impact of the annual ECR retreat. We especially welcome the dedication of our young scientists who have established an ECR network to exchange ideas across disciplines.

Evaluation Summary & Key Takeaways:

- **Scientific Strength:** The panel was impressed by our diverse team, noting that our interdisciplinary approach—spanning microbiology, hydrology, and atmospheric chemistry—is critical for solving grand societal challenges.
- **Modelling Leadership:** Our work with the Norwegian Earth System Model (NorESM) was highlighted as being at the national forefront and internationally competitive.
- **Strategic Ambitions:** The panel strongly recommended that CBA positions itself as a driving factor for the University's new Centre for Sustainability and prepares a robust application for a national Centre of Excellence.

Research Milestones: BioGov and Beyond

The BioGov project remains at the core of our activities. The evaluation panel cited BioGov as a "blue-print" for the centre's research focus and structural organization, praising its ability to link climate forcing with terrestrial responses.

New Funding in 2024

Building on this momentum of success, we are proud to highlight new project funding for 2024.

IMPACT: A new project investigating the impact of administered drug use on the development of environmental antibiotic resistance genes.

This expands our scope to address direct human health risks alongside biogeochemical interactions.

INES2: The funding for "Infrastructure for Norwegian Earth System modelling phase 2" further solidifies our position as a premier hub for Earth System modelling.

Looking Ahead

Since its inception in 2018, CBA has evolved into a robust network, actively engaging partners from the University of Oslo, NMBU, and NIVA. As we move forward, we are committed to refining our vision and mission as recommended by the panel, ensuring we are well-positioned to compete for Centre of Excellence status.

We would like to give a massive thank you to our dedicated researchers, partners, and supporters. Your hard work and insight turns complex science into actionable understanding of our changing planet.



Photo: Hannes Grobe
CC ShareAlike-2.5

Special focus

Continued Work on Tipping Points



Dag Olav Hessen
Professor, Department of Biosciences

Tipping point: a non-linear, often abrupt change in system state, primarily related to climate induced changes in the Earth System.

FOLLOWING THE Global Report on Tipping points presented at COP29 in 2023 - which CBA researchers actively contributed to -

the work continued throughout 2024 on the new, updated report. This updated Tipping Points Report will be presented at COP30 in Belém, Brazil in 2025.

In between, several papers have been published that address various and more specific aspects of tipping points, such as tipping points in lakes and water bodies located on permafrost, as well browning and eutrophication processes that both promote deepwater depletion of O_2, and thus increased release of CO_2 and CH_4 (Hessen et al. 2024). In addition, a paper on public perception of tipping points risks (Nadaeau et al. 2024) and a work on governance for earth system tipping points (Milkoreit 2024) was published, both with multiple CBA-people involved.

Some of this work is also related to the multidisciplinary project DemoCrisis, funded by UiO Democracy, where the potential shortcomings of democracies with short time horizons, among both voters and politicians, often runs counter to the best long-term decisions for climate, nature and future generations.

A poll on time-perception among people is financed, set up in 2025, and will be conducted early in 2026. ■



Figure 1: Retreating glaciers in Jotunheim
Photo: Dag Hessen

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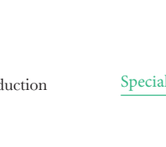
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The Danube: A 2,800 Kilometer Patient

New Bioindicators for Measuring River Health



Alexander Eiler
Professor, Department of Biosciences

Imagine you're a doctor.

The patient in front of you is 2,850 kilometers long, touches ten different countries, and provides water, transport, and life for over 81 million people. Your patient, the Danube River, is the blue artery of Europe. And just like any patient, you need to monitor its health.

But how do you give a medical checkup to a continent-spanning river?

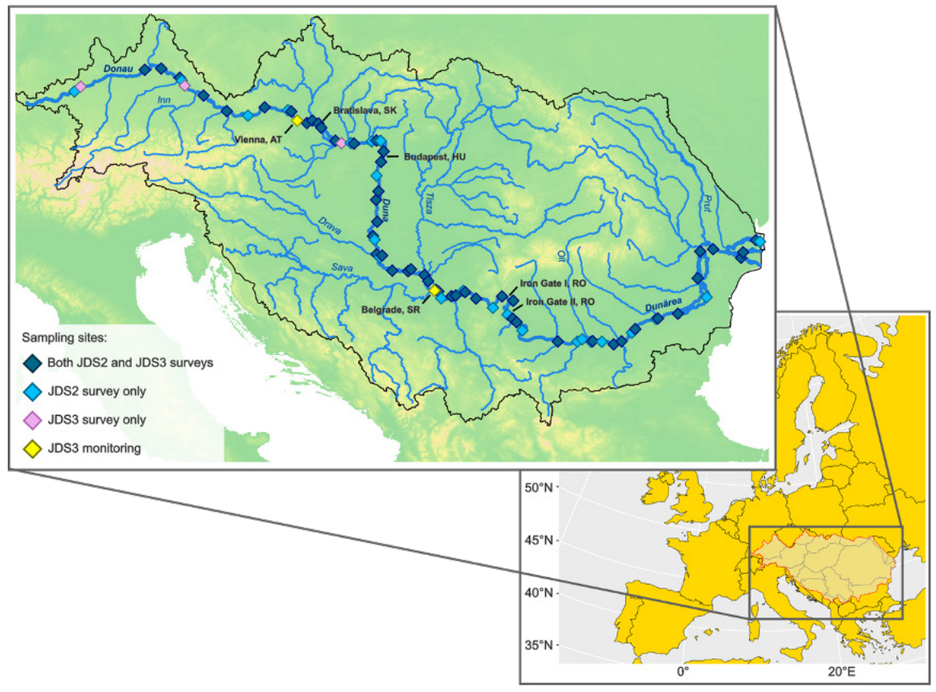


Figure 1: A map of the Danube

FOR DECADES, THE the way to measure river health was surprisingly "old-school".

Scientists traveled the river in boats and collected samples of charismatic river life: fish, aquatic plants and, most importantly,

macroinvertebrates.

Macroinvertebrates are the little bugs, worms, and snails that live in river mud.

This collection of critters, or lack thereof, was then used to calculate the *Saprobic Index*, a sort of "official health score" for rivers.

The method is reliable, but has two massive drawbacks.

First, it's slow and incredibly expensive. It requires highly trained taxonomists, experts who can tell one tiny mayfly nymph from another, to spend hours at a microscope. The analysis can take weeks or months.

Second, it's a *reactive* measurement. By the time sensitive insects are no longer detectable by this method, pollution and other environmental stressors have already done the damage.

It's like a doctor diagnosing an illness only after the patient is in critical condition.

For years, scientists have dreamed of a better way. A faster, cheaper, and predictive system.

What if, instead of looking for the victims of pollution, we could listen to the river's own first responders *before* the situation became critical?

What if we could take the river's microbial pulse?

Listening to the Unseen Engineers

A ***single drop*** of Danube river water teems with millions of microorganisms, primarily bacteria. This is the *bacterioplankton,* an invisible world that — in terms of sheer biomass and metabolic power — ***is*** the river.

These bacteria are the planet's chemical engineers. They process nutrients, break down pollution, and form the absolute base of the food web.

(The Danube, continued)

More importantly, they are *astoundingly sensitive*. With life cycles that can be as short as 20 minutes, they respond to the slightest change in their environment almost instantly. A whisper of pesticide runoff, a slight increase in water temperature, or a new source of nutrients: all will trigger a measurable response in the state of the bakterioplankton.

"It's like a doctor diagnosing an illness only after the patient is in critical condition."

They make the perfect "canary in the coal mine." Why were these not used to measure river health earlier? The problem is, simply put, there are so many of them.

Until recently, this microbial world did not give a clear signal to scientists. Rather, it was a deafening roar of data. A single sample can contain ***thousands*** of different bacterial species. For decades, we lacked the tools to make sense of this deluge of data. How could you possibly find the one or two *indicator* species in a soup containing billions of organisms representing thousands of species?

This is the challenge a team of CBA scientists, led by Laurent Fontaine and Alexander Eiler, set out to solve. Through their efforts, they created a two-part tool kit that could identify an actionable signal in all the microbial noise. Their solution was a fusion of state-of-the-art molecular biology and artificial intelligence.

Two-part Tool Kit

1. The "Genetic Barcode Scanner" (Metabarcoding)

Instead of trying to grow the bacteria in a lab dish — which is impossible for over 99% of them — the team used *metabarcoding*. They scooped 160 water samples from 60 locations along the entire 2,600-km navigable stretch of the Danube, from Germany to the Black Sea.

"The result? A massive, high-resolution who's who list for every sample."

They extracted all the DNA from the water and sequenced one specific gene: the 16S rRNA gene. This gene is the perfect universal barcode for bacteria. It's present in all of them, but contains small, unique variations in its DNA sequence for each different type.

The result? A massive, high-resolution who's who list for every sample.

They identified 3,509 unique Amplicon Sequence Variants (ASVs), which represents a single type of bacteria

Acting as a kind of *genetic barcode*, these ASVs could be used to measure the river's bacterial diversity from their samples.

2. The "Pattern-Finder" (Machine Learning)

A human cannot look at a spreadsheet with 3,509 columns and 160 rows and find a meaningful pattern. But machine learning (ML) models can.

The team employed a powerful method called "XGboost" (Extreme Gradient Boosting), the same kind of algorithm that powers championship-winning data science competitions. They decided to train this ML on the data.

They fed the ML two sets of data for each sample location:

The potential *Indicators*

The complete list of 3,509 bacterial ASVs (DNA barcodes) and their relative abundance.

The Diagnosis

The "old school" official health score for that same location — that is, the *Saprobic Index* based on insects, and the chlorophyll-a level as a proxy for algae blooms.

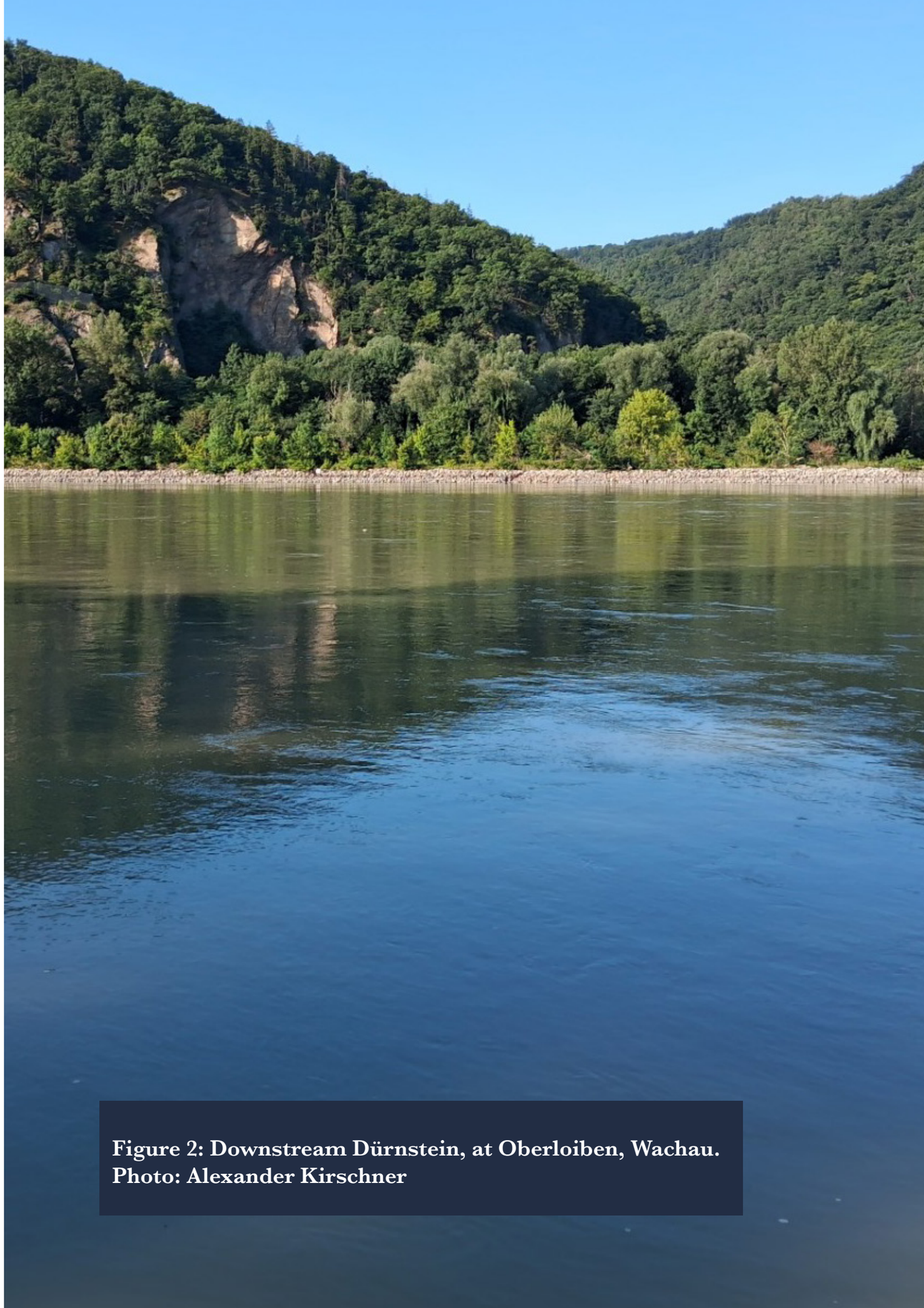


Figure 2: Downstream Dürnstein, at Oberloiben, Wachau. Photo: Alexander Kirschner

"What if we could take the river's microbial pulse?"

(The Danube, continued)

The question was simple:

Dear ML, Have a look at this river biodiversity data. Can you find any hidden patterns that could predict its official health score?

The model's answer was a resounding "yes." And not just a "yes", it could find various combinations of indicators.

The Biological Weather Forecast

"It worked *stunningly* well"

The first major finding was that the bacterial communities weren't chaotic at all. They were highly **structured**, shifting in predictable ways along the river's entire length

As the river flows, it changes. The headwaters in Germany are narrower, faster, and more influenced by the surrounding catchment. The water here is rich in nitrogen and different types of organic matter. Further downstream, the river becomes a vast, slow-moving giant, a different ecosystem entirely.

The bacteria followed this pattern perfectly. The team's analysis revealed a clear "changing of the guard."

In the nutrient-rich *upstream* reaches, bacteria from the phylum *Bacteroidota* were more common. These bacteria are *r-strategists*, or "opportunists". They are fast-growing and excel at feasting on the buffet of easily available nutrients from land runoff.

In the relatively nutrient-poor *downstream* reaches, the community shifted to favor the phylum *Actinobacteriota*. These are *k-strategists* or "specialists"—they are slow, steady, and highly efficient, masters of surviving in more austere environments.

This discovery confirmed that the bacterial community represented more than just random noise; it was a living, dynamic mirror of the river's environmental conditions.

But the team pushed it one step further, asking a question that sounds like science fiction: Could they use the river's own flow to *predict the future*?

Because a river flows, the water (and its microbial community) at Point A will eventually arrive at Point B, downstream. The team hypothesized that the bacterial community *upstream* must hold information about the water quality *downstream*.

They built a *spatio-temporal* model; that is, a model that considers both space and time. They fed this model the bacterial data from upstream sites and asked it to predict the biological status (the *Saprobic Index*) of sites *further downstream*.

It worked *stunningly* well.

They had created a "biological weather forecast." By reading the microbial community at one location, they could accurately forecast the ecological conditions kilometers downriver. This moves biomonitoring from a *reactive* snapshot of the past to a *predictive* tool for the future.

But the biggest, most game-changing discovery was yet to come.

The A-Team: Two Bacteria that Tell the Whole Story

The models had one more secret to share.

When digging into the findings from their models, the team noticed something exciting. The models did not require bacterial barcodes from all 3,509 species present to make its predictions. It could tease out the same signal using just a few.

This is a concept called *informational redundancy*. Think of it like a political poll. You don't need to ask every single voter in a country to predict an election. A well-chosen, representative sample of 1,000 people can give you the answer with high accuracy.

It turns out the same is true for the Danube's 3,509 bacteria. Most of them are "redundant" — they are all telling the same story.

The scientists began to filter their models, trying to find the absolute minimum number of bacteria needed to get

(The Danube, continued)

a perfect score. The answer was astonishing.

The team found they could achieve **100% accuracy** in predicting the river's biological status (whether it was `Good`, `Moderate`, or `Poor`) using models that contained **as few as two or three** bacterial ASVs.

The noise was silenced, revealing a crystal-clear signal. It's not about the thousands of species; it's about identifying the *right* species.

Eiler and Fontaine had identified the "Microbial A-Team." The models yielding perfect accuracy were almost always a combination of just a few key players. The simplest, most elegant model, for instance, paired one genetic fingerprint from the genus **Fluviicola** with one from either **Acinetobacter** or **Flavobacterium**.

That's it. Just *two* DNA barcodes, out of thousands, were enough to give the *exact same* biological health score.

In contrast, the same result would have required months of analysis time and orders of magnitude more resources to find with the "old-school" method.

Genera like *Rhodoluna* and *Flavobacterium* were identified as the most frequent and most important information carriers. These weren't necessarily the *most abundant* bacteria, but they were the most *informative*. They were the bellweathers, the true "canaries in the coal mine."

"The team found they could achieve 100% accuracy"

The Future: A "Fitbit" for the World's Rivers

This discovery, published in the journal ***Communications Biology***, can act as a blueprint for the future of environmental monitoring.

The old way was like sending a patient to a specialist for an expensive, invasive, and-slow biopsy once a year.

The new way unlocked by this research is the equivalent of a "Fitbit" for the river.

Imagine a small, cheap, on-site biosensor — a so-called *lab-on-a-chip* — that is dropped into the water. This device doesn't need to be a million-dollar sequencing lab. It only needs to be programmed to look for a handful of DNA barcodes: the "A-Team" of *Fluviicola*, *Acinetobacter*, *Rhodoluna*, and *Flavobacterium*.

This device could float down the river, or sit anchored to a bridge, and beam its results to a satellite in real-time.

For example,

```
Health: Good
```

- or -

```
Warning:Nutrient
Spike Detected
```

- or -

```
Alert: Pollution
Event at Kilome-
ter 200
```

This is no longer science fiction. This study proves the principle. By combining the precision of genetic sequencing with the pattern-finding power of ML, we've learned to speak the river's native language. We've learned to listen to the invisible watchmen that have been monitoring our waterways for millennia.

And for the first time, by listening to just two or three of them, we can finally understand what the entire river is trying to tell us. ■

Reference

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Figure 3: The Danube
Photo: Alexander Kirschner

Finnmark Fieldwork: A Photo Essay



Sebastian Westermann
Professor, Department of Geosciences

In 2024, we conducted two sampling campaigns in permafrost peatlands in Finnmark, Northern Norway. The goal was to obtain peat material for chemical and microbial analysis, as well as controlled experiments to estimate their greenhouse gas emission potential during and after permafrost thaw.



Anfisa Pismeniuk, Sunniva Sheffield and Mats Ippach taking a core at the Áidejávri permafrost peatland..
Photo: Taylor Alaina Liebenstein Smith

The sampling campaigns were planned with the help of drone imagery which we had obtained at the study areas for almost ten years. These air photos made it possible to pinpoint when exacly permafrost thawed at the sampling locations so that we could obtain peat material along a chronosequence of thaw.

The frozen river Guovdageaineatnu (Norwegian: Kautokeinoelva) in March 2023
Photo: Sebastian Westermann



Anfisa Pismeniuk, Clarissa Willmes and Mats Ippach (left to right) with a fresh core obtained from a thermokarst lake.
Photo: Sebastian Westermann

In summer, it is possible to reach most parts of the permafrost peatlands on foot, but some areas, especially the thermokarst ponds left as a result of permafrost thaw, cannot be sampled. For this reason, we conducted a field campaign during freezing temperatures in March, during which we were able to sample the bottom of different thermokarst ponds from the ice. The samples are currently being analyzed in several of the BioGov PhD projects.



Transport of coring equipment with skis and pulks
Photo: Sebastian Westermann



Not all sampling sites are close to a road - the permafrost peatland in Iškoras can only be accessed by snowmobile during winter.
Photo: Sebastian Westermann

Thawing permafrost in Finnmark, Norway - a palsa (elevated permafrost mound) collapses into a newly formed pond.

The loss of this permafrost is likely irreversible, and it is already happening at the current warming levels.

Photo: Sebastian Westermann

Research



Arctic Char at Risk Due to Climate Change

Decades-old lake data, re-examined with modern machine learning, forecast severe habitat loss for Arctic char under climate warming.



Dag Olav Hessen
Professor, Department of Biosciences

ARCTIC CHAR (*Salvelinus alpinus*) is the world's most cold-adapted and northerly distributed freshwater fish. It has a wide range across Scandinavia and other northern regions, and is the only freshwater fish found on Svalbard.

New research shows it faces a dramatic loss of habitat as the climate warms. A 2024 study co-authored by CBA researcher Dag Hessen combines extensive field surveys from the mid-1990s with modern machine-learning techniques to gain fresh insight from decades-old data.

In the mid-1990s, scientists surveyed fish communities and environmental conditions in 1,762 lakes across Norway, Sweden, and Finland. The new study revisited these baseline surveys using advanced machine-learning models. This allowed researchers to assess the climate vulnerability of Arctic char, including the effects of rising temperatures and the spread of its main predator, northern pike *(Esox lucius*).

The models predicted Arctic char occurrence with 89% accuracy.

It revealed that both abiotic (i.e., environmental conditions, such as temperature) and biotic (i.e., species interactions) factors strongly predict where the fish can survive.

Temperature emerged as the dominant factor. Arctic char rarely occurred in lakes where mean summer air temperatures exceeded 13°C. However, in warmer areas they were 1.5 times more likely to persist in larger lakes, likely because deeper waters provide cold, oxygen-rich refuges.



Figure 1: Two sizes of Arctic char, migratory and resident, from field work in Svalbard **Photo:** Dag Hessen

Water "browning," caused by rising levels of dissolved organic carbon that darken lake water and reduce deep-water oxygen, also strongly reduced Arctic char presence.

In addition, lakes containing northern pike were roughly half as likely to support Arctic char populations, reflecting competition and predation pressures.

As the climate warms, many species are expected to shift their ranges northward or to higher elevations. But for Arctic freshwater species already living at the northern and upper limits of available habitat, there is little room left to move. Instead, suitable habitat may simply disappear.

Under a high-emissions scenario (RCP8.5), ***81% of existing Arctic char populations are projected to face a high risk of local extinction by 2080.*** The most vulnerable populations occur near the southern edge of the species' range and at lower elevations.

Potential refuges remain in some mountainous regions and along Norway's northern coast. Lake size can partly buffer warming impacts, while the presence of predators and competitors amplifies risk.

The study's findings suggest that range shifts may give way to range contractions for this cold-water specialist — highlighting the urgent need for proactive conservation efforts to protect Arctic freshwater biodiversity. ■

Reference

Muhlfeld et al. (2024). Climate change vulnerability of Arctic char across Scandinavia. *Global Change Biology*, https://doi.org/10.1111/gcb.17387

Weirder Winter Weather and the FATES of Plants

From frost droughts to rain-on-snow events, scientists are uncovering how extreme winter conditions shape plant survival in northern ecosystems.



Frans-Jan Parmentier
Senior Researcher, Department of Geosciences

THE RECENTLY funded CBA project "SnowLess" will investigate how winter extremes may lead to more vegetation damage in the future, acting as an increasing disturbance for arctic-boreal ecosystems.

Traditionally, studies quantifying the impact of climate change on ecosystems focused on the summer, even though climate warming is strongest in winter – especially in Norway and elsewhere in the Arctic-Boreal region. This has led to increasingly variable winter weather, such as more frequent mid-winter warm spells, rain-on-snow events and frost droughts.

These extreme winter events can damage vegetation, causing economic losses for forest industries while also affecting the amount of CO_2 that plants take up from the atmosphere. SnowLess will *quantify* these impacts by merging field measurements, lab experiments and process modeling to – for the first time – accurately simulate the response of vegetation to changing winter weather in a land surface model.

Quantifying the response of northern ecosystems to climate change is crucial to understanding the global climate system. The vegetation and soils of the Arctic-boreal region hold immense amounts of carbon, and if only a fraction is released into the atmosphere as a greenhouse gas this may amplify climate change. Plants take up CO_2 from the atmosphere, and extreme winter events may diminish that capacity. Even though observations have clearly shown these impacts, the problem is that models remain incapable of simulating them accurately.



Figure 1: The snowmaker in the climate container, with shrubs in the foreground. Photo: Frans-Jan Parmentier

Worryingly, this means that we do not know how these dynamics will play out with continued climate change. The SnowLess project, funded by the Research Council of Norway, addresses this problem through a collective effort by the University of Oslo, Nibio and Cicero, while collaborating closely with field partners in Norway, Greenland and the USA. Together, we will quantify the potential for extreme winter events to affect the CO_2 balance of the Arctic-Boreal region in the future.



(Weird Winter Weather, continued)

EXTREME WINTER events are broadly classified into three types:

1) Frost droughts: when severe cold occurs in the absence of snow, leaving vegetation exposed to cold, dry air while soil water is frozen and unavailable. If combined with strong wind or sunshine, this can cause extensive vegetation damage through desiccation.

2) Rain-on-snow events: if rain falls mid-winter upon a pre-existing snowpack, a poorly-insulating ice layer can form when the saturated snowpack refreezes, subjecting plants to extreme cold and mechanical damage.

3) False springs: when temperatures are sufficiently above freezing for plants to wake up from dormancy, making them more susceptible to frost damage upon a return to winter conditions.

The damage incurred from all three of these winter events has a lasting effect, negatively affecting vegetation growth and greenhouse gas exchange with the atmosphere in the following summer.

One of the obstacles to studying the impact of these events is their stochastic occurrence, which means that it is extremely challenging to have monitoring equipment in the right place and at the right time to measure plant responses in the field.

In SnowLess, therefore, we will use a frozen laboratory at the University of Oslo – the cold climate container – to recreate these events in the lab. This laboratory can maintain temperatures from +20°C down to -40 °C and contains a snow-producing machine to create a realistically structured snowpack covering the vegetation, while soil temperatures are controlled separately from the air temperature. Combined with realistic light levels, we can subject short-statured vegetation such as shrubs and tree saplings to normal snow-covered winters, as well as extreme winter events.

In this cold lab, we will recreate the conditions of a range of extreme winter events, including frost droughts and false springs, while measuring the cold tolerance of plants and transport of water through their tissues. In addition, this project will also learn from field experiments in Norway, Svalbard, Greenland and the USA in close collaboration with local partners.

Where relevant, we will also visit select arctic field sites to gather vegetation samples and additional field data to help parameterize the model. The goal is to provide a completely novel set of data on this previously overlooked aspect of plant physiology.

"Plants take up CO_2 from the atmosphere, and extreme winter events may diminish that capacity."

Our field observations and lab experiments will provide a crucial link between Earth system modeling and detailed ecological research which will inform calibration of the land surface model CLM-FATES. The overarching aim of this project is to forecast the impact of extreme winter weather on vegetation, by leveraging the Norwegian Earth System Model (NorESM), to show how these dynamics may amplify globally important climate feedbacks from the Arctic-boreal region in the future.■

Figure 2: (Opposite page) Shrubs in the climate container, showing partial browning. Photo: Frans-Jan Parmentier

Finse

The Long-term Microbiome Observatory



Alexander Eiler
Professor, Department of Biosciences

THE GLACIERS of Norway, including those near Finse and the Hardangervidda mountain plateau, are iconic symbols of the Nordic landscape. Yet, they are in rapid retreat, shrinking before our eyes as the climate warms (Figure 1).

This melting is more than just a loss of ice; it represents a profound, cascading change for the downstream freshwater ecosystems that rely on glacial meltwater.

For the past seven years, our research team has been on the ground, conducting an in-depth study to understand the ecological consequences of this massive shift.

Seven Years of Research Tracks the Impact of Climate Change on Mountain Ecosystems

Our work is focused on the water bodies immediately downstream of these disappearing glaciers, employing a powerful, two-pronged approach.

First, we use a space-for-time substitution, also known as a **chronosequence** approach, by sampling lakes at various distances from the glacier – from the glacier front to lakes in the forested valleys. This allows us to rapidly infer the long-term changes that lakes undergo as its glacial source retreats over decades.



Figure 1: Melting snow in Finse, Photo: Alexander Eiler

The second part of our research is long-term observation — seven years and counting — to directly track these changes over time. Every sample we collect is a wealth of information, revealing critical transformations happening at the most fundamental level: the microbiome.

The Invisible Engine: Microbial Changes and Metabolic Shifts

We measure the life found in the waters. By analyzing DNA and RNA, we monitor microbial diversity — both prokaryotic (bacteria and archaea) and eukaryotic (algae and protists).

This tells us both *who* is in the water and *what* they are doing.

As the glacier retreats, it exposes new land and alters the water chemistry. We see striking changes in the microbial communities and their metabolic capabilities. For instance, what happens to the tiny organisms that process carbon and nutrients when the input of cold, mineral-rich meltwater changes?

Our chemical measurements track these critical changes in nutrient status, providing the ecological context for the microbial shifts we observe.

"Every sample we collect is a wealth of information, revealing critical transformations happening at the most fundamental level:

the microbiome"



Figure 2: Finse landscape, Photo: Alexander Eiler



Figure 3: Finse Sampling Sites, Google Earth

(Finse, continued)

The Greenhouse Gas Connection

Finally, our research directly addresses the impact of glacial retreat on the climate itself. Lakes are major sources of atmospheric gases, and the warming of glacial systems can turn them into unexpected sources.

In a previous study (Wei et al. 2023), we measured the greenhouse gases CO_2, CH_4 and N_2O and estimated their emission, production and consumption rates in the glacial fed lakes. The major objective was: Are they becoming a source or sink of carbon as the glacier disappears?

By combining seven years of field data with genomic analysis and gas flux measurements, our work offers an unparalleled look into the cascading ecological effects of glacial retreat. This long-term research in Finse and Hardangervidda is essential for accurately predicting how these fragile mountain ecosystems and their role in global cycles will evolve in a warmer world. ■

Reference

Wei, J., Fontaine, L., Valiente, N., Dörsch, P., Hessen, D. O., & Eiler, A. (2023). Trajectories of freshwater microbial genomics and greenhouse gas saturation upon glacial retreat. Nature Communications, 14(1), 3234. https://doi.org/10.1038/s41467-023-38806-w

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Outreach

CBA researchers love to engage in public outreach. They participate in public debates, create newspaper articles and even write books for lay audiences.

Outreach 2024

Outreach articles, debates and interviews *by* CBA members

- De aller fleste er for naturen. Likevel trekker naturen altfor ofte det korteste strået
  Bruvoll, A., **Hessen, D.** O., Navrud, S., Rosendahl, K. E., & Vandvik, V.
  Dagens Næringsliv.
  April 11, 2024.

- På vei mot nye høyder: Tre- og skoggrensene stiger
  Bryn, A., Berntsen, T. K., Horvath, P., Isaksen, K., Liahjell, G. T., **Naas, A. E.**, Potthoff, K., Stordal, F., & Tjessem, I. K., I. V. &. Volden.
  Arr – Idéhistorisk Tidsskrift
  May, 2024

- Naturen må også reddes fra klimaødeleggelse
  Bryn, A., Di Biagio, A. J., Stordal, F., & Kausrud, K.
  Forsker Sonen
  December 5, 2024

- Klimatilpasning med skog i skredutsatt terreng
  Di Biagio, A. J., & **Bryn, A.**
  Nationen

- Plast [Video interview]
  Eiler, A. (Interviewee). Video segment 18, Dagsrevyen, NRK TV
  June 22, 2024

- Stortinget må sette kunnskapen i arbeid for å stoppe naturtapet.
  Hessen, D.O., et al.
  Khrono
  November 12, 2024

- En sang om is og trær
  Parmentier, F.-J.
  Klassekampen
  October 7, 2024

- Forskning er ikke nok til å forstå hva som skjer i Arktis
  Parmentier, F.-J.
  Klassekampen
  December 23, 2024

- Hvem har skapt metanmonsteret?
  Parmentier, F.-J.
  Klassekampen
  April 8, 2024

- Kan naturen forhandles som en pengesum?
  Parmentier, F.-J.
  Klassekampen
  February 19, 2024

- Når et tre brenner uten at noen måler det
  Parmentier, F.-J.
  Klassekampen
  July 8, 2024

- Snøkaos og klimakaos
  Parmentier, F.-J.
  Klassekampen
  January 29, 2024

- Vi trenger en Marshallplan for offshoreindustrien
  Parmentier, F.-J.
  Klassekampen
  August 26, 2024

- Hytter og beitedyr: Arealkonflikter kan forebygges
  Pedersen, C. R., Krøgli, S. O., & Bryn, A. Parmentier, F.-J.
  Kommunal Rapport
  2024

- Regjeringen gambler med havbunnen som innsats (Debatt)
  Pedersen, C. R., Storfjell, S.
  Forsker Sonen
  December 21, 2023
  (not included in 2023 report)

News items *featuring* work by CBA members

- Source or Sink? A Review of Permafrost's Role in the Carbon Cycle
  Derouin, S.
  Featuring work by:
  Parmentier, F.-J.
  Eos
  March 4, 2024.

- Bakteriar hindrar utslepp frå innsjøar med mykje metan
  Helleve, T.
  Featuring work by:
  Pedersen, C. R.
  Forskning.no
  November 12, 2024.

- Ser håp, ikke bare undergang i menneskets tidsalder
  Høgestøl, S. J.
  Featuring work by:
  Hessen, D. O.
  Vårt Land
  November 12, 2024.

Podcast Guest Appearances

- Abels tårn
  Host: Torkild Jemterud
  Participants: Lene Liebe Delsett, **Dag Olav Hessen** and Torunn Kjeldstad
  May 24, 2024

- Real læring
  Realistfabrikken: Hvordan lage biolog
  Host: Vidar Skogvoll
  Participants: Dag Olav Hessen and Tone Fredsvik Gregers
  May 2, 2024

- Naturviterpodden.no
  Engasjement kan redusere tap av natur og løse naturkrisen
  Host: Torbjørn Hundere
  Participants: Dag Olav Hessen, Anne Sverdrup-Thygeson and Vigdis Vandvik
  February 2, 2024

Books



Å tenke med Zapffe

Forfatteren, filosofen, pessimisten, humoristen, klatreren

Hessen, D.O. 2024.. Kagge

ISBN: 978-82-4893-689-3

> *Dag O. Hessen gir oss en spennende innføring i Zapffes pionertanker om naturvern, hans kritikk av veksttankegang og hans dypt originale filosofi om hva det vil si å være menneske.*

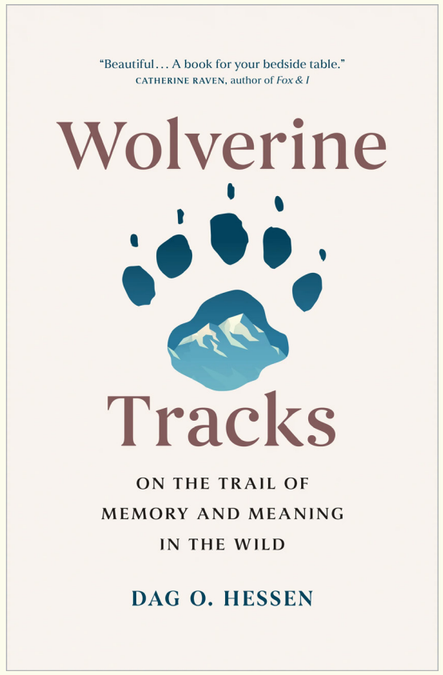


Jervesporet

Hessen, D.O. 2024.. Cappelen Damm

ISBN: 978-82-0267-700-8

> *Jervesporet* er Hessens mest personlige bok hittil. Det er et portrett av norsk naturs mest fascinerende og folkeskye dyr, så kompakt i sin villskap og kraft at det knapt finnes maken. Med en kjeve sterk nok til å knuse de tykkeste lårbein, og styrke nok til å nedfelle et dyr mange ganger sin egen vekt, bite hodet av det, for så å ta det med seg opp i et tre. Å se dyret i sitt naturlige habitat er svært få mennesker forunt.



An English translation of *Jervesporet* was also published by Greystone Books



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2024

Events

2024

Events

CBA Events

PhD Defenses

May

Sabrina Schultze

From the land to the sea: Dynamics and ecotoxicological implications of rising levels of terrestrially derived organic matter entering river and fjord systems

June

Elin Cecilie Ristorp Aas

To mimic microbes with models: Development and application of the microbially explicit soil model MIMICS+ in cold climates

Guest Lecture

Njord Seminar

Slow Closure of Earth's Carbon Cycle

4 February 2024

Dr. Daniel H. Rothman

Professor of Geophysics in the Department of Earth, Atmospheric and Planetary Sciences at MIT

Hosted on Zoom

Annual CBA Meeting and Site Visit

The CBA annual meeting was held over two days, as part of the CBA site-visit.

It was held in Kristine Bonneveis hus, at UiO's Blindern campus. The lectures were open for all to attend.

October 24–25, 2024

Thursday 24th October

- Sebastian Westermann
  Permafrost dynamics, thaw, age, fate and flux of "old carbon"
- Eira Carlsen
  Meet the PhD students – pitches on thesis projects
- Terje Berntsen
  Climatic change and feedback
- Norbert Pirk
  Land-Atmosphere interactions + ERC starting grant project ACTIVATE
- Heleen de Wit
  Soil-water interactions, fate and flux of dissolved organic matter and key elements

Friday 25th October

- Alexander Eiler
  Microbial metabolism and genomics
- Dag Hessen and Adriana Lopes dos Santos
  Freshwater and coastal ecosystem responses, focusing on “browning” and “darkening”
- Thomas Rohrlack
  Research on greenhouse gases and mixotrophic algae – CBA associated projects and infrastructure at NMBU
- Dag O. Hessen
  Highlights from Biogov
- Frans-Jan Parmentier
  Climate-driven disturbances in cold regions: impacts on vegetation composition and the carbon cycle
- Nikita Sobolev (KI) and Franck Lejzerowicz (IBV)
  Nano and Microplastics



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Education

Courses at CBA

Spring 2024

GEO5900

Chemical processes in soil and ground water

The main geochemical reactions controling the chemical composition of soil and ground water are treated in detail, and how these can be quantified and used in interpreting different processes effecting the water quality. Equilibria and kinetics in water-mineral-gas systems are covered, with special emphasis on CO_2 – carbonate reactions, mineral weathering, redox-reactions, ion exchange, sorption, and pollution of organic chemicals. An understanding of these procecces and a corresponding quantification is required to predict the effect of contaminant spill and human influence. Lectures and home works are accompanied by training in computer modeling of geochemical reactions and transport of solutes in groundwater.

GEO9915

Ecological Climatology

The course provides an overview of the relationships between climate and ecology, with focus on climate related feedbacks within boreal, alpine and arctic terrestrial ecosystems. Through the program, students will understand the connections and interactions between land and atmosphere, with an emphasis on terrestrial vegetation ecology and dynamic vegetation modeling. The main focus will be on processes at northern latitudes.

KJM1700

Environmental and climate challenges

The course provides a basic scientific introduction to the environmental challenges and several of the UN's sustainability goals, and how environmental authorities use scientific insights. A group project assignment provides an in-depth look at a chosen environmental theme and training in scientific publishing. The course has an interdisciplinary approach that makes it suitable for students from other disciplines who need basic knowledge of the environment and climate in the academic community.

TFF3219

Cross-disciplinary ecology in the Anthropocene

Anthropocene, the age of humans, is suggested as the name for the geological epoch that we are currently in. Humans are seen as the most important force in the large changes that can be observed in climatic patterns, atmosphere, biodiversity, cryosphere, seas and lakes. IPCC has stated that the climate change is caused by anthropogenic activity, indicating a new link between humans and nature.

This implies a cross-disciplinary challenge for any scientific discipline, from humanities and social sciences to biology, geology and other natural sciences. With the cross-disciplinary research project ECODISTURB as our starting point, this course provides an opportunity to understand and discuss the cross-disciplinary challenges arising in the Anthropocene.

CBA's researchers teach several courses on topics related to biogeochemistry

Fall 2024

BIOS3070/KJM3070

Biogeochemistry

The global environment is tightly linked to the global cycles of carbon and other key elements like nitrogen, phosphorus and iron. These elements are also closely related to the hydrological cycle as well as biological production, diversity and ecosystem services, and chemical properties of the environment. The course will focus on couplings between biological, geological and chemical processes, on the interactions between climate and the environment, and human impacts on these processes.

The lectures are common for the courses KJM3070 and KJM4070 while most of the colloquia, workshops and labs are being held separately.

GEO4161

Contaminants in the geoenvironment

Contaminants in soils and ground water pose a threat to our society and the limited land and water resources. The course will cover:

- Types of contaminants, both organic and inorganic
- Physical/chemical distribution among phases/media
- Biogeochemical processes in soils and groundwater
- Transport of contaminants
- Risk assessment
- Natural attenuation

BIOS4500

General Toxicology

The course will cover basic toxicology and ecotoxicology, including how toxic substances are taken up in the organisms, distributed, biotransformed and excreted, how toxic substances react with biomolecules and downstream consequenses for the organism, as well as knowledge about toxic substances, e.g. metals, organic contaminants and pesticides. The course aims to provide a holistic view of the topic by bridging human toxicology and ecotoxicology.

KJM5700

Environmental Chemistry

The course provides an integrated description of the chemical processes and equilibrium systems that determine mobility, transport, turnover and effects of chemical contaminants in air, soil and water. It also provides an introduction to natural chemical processes in the environment. The lectures are given by external and internal researchers with examples from our own current research.

BIOS5411

Toxicants in ecosystems and humans: effects

The course gives insight into how toxicants affects humans and the environment, with a particular focus on individual effects. Toxicants affect many of the same processes in different organisms and the course will discuss similarities and differences between different species, using mammalian toxicology as a starting point. The course includes aspects of both ecotoxicology and human toxicology.



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Scientific Publications

Peer reviewed articles CBA 2024

A

Aas, E. R., Althuizen, I., Tang, H., Geange, S., Lieungh, E., Vandvik, V., & **Berntsen, T. K.** (2024). Implications of climate and litter quality for simulations of litterbag decomposition at high latitudes. *Biogeosciences*, 21(16), 3789–3817. https://doi.org/10.5194/bg-21-3789-2024

Aas, E. R., **de Wit, H. A.**, & **Berntsen, T. K.** (2024). Modeling boreal forest soil dynamics with the microbially explicit soil model MIMICS+ (v1.0). *Geoscientific Model Development*, 17(7), 2929–2959. https://doi.org/10.5194/gmd-17-2929-2024

B

Basso, S., Musolff, A., & **de Wit, H. A.** (2024). More Frequent Runoff and Connected Sources in Headwaters Promote Browning of Northern Freshwaters. *Environmental Science & Technology Letters*, 12(1), 51–56. https://doi.org/10.1021/acs.estlett.4c00939

Bergström, A.-K., Creed, I. F., Paltsev, A., **de Wit, H. A.**, Lau, D. C. P., Drakare, S., … **Hessen, D. O.** (2024). Declining calcium concentration drives shifts toward smaller and less nutritious zooplankton in northern lakes. *Global Change Biology*, 30(3), e17220. https://doi.org/10.1111/gcb.17220

Bryn, A., **Berntsen, T. K.**, **Horvath, P.**, Isaksen, K., **Liahjell, G. T.**,**Naas, A. E.**, … I.k., V. (2024). På vei mot nye høyder: tre- og skoggrensene stiger. *Arr -- Idéhistorisk Tidsskrift*, 1, 87–100

C

Carlsen, E. C. L., Hjelset, S., Gomes, T., Igartua, A., Sørensen, L., Booth, A. M., … **Eiler, A.** (2024). Synthetic and natural rubber associated chemicals drive functional and structural changes as well as adaptations to antibiotics in in vitro marine microbiomes. *Ecotoxicology and Environmental Safety*, 273, 116134.https://doi.org/10.1016/j.ecoenv.2024.116134

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E

Eklöf, K., von Brömssen, C., Huser, B., Akerblom, S., Augustaitis, A., Braaten, H. F. V., **de Wit, H. A.**, Dirnböck, H.T., Elustondo, D. Grandin, U. Holubová, A. Kleemola, S., Krám, P. , Lundin, L., Löfgren, S., Markensten, H., Moldan, F., Karlsson, G. P., Rönnback, P., Valinia, S., and Vuorenmaa, J. (2024). Trends in mercury, lead and cadmium concentrations in 27 European streams and rivers: 2000-2020. *Environmental Pollution* 360: 9. https://doi.org/10.1016/j.envpol.2024.124761

H

Hessen, Dag O. (03 2024). Why we do science—marine ecosystems in context. *ICES Journal of Marine Science*, 81(4), 643–651. https://doi.org/10.1093/icesjms/fsae027

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Nadeau, C., **Milkoreit, M.**, Eriksen, T. H., & **Hessen, D. O.** (2024). Missing the (tipping) point: the effect of information about climate tipping points on public risk perceptions in Norway. *Earth System Dynamics*, 15(4), 969–985. https://doi.org/10.5194/esd-15-969-2024

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R

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S

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CBA's Economy in Short

CBA operates as an interdisciplinary centre under the Faculty of Mathematics and Natural Sciences. Financially, the Centre is supported through a cooperative model involving three host institutes:

- Dept. of Biosciences (IBV)
- Dept. of Chemistry (KI)
- Dept. of Geosciences (IG)

Since its inception in 2018, the Centre has relied on a foundational grant structure where each institute contributes 500,000 NOK annually. This funding has been critical for covering core operations.

The Centre's economic strategy was designed to transition from direct faculty support to a model driven by external funding. This model utilizes a shared overhead division from external projects, where 60% of the overhead is returned to the respective host institutes and 40% is allocated to CBA.

A major milestone in this transition was the successful acquisition of the "Biogeochemical processes Governing boreal C cycling" (BioGov) project, funded by the Research Council of Norway (RCN). With a total budget of 25 million NOK (running September 2022 – 2027), BioGov currently serves as the financial anchor for the Centre. It funds a significant portion of permanent staff time across all three institutes, as well as multiple PhD and postdoctoral positions.

As we enter 2025, the financial framework for the University of Oslo and the Faculty of Mathematics and Natural Sciences is shifting significantly. The Faculty faces a tightening budget, characterized by "flat cuts" across units and reduced allocations to institutes. Specifically, key partner institutes such as Chemistry and Biosciences are experiencing reduced basic allocations due to fluctuations in study credit production and general framework cuts.

These university-wide financial pressures have immediate implications for CBA:

- We anticipate a scaling down of the direct annual contributions from the partner departments starting in 2025.
- With the reduction in basic funding, the 40% retained overhead from external projects will become the primary engine for CBA's daily operations.
- The Centre must pivot from being a supported unit to becoming a net contributor to the institutes' economies through aggressive external grant acquisition.

To mitigate these risks and ensure financial robustness, CBA is implementing the following measures:

- We are aggressively targeting high-value grants from the RCN and EU (Horizon Europe). This is not only to fund research but to generate the necessary overheads to sustain the Centre's infrastructure.
- Work is underway to position CBA for a Norwegian Centre of Excellence application. Success in this arena would secure long-term, high-volume funding that immunizes the Centre against fluctuations in faculty-level budgets.
- We are reviewing operational costs to ensure maximum efficiency, leveraging synergies between the BioGov project and other affiliated research to cover shared infrastructure costs.

In conclusion, while the financial environment at the Faculty level presents challenges, CBA's established portfolio of external projects provides a solid foundation. The coming year will be defined by a disciplined shift towards full economic self-sustainability.

Centre for Biogeochemistry in the Anthropocene

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