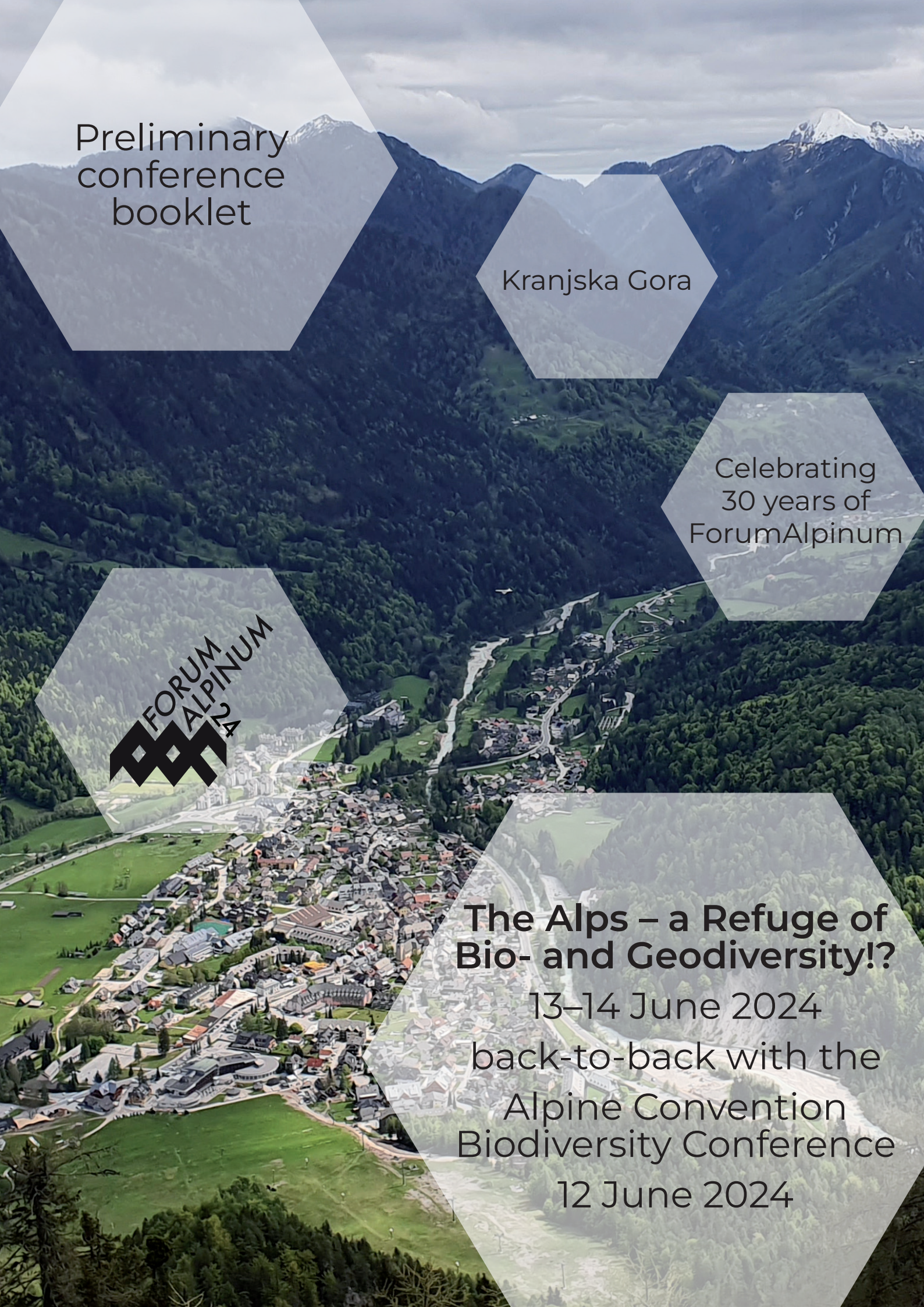

Preliminary conference booklet

Kranjska Gora

Celebrating 30 years of ForumAlpinum

FORUM ALPINUM 24

The Alps – a Refuge of Bio- and Geodiversity!?

13–14 June 2024

back-to-back with the Alpine Convention Biodiversity Conference

12 June 2024

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ORGANISATION

Scientific Board
Janez Nared, Irma Potočnik Slavič, Živa Novljan, Elisa Frank, Valerie Braun (chair)

Organizatorial Board
Blanka Bartol, Andrej Arih, Peter Skoberne, Taja Lakota, Janez Nared, Daniela Ribeiro, Anja Trobec, Elisa Frank, Irma Potočnik Slavič (chair)

Organizers of the ForumAlpinum and the Alpine Convention Biodiversity Conference
International Scientific Committee on Research in the Alps – ISCAR
Ministry of Natural Resources and Spatial Planning, Slovenian Presidency of the Alpine Convention
Permanent Secretariat of the Alpine Convention
Slovenian Academy of Sciences and Arts
Research Center of the Slovenian Academy of Sciences and Arts
University of Ljubljana – Faculty of Arts
Triglav National Park

Co-organizer of the ForumAlpinum 2024
Austrian Academy of Sciences – Institute for Interdisciplinary Mountain Research

Host institution of the ISCAR office
Swiss Academy of Sciences

IMPRESSUM

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WELCOME & INTRODUCTION

Thirty years ago, in September 1994, the first ForumAlpinum took place in Disentis, Switzerland. At this event, the need for interdisciplinarity and cooperation in Alpine research was recognized as urgent to ensure synergies between the existing research projects and programmes, as well as the policies, and to connect and bridge – scientists and policymakers, different disciplines, and different countries and languages. In addition, there was an important shift in Alpine research – from the Alps as a scientific phenomenon to the Alps as a living place – which brought ecological and utilization policy issues more into focus.

The idea was to promote research and scientific results and, by the exchange with the policy level, provide insights for better planning. Through the science-policy dialogue and the involvement of affected interest groups, the research results could quickly lead to data-based decisions and measures.

The research topics identified thirty years ago show the foresight of the participants, especially as many of the topics identified in 1994 are still highly relevant today, such as

- the challenges of tourism and its impact on the Alps,
- the position of the Alps in the context of European economic development,
- the perception of socio-economic changes by the affected population and how to adapt to them,
- the systematic recording of cultural diversity,
- stability and resilience of the Alpine ecosystems,
- the influence of climatic changes on Alpine ecosystems,
- natural and human-influenced material cycles and energy flows in mountain regions in relation to regional water, energy and bioresources, or
- aspects of human well-being, physical and mental health in the Alps.

Since then, the ForumAlpinum has developed into a discussion platform aimed at exchanging the latest research findings, setting new research priorities, promoting interdisciplinary research, launching national and international research programmes, and placing the Alps on the European research policy agenda, identifying practical needs and knowledge gaps, and transferring knowledge between science, politics, business, and society.

Five years later, the International Scientific Committee on Research in the Alps – ISCAR for short – was founded to pursue these goals.

The bridge between science and policy is especially relevant this year, when we are holding an event with the Slovenian Presidency of the Alpine Convention and addressing biodiversity as one of the priorities of the Slovenian Presidency and the first priority area of the Multi-Annual Work Programme of the Alpine Conference 2023–2030, namely the conservation and assessment of Alpine biodiversity and ecosystems.

I strongly believe that such a dialogue is a must in order to achieve a sustainable future in the Alps and I thank the Slovenian Presidency and the Permanent Secretariat of the Alpine Convention for this joint endeavour, as well as all authors who provide their latest research results and enable this science-policy dialogue.

Dr. Janez Nared, *ZRC SAZU, President of ISCAR*

KRANJSKA GORA

The Municipality of Kranjska Gora (256 km^2, 5878 inhabitants, SURS 2023) is located in the Upper Sava River Valley in the far northwest of Slovenia: in the north, the municipality borders on Austria and to the west on Italy. In the Peč summit above Rateče (1,508 m) the borders of the three countries meet. In the north, the Karavanke Mountains ridge rises above the Sava Dolinka River Valley, and in the south, the Julian Alps rise to Triglav (2,864 m). A large part of the municipality's area belongs to the Triglav National Park (established in 1924). The municipality also houses the Zelenci Nature Reserve, and the Municipality of Kranjska Gora has 14,522 hectares or 56.66% of the total area of the NATURA 2000 area.

Due to its natural features the municipality has developed into an important tourist centre in the heart of the Alps. The beginnings of tourism in Kranjska Gora date back to the first half of the 19th century and are connected with pilgrimage tourism on Svete Višarje Mountain (Italian: Monte Lussari, German: Luschariberg, Friiulian: Mont Sante di Lussari) above Trbiž/Tarvisio/Tarvis. An important stimulus for tourism development was the construction of the so-called Gorenjska (Carniola) Railway (built to Tarvisio in 1870). In the 1930s, Kranjska Gora developed into one of the most important tourist destinations in former Yugoslavia, and also became recognized abroad as a winter tourist destination (mainly for the ski jump infrastructure and championship in Planica). After World War Two, Kranjska Gora became the most important Slovenian and Yugoslav winter sports centre, and the summer season has gradually developed, with a special quality leap in the construction of the Planica Nordic Centre. The Municipality of Kranjska Gora has the status of a tourist destination and was among the first municipalities in Slovenia to establish a public institute for the promotion and development of tourism (1997). In a detailed analysis the Environmental Agency of the Republic of Slovenia confirmed that the destination fully meets the criteria for a "*tourist place in a healthy climate*".

The importance of tourism in the local economy is evident from the data on tourist visits for the year 2023: the municipality of Kranjska Gora (as the so-called »mountain« municipality) ranks third among all Slovenian municipalities in terms of the number of tourist overnight stays. In the year 2023 (SORS 2024), the municipality of Kranjska Gora registered 355,645 tourist arrivals (70% of foreign ones), who generated 961,144 overnight stays (30% domestic guests). From 2009 to 2023, the number of arrivals increased by an index of 245 and the number of overnight stays by an index of 212, while the number of permanent tourist beds increased: from 5639 (in 2009) to 6710 (in 2018).

As part of the preparation of the tourism development strategy in the period 2015–2025 (Development Strategy …. 2015) various activities are underway in 2024 to prepare the strategy for the period 2025–2035, which can be seen on https://obcina.kranjska-gora.si/objava/874452), local residents and stakeholders recognized at workshops that destination Kranjska Gora offers visitors and tourists "*… exceptionally beautiful nature and activities and experiences in it (skiing, cycling, relaxation, peace, forest, mountain trails, etc.); good cuisine; competitive prices of overnight stays compared to neighbouring regions (Carinthia, Friuli); pleasant, family-friendly; easy accessibility; cultural heritage; friendliness; Three-border area; sport events; fun; many accommodation facilities; clean, mountain air.*" (Tourism Development Strategy in the Municipality of Kranjska Gora 2015–2025, 2015).

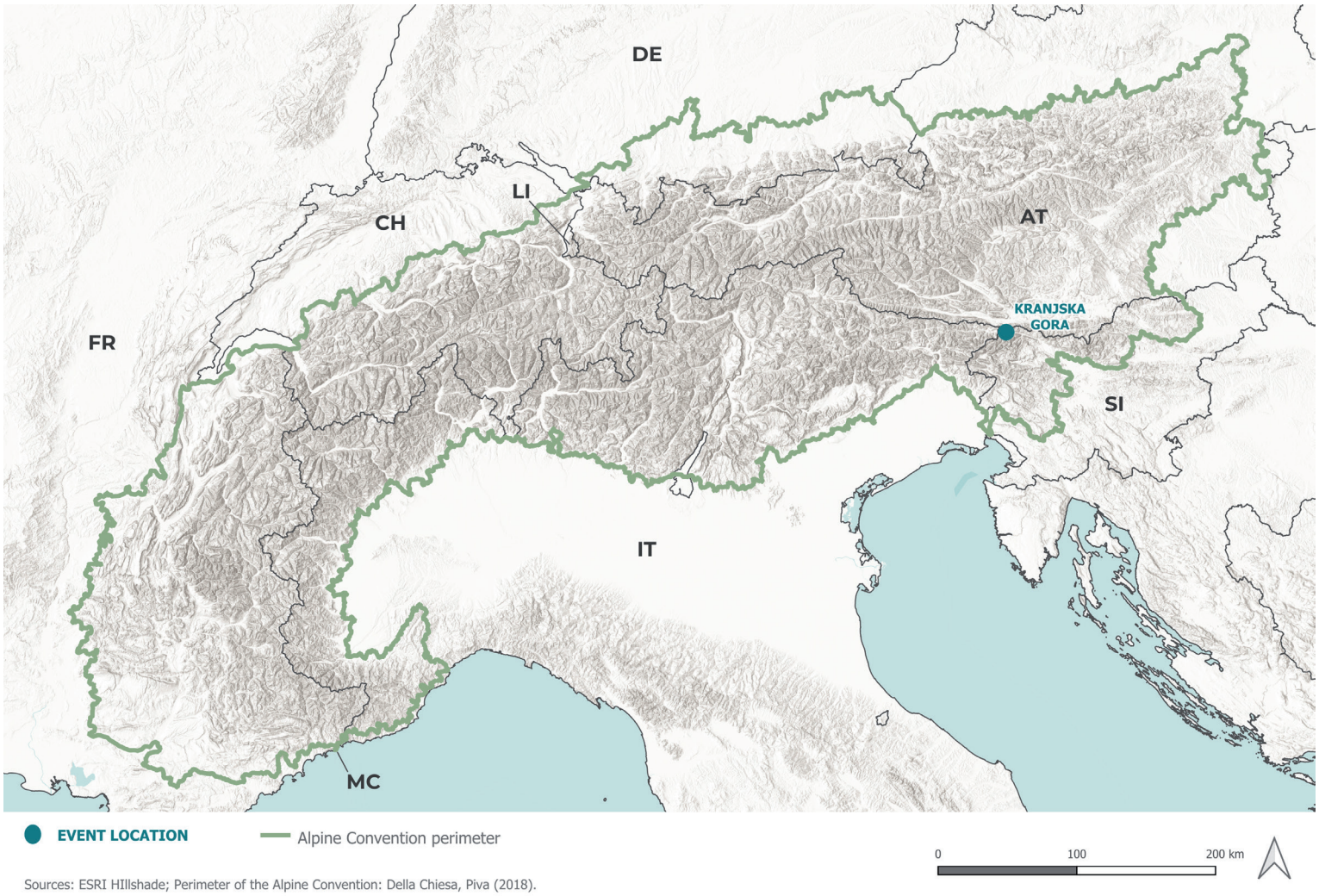
In accordance with the national and regional guidelines for tourism development and with the participatory involvement of local actors and stakeholders, the strategy also set out a vision for the development of tourism in the municipality of Kranjska Gora by 2025.

"*The Municipality of Kranjska Gora will represent an attractive tourist area for residents and visitors, based on sustainable development, natural and cultural heritage and a healthy living climate. It will focus on the connected sports tourist offer, openness and cooperation at the crossroads of the three countries. It will be distinguished by a specialized offer throughout the year, which will enable an authentic, healthy and active holiday with well-being in an environment of homeliness and mystery. The spatial and infrastructural arrangement of the municipality will support the development of tourism, agriculture as well as the development of all tourism-related activities.*" (Tourism Development Strategy in the Municipality of Kranjska Gora 2015–2025, 2015).

The development strategy of the tourist destination Kranjska Gora focuses on three key development fields: (1) increasing the competitiveness of the tourist destination and stimulating business environment, (2) sustainable development of all stakeholders of the tourist destination, and (3) effective marketing and promotion of the destination. As many Alpine tourist destinations, Kranjska Gora faces green winters, pressures of mass tourism, measurable weather volatility, demands and expectations of the local community and investors, etc.

ForumAlpinum 2024 brought you to Kranjska Gora in June 2024 – welcome. As an internationally recognized green tourist destination at the entrance to the Triglav National Park, which celebrates its 100th anniversary in 2024, Kranjska Gora is in any way a suitable location for an engaged and critical reflection on bio- and geodiversity in the Alps and other mountain areas around the world. Several aspects of bio- and geodiversity in the Municipality of Kranjska Gora and the Triglav National Park and the Alpine macro-region in Slovenia will be highlighted by contributions at a scientific conference, while individual locations could be experienced on a field excursion.

Irma Potočnik Slavič, *Professor for Human and Regional Geography at the Department of Geography (Faculty of Arts, University of Ljubljana, Slovenia).*



Location of the municipality of Kranjska Gora within the Alpine perimeter of the Alpine Convention.

FOREWORD OF THE SECRETARY GENERAL OF THE ALPINE CONVENTION

The Alps are a special place, a mountain range crossing several borders and including many unique environments and landscapes. They are home to almost 15 million people, 30,000 animal species, and 13,000 plant species. Biodiversity and geodiversity are interlinked and integral parts of the Alpine landscapes and are part of what makes the Alps such a unique place. These natural features attract people to visit the Alps as well as to live and work here and are thus fundamental enablers of human life in the region.

However, the Alps are increasingly faced with a myriad of challenges, from the climate crisis to the loss of biodiversity. The reduction of habitats and overexploitation of resources is threatening the unique features of the Alps. Their protection and sustainable development are therefore crucial for a good quality of life of the Alpine inhabitants as well as other Europeans, as the Alps have an ecological significance for a large part of the continent.

This is where the Alpine Convention comes in, an international treaty created to ensure the natural landscapes are protected and human settlements and infrastructure develop in a sustainable manner. Together with the European Union, the eight Alpine countries came together to address the common challenges facing the Alps. Research plays a vital role in the sustainable development of the Alpine region. Data underpins all aspects of policy development, starting with the analysis of developments and trends as well as identifying issues. It enables informed decision-making, the formulation of necessary measures and an evaluation of their impacts.

In order to find and implement solutions to current crises, we need to understand and monitor different processes in the environment and society. This also requires us to work together across borders and exchange knowledge. The International Scientific Committee on Research in the Alps not only encourages this exchange in the research sphere but uses its status as an official Observer of the Alpine Convention to facilitate the use of the acquired knowledge in policymaking. The ForumAlpinum, organized back-to-back with the international biodiversity conference on joint biodiversity action in the Alps presents a unique opportunity for such exchanges, providing a platform for policymakers and researchers to meet and share insights and experiences.

Exchanging knowledge and ideas is the key to unlocking solutions to our shared challenges. It is especially crucial for biodiversity and geodiversity, which are fundamental to our very existence and ability to flourish in the Alpine region. The Alpine Convention recognizes the importance of this diversity, which is reflected in the priorities of its current work. Biodiversity is one of the three pillars of the Multi-Annual Work Programme of the Alpine Conference 2023–2030 as well as the programme of the current Slovenian Presidency. Geodiversity is addressed within the two other priorities – climate action and quality of life. Setting these priorities shows the Alpine Convention's commitment to preserve what makes the Alpine region so special. Together we can take steps to help make the Alpine region a refuge for biodiversity and geodiversity and keep on leading the way for sustainable life in the Alps.

Alenka Smerkolj, *Secretary General of the Alpine Convention*

FOREWORD OF THE CHAIR OF THE SCIENTIFIC BOARD

Dear participants!

It is with great pleasure that we present the proceedings of the ForumAlpinum 2024, held from 12–14 June 2024 in Kranjska Gora, Slovenia.

This year's theme "The Alps - a refuge of bio- and geodiversity!" invites you to take a closer look at and discuss the extraordinary biological and geological diversity of the Alps.

The Alps are not only an impressive backdrop of majestic peaks, clear lakes, and lush forests, but also a hotspot of biodiversity and geodiversity. They are home to a multitude of habitats and species, many of which are unique and endemic. At the same time, they offer a rich geological diversity, which is reflected in spectacular rock formations and glaciers.

In the Alps, the gradient, climate, soil types, and geology influence the distribution of species, resulting in a diversity of ecosystems and habitat types. Taxonomic diversity is made possible by mountain uplift, increasing relief structure, glaciation cycles, and climate change from the late Tertiary to the present day. The contraction of the bioclimatic belts along the altitudinal gradient offers a large number of habitat types. Added to this is the complex topography, which favours a wide variety of microclimates with different heat and humidity conditions and thus an extraordinarily great biological diversity. Furthermore, the geological heritage of the Alps (geological structures, lithologies, landforms, soils) is very rich and diverse and the result of a complex geological and climatic history.

The diverse geo- and biodiversity of the Alps is linked to the development of a diverse cultural landscape. For generations, the concept for the sustainability of the Alpine region has been multifunctionality in terms of forestry and agriculture. Today, the Alpine region is directly and indirectly affected by land-use changes, the abandonment of small-scale agriculture, infrastructure construction, tourism, climate change, and habitat fragmentation, all of which have an impact on biodiversity in the Alps.

In cooperation with the Alpine Convention, which has been committed to the protection and sustainable development of this unique natural and cultural area for many years, we want to emphasize the importance of the Alps as a refuge for biological and geological diversity at this Forum Alpinum. It is of utmost importance that we not only preserve these treasures, but also actively protect them and develop sustainable solutions to the challenges of climate change and human intervention.

Our conference will provide a platform to share scientific knowledge, discuss innovative conservation measures, and strengthen partnerships. Experts and scientists from different disciplines will present their latest research findings and discuss them with policy makers.

Valerie Braun, *Institute for Interdisciplinary Mountain Research, Austrian Academy of Sciences*
Chair Scientific Board & ISCAR-P

PROGRAMME

THURSDAY, 13 JUNE 2024

8:00 **Registration**

9:00 – 18:30 **ForumAlpinum – ISCAR Scientific Conference**

Room: Plenary room
Moderator: Irma Potočnik Slavič

9:00 – 9:15 **Welcome, introduction, and keynote speakers**
Janez Nared, President of ISCAR
Alenka Smerkolj, Secretary General of the Alpine Convention
Valerie Braun, Chair of the Scientific Board of ForumAlpinum 2024

9:15 - 9:45 **Keynote 1: Kurt Hanselmann**
The value of science is not just what you find out, but who cares about it

9:45 - 10:15 **Keynote 2: Špela Čonč**
Linking bio- and geodiversity: importance of landforms for the ecology and conservation of the Eurasian Lynx (*Lynx lynx*)

10:15 – 11:00 **Coffee break**

11:00 – 12:30 **Interactive parallel sessions**

11:00 – 12:30 **Grazing & Alpine pastures**
Room: Planica A
Chair: Andrea Omizzolo

Bacterial and fungal diversity of Alpine pastures
Giulio Galla, Nadine Praeg, Theresa Rzehak, Matthias Scholz, Filippo, Colla, Julia Seeber, Paul Illmer, Heidi C. Hauffe

Climate change effects on agronomic performance and biodiversity in Alpine pastures
Bernd Panassiti, Jörg Ewald, Martina Hofmann, Christina Hartung, Sebastian König, Sebastian Seibold

Vegetation dynamics since 1953 in a part of the Stelvio National Park (Italy)
Katharina Ramskogler, Lèon Lepesant, Erich Tasser

11:00 – 12:30 **Tourism**
Room: Planica B
Chair: Cristina del Biaggio

PEMS: People experience of mountain soundscapes
Balandino Di Donato, Iain McGregor

Overtourism or inadequate dispersal – applicative testing of a new monitoring method in Bohinj Lake area, Slovenia
Pija Lapajne, Matevž Premelč, Klemen Strmšnik, Aleksandra Krajnc, Matjaž Harmel

The development of ecotourism and biodiversity conservation in the Albanian Alps
Mirela Tase, Manjola Xhaferri

11:00 – 12:30 **Biodiversity I**
Room: Plenary room
Chair: Andrej Arih

A century of rewilding affects mountain biodiversity at different spatial scales
Sonja Wipf, Ruedi Haller, Stefanie Gubler

AtlasFloraAlpina – a new flora online-atlas for the entire Alpine arc
Stefan Eggenberg, Sylvain Abdulhak, Alessio Bertolli, Jörg Ewald, Philippe Juillerat, Adrian Möhl, Brigitte Marazzi, Filippo Prosser, Branko Vreš, Thomas Wilhalm

Eastern Alpine basophilic scots pine and black pine forests in Triglav National Park, Slovenia: distribution, vegetation, and stand characteristics
Matija Klopčič, Andreja Nève Repe, Matjaž Guček, Andrej Rozman, Valerija Babij, Aleš Poljanec

The Long-Term Biodiversity Index (LBI) – A new tool for monitoring and planning the restoration of abandoned mining areas and landfills
T*obias Köstl, Hanns Kirchmeir*

Long-term changes in bio/geodiversity of the Julian Alps – a consequence of climate fluctuations or human influence?
Nina Caf, Maja Andrič

12:30 – 14:00 Lunch break

14:00 – 15:30 Interactive parallel sessions

14:00 – 15:30 **New technologies**
Room: Planica A
Chair: Lea Reusser

Unlocking nature's Secrets: Digital Twins, eDNA and AI in nature conservation – A glimpse into the BioMONITec Project
Vanessa Berger

Remote sensing for monitoring restoration efforts in Alpine areas
Manuela Hirschmugl, Florian Lippl, Petra Miletich, Corinna Hecke, Larissa Posch, *Hanns Kirchmeir*

Conceptualising the management of conservation areas: The launch of IPAM Toolbox 2.0
Michael Jungmeier, Vanessa Berger, Hanns Kirchmeir, Dariia Strelnikova
Digital Trails: Harnessing Outdoor and Fitness App Data for Sustainable Tourism Management in Sensitive Ecosystems
Lilia Schmalzl, Isidoro de Bortoli, Karolina Taczanowska

Datafication in outdoor recreation and tourism – emerging potential of Big Data for sustainable management of nature trails in the context of bio- and geodiversity
Karolina Taczanowska, Fruzsina Stefan, David Ganhör, Kamil Choromański, Dariusz Gotlib, Mariusz Ciesielski

14:00 – 15:30 **Biodiversity and culture & Historic changes**
Room: Plenary room
Chair: Christian Rohr

Landscape features as the cornerstones of landscape character, identity, and biodiversity
Nadja Penko Seidl, Barbara Kostanjšek, Mojca Golobič

Study Circles to reinforce existing values regarding biodiversity
Daniela Ribeiro, Mateja Šmid Hribar, Patricija Rejec

Dynamics of ecosystem services in response to land use and climate change: A case study in the Italian Alps
Clara Tattoni, Paolo Zatelli, Gianluca Grilli, Marco Ciolli

The Alps: Green or Colourful? From Early-Modern to Post-Modern Attitude to Meadows
Žiga Zwitter

14:00 – 15:30 **Water resources & Geodiversity**
Room: Planica B
Chair: Leopold Füreder

Let's go! Valorisation of spring habitats in an inner-Alpine region
Angelika Abderhalden, Stefanie von Fumetti

Long-term research on springs and springbrooks in the UNESCO Biosfera Engiadina Val Müstair
Stefanie von Fumetti, Angelika Abderhalden

Warming alpine streams: differential vulnerabilities of aquatic invertebrates
Georg H. Niedrist, Leopold Füreder

Increasing population trends of non-native fishes in rivers of the Eastern Alps
Georg H. Niedrist, Andreas Hilpold, Petra Kranebitter

Mountain pasturing and quality of water sources in the Kamniško-Savinjske Alps
Natalija Špeh, Anja Bubik

Valuing geodiversity in Alpine environments: selected case studies from Slovenia
Borut Stojilković

15:30 – 16:30 Coffee break & Poster session

15:30 – 16:30 **Posters**
Hotel Ramada Resort in the coffee break area

Second homes and resilient communities in Alpine resorts – A geographical approach to multi-local inhabitant footprints in France, Switzerland, Italy, Austria and Slovenia
Quentin Benoît Guillaume Drouet

The potential of OpenStreetMap for proactive, digital visitor guidance in ecologically sensitive areas
David Ganhoer, Karoline Zsak, Manuel Steinbauer, Arne Schwietering, Fruzsina Stefan, Karolina Taczanowska

Detection of forest stress from European spruce bark beetle attack in northern Italy through remote sensing techniques
Matteo Giomo

Plant communities of mountain pastures in the Berchtesgaden region
Christina Hartung, Bernd Panassiti, Jörg Ewald

'I need this water as a driving force' – Introduction of hydroelectric infrastructure in the villages below the Karawanks, 1904–1908
Sara Šifrar Krajnik

Footprints in the Julian Alps: Identifying hiking hotspots
Jasna Sitar

16:30 – 18:00 Interactive parallel sessions

16:30 – 18:00 **Spatial planning**
Room: Planica B
Chair: Hubert Job

Alpine Spatial Planning Perspectives: Green infrastructure, energy, and spatial development
Dominik Bertram, Tobias Chilla, Markus Lambracht

A tailored and trans-scalar approach to face the Alpine region's challenges
Luisa Pedrazzini

Planning without planning: Do renewable energy projects endanger open spaces in the Alps while undermining spatial planning frameworks?
Marco Pütz, Arthur Schindelegger, Hubert Job, Constantin Meyer

Monitoring tourism flow to high-altitude mountain and protected areas in the Alps: A cartographic and spatio-market planning methodology
Ahmed Shams

Climate change and the Alpine quality of life: Questioning the status quo of spatial planning in the Alps and its functionality to tackle long-term water security
Kerstin Ströbel

16:30 – 18:00 **Ecosystem services & connectivity**
Room: Planica A
Chair: Daniela Ribeiro

Microplastics contamination in high mountain lakes – case of Triglav National Park
Matej Kovač, Andrej Kržan, Irena Mrak

Priority ecological connectivity areas for spatial planning interventions – An in-depth analysis of a potential ecological network and of human barriers in the EUSALP area
Peter Laner, Andrea Omizzolo, Filippo Favilli

Can the concept of ecosystem services help in the management of protected areas?
Ilona Rac, Anže Japelj, Suzana Vurunić, Mateja Šmid Hribar

Finding open spaces: a consensus-based mapping for Swiss mountain regions
Matteo Riva, Felix Kienast, Adrienne Grêt-Regamey

16:30 – 18:00 **Biodiversity II**
Room: Plenary room
Chair: Roland Psenner

Saving Dinaric–SE Alpine Lynx Population as contribution to lynx conservation in the Alps
Rok Černe, Miha Krofel, Urša Fležar, Maja Sever, Tilen Hvala, Matej Bartol, Tomaž Skrbinšek, Miha Marenče, Lado Bradač, Aleš Pičulin, Maruša Prostor, Miha Marolt, Aleksandra Majič Skrbinšek, Tomislav Gomerčič

Impact of hybridisation on *Lepus timidus* and *L. europaeus* gut microbiota in the Italian Alps
Lara Marinangeli, Giulio Galla, Barbara Crestanello, Nadine Praeg, Theresa Rzehak, Francesco Nonnis-Marzano, Julia Seeber, Paul Illmer, Heidi Christine Hauffe

Conservation and sustainable management of the Alpine ibex in the cross-border area of the Julian Alps
Andreja Nève Repe, Andrej Arih, Marco Favalli, Maruša Prostor, Jernej Javornik, Aleš Poljanec

More than meets the eye: unravelling anthropic land-use impacts on skin microbiota of an opportunistic amphibian species
Lucia Zanovello, Giulio Galla, Matteo Girard, Stefano Casar, Irene Lo Prest, Paolo Pedrin, Giorgio Bertorelle, Heidi Christine Hauffe

18:00 – 18:30 Report to the plenary, short reflections and conclusions

FRIDAY, 14 JUNE 2024

8:30–13:00 Forum Alpinum Excursions (Registred participants only)
8:30–15:00

8:30–13:00 Radovna River valley

Itinerary (bus and short walks):

Zgornja Radovna: visit of the Pocar Homestead, short walk to the hummocky meadow; Mojstrana: coffee break; Slovenian Alpine Museum in Mojstrana: visit of the museum and Alpine Convention Infopoint.

The Pocar Homestead is a museum-style house, which is considered as one of the oldest homesteads in the Triglav National Park. It also includes an information point, an exhibition and an event space. Pocar Homestead is a cultural monument of national importance.

In 2006, the Triglav National Park received the Europa Nostra Diploma for the Pocar Homestead (European Union Prize for Cultural Heritage in the category of architectural heritage).

The Slovenian Alpine Museum illustrates the development and the histor of Slovene mountaineering, climbing, and mountain rescue, interwoven with educational and conservational content. Its rich collection of historical objects and artefacts, diversity of photographic, film, book, and museum archives, and an exten- sive museum library, provide clear insights into the powerful, lasting impact of mountains and mountaineering

8:30-15:00 Soča River valley

Itinerary (bus and short walks):

Stari Tamar (Old Tamar)–Šupca (vista)–the source of the Soča River (short walk); Trenta: coffee break; visit of the Dom Trenta (Triglav National Park Information Centre); short lunch break

Soča River – the Great Gorge (short walk); Predil pass.

Stari Tamar – Šupca: an area located along the Tamar River, which is a tributary of the Soča River. The area is attractive to visitors due to its historical significance and well-preserved nature. Šupca offers panoramic views of the Soča Valley and the Julian Alps.

The Dom Trenta is the cultural and social centre of the sparsely populated village Trenta. It presents the cultural landscape, rich ethnological heritage, nature and past life in Trenta, as well as the peculiarities of the Triglav National Park.

Soča River – Great Gorge: also known as the "Emerald Beauty", the Soča River is renowned for its striking turquoise color, which is the result of the river's unique limestone bed. It originates in the Trenta valley and flows through the picturesque Julian Alps, carving its way through the stunning landscapes of the Triglav National Park. The Great Gorge is a breathtaking natural wonder of the Soča River with its stunning depth and clear, emerald-green waters and with the dramatic and picturesque landscape of surrounding rocks and cliffs.

ACCOMPANYING ACTIVITIES

12 June 2024 at 17:15 in the Vršič room (3rd floor)

DINA Project presentation: Coexistence with large carnivores and concern for nature protection – the example of the Municipality of Pivka

The municipality of Pivka is located in the southwestern part of Slovenia in the Karst region of the Dinaric mountains, where as much as 70 % of the municipality is covered by forest. The area contains several Natura 2000 areas and nature is well preserved in the region. Ten years ago, the municipality recognised the wealth of nature here and founded the Pivka intermittent lakes Landscape Park with the aim of protecting special living environments and species as well as water sources in the Pivka Basin.

A great deal of emphasis and activities were focused on awareness-raising and communication activities related to the protection of nature, large carnivores, and how to coexist with them. There are two interpretive centres dedicated to nature in the municipality, the Ecomuseum of the Pivka intermittent lakes and the Dina Centre for Large Carnivores. In the latter, in addition to informing about large carnivores through various activities and guided tours, visitors can learn about nature conservation measures to achieve a successful coexistence of the local population and large carnivores.

During this presentation, communication and awareness-raising activities related to large carnivores and nature protection will be shared, as well as measures taken by the Municipality of Pivka for nature conservation and coexistence with large carnivores.

Speakers:
Tadej Kogovšek, Municipality of Pivka, Pivka intermittent lakes Landscape Park,
Helena Šneberger Mandelj, Dino Pivka Center for Large Carnivores

12–13 June 2024 on the staircase of the Ramada Hotel

Exhibition of the “Youth and Life in the Alps” project posters

The project aimed at raising awareness and encouraging young people, from Jesenice region schools, to protect the Alpine environment in which they live.

KEYNOTES

The value of sciences is not just what you find out, but who cares about it

Kurt Hanselmann

swiss i-research & training, Zürich, Switzerland

The Disentis ALPINE FORUM of 1994 was designed in response to the needs of the time

In 1993, the Swiss Academy of Natural Sciences felt a special effort was needed to strengthen collaboration between those involved in alpine research and launched the AlpineForum. It invited other Alpine Countries to participate. The mandate was to define collaboration for actions to protect the alpine environment for the benefit of itself and its inhabitants.

Mountain research was in no way new to the eight countries of the Alpine Arc

Geological Alpine Research in Switzerland started in the 18th century. Bénédict de Saussure (1740–1799), a geologist from Geneva, who climbed and investigated Mont Blanc in 1787, Louis Agassiz (1807–1873) who developed a theory of glaciers by studying the Aare glacier and, Albert Heim (1849–1937), are credited with pioneering geological studies of the Alps. Some 200 years earlier, Conrad Gessner (1516–1565) who collected, made drawings and described alpine plants is considered the first alpine GeoBotanist. The 20th century began with engineering and disaster prevention challenges (the construction of the Jungfraubahn in 1912, of the Sphinx Meteorological Observatory in 1937 which later became the High Altitude Research Station Jungfraujoch at 3,554 m a.s.l.). In 1942, the Swiss Federal Institute for Snow and Avalanche Research (SLF) opened its first snow laboratory at Weissfluhjoch. A broader interest in the "High Altitude Research" began in the 1930 when the Swiss Foundation for Alpine Research supported scientific exploration expeditions to the Himalayas first and second climbs of the Lohtse (8,501 m) and Mount Everest (8,850 m), respectively, in 1953.

The 1990ties were the times when the referendum on the protection of the Alps from transit traffic was accepted by the Swiss voters (1994) and a number of national and European research programs were supported by the Swiss National Science

Foundation and the EU framework program. ProClim, the Academy's Forum for Climate and Global Change, was established with the mandate to also compile ongoing mountain research projects in these topics in a publically accessible database.

Today, the Swiss Agency for Development and Cooperation (SDC), a coordinating body for international collaboration of the Swiss Federal Department of Foreign Affairs and the Swiss Academy of Sciences support the Mountain Research Initiative (MRI) at the University of Bern. The MRI coordinates mountain research communities world wide. It emphasises the socio-economic and socio-ecologic role of knowledge gained through research in mountain areas and its impact on cultural development and policy processes.

The most recent addition to the "Third Pole" initiative is the Swiss Polar Institute (SPI) established at EPFL in Lausanne in 2018. Although its main objective is to promote Swiss research in the "real" polar regions of the Earth, it also supports synergistic research in extreme environments at the "Third Pole", i.e. cryospheric, biogeochemical, engineering and ecosystem studies in alpine and other extreme environments. At the same time the Université de Lausanne began to assemble research groups in a *Centre interdisciplinaire de recherche sur la montagne*. Its office is housed at Sion.

The global declaration period

The last quarter of the 20th century is characterised by measures to protect the Alps. The years were full of international conferences and declarations addressing global change issues, and several European and national mountain research projects were underway.

The first United Nations Conferences on the Human Environment took place in Stockholm, Sweden in 1972. It took 2 decades until the next UN Conference on Environment and Development, in Rio de Janeiro, Brazil, in 1992. This was 30 years after Rachel Carson's last book on the "Silent Spring", 1962. The Rio Conference set the agenda for a worldwide renewed awareness of a rapidly changing environment. The conferences produced general action plans, assessment programs, and management activities to express concern about the state of the environment. The 2015 UN summit in New York created the resolution "Transforming Our World: The 2030 Agenda for Sustainable Development", and listed 17 Sustainable Development Goals. In the same year, the Conference on Climate Change released the Paris Agreement, ratified by many countries and organizations. The reports of the Intergovernmental Panel on Climate Change (IPCC) are updated regularly and COP conferences assess the progress and agree on new timelines. The Panel aims to limit the global average temperature increase to less than 2°C above the preindustrial level. In the Alps, this value has more than doubled during the same period.

The Disentis ALPINE FORUM occurred during the global "Declaration Period". We ended the forum with an action plan, actually a wish list of research that we were going to pursue anyway, provided the envisioned collaborations could get funded. Some projects did, and many did not.

Where do we stand today, after decades of declaring noble intentions?

I was born into an atmosphere whose CO_2 concentration was back-calculated to between 300 and 310 ppm; today it is 425 ppm and still rising. We skied for weeks every winter in front of the house, skated on the ice of natural ponds, and walked across the frozen lake Constance in 1963. These things will never return.

We have created many programs and laws aimed at protecting alpine ecosystems, with their biodiversity, have limited human expansion into delicate landscapes, but have failed to reduce the major causes of environmental degradation: the wasteful use of energy and material resources. One must come to realize that it's not nature, it's us and our behavior that have hindered progress in achieving the goals set forth. The declarations reiterated over and over again for half a century of conferencing and the action plans have remained hopeful intentions.

Did the Disentis AlpineForum have an impact?

The greatest result of 30 years of research in and about the Alps since Disentis is the continued need and existence of the ForumAlpinum as a platform for exchanging knowledge about Alpine ecosystems. After we failed to establish Disentis as a Center for Alpine Education where the FORUM ALPINUM would have occurred regularly, we began implementing ideas from the 1994 action plan into an annual workshop aimed at researchers, students, teachers, and the public. We used our experience with the Lake Cadagno Research Station (today Centro Biologica Alpina at Piora) and the observation of how it has strengthened the local sciences. The success with Cadagno inspired and encouraged us to follow the pioneers' spirit of discovery and create an educational activity for high-altitude ecological research. Focusing on Science, Technology, Education, Economics, and People (STEEP), we opened a transdisciplinary platform for discipline-oriented researchers and encouraged participants to do the same at their home institutions.

The high-altitude STEEP program

Since 1998 STEEP courses have taken place in the Jöri-Silvretta Arena in the southeastern part of the Swiss Alps. The program focuses on seeing, experiencing, and studying biogeoscience topics in the natural environment. I will discuss some contents of the STEEP program such as

- The evolution of ecosystems where ice retreats.
- The role of the Alps in the global carbon cycle.
- What we learn from linking the Alps to the Oceans and Mars.
- The climate-energy dilemma and the business with "sustainability",

and will illustrate a few "Da Vinci Discovery Projects" to highlight the course program:

- How glacial lakes can kill cows.
- The rocks that heat the Earth and how iron scavenges nutrients.
- How little works in nature without microbes.
- How artists perceive science, and
- how alpine life might look in a post-global-change world when AI might help to master it.

This year's workshop flyer is available as pdf via "Guest access" under the URL: https://lms.uzh.ch/url/RepositoryEntry/16318464010/CourseNode/109529786267279

The main course working set can be reached from the links on the flyer.

The future

Presently mankind struggles between dealing with the frequency and the consequences of environmental disasters. We know what causes them, but I am not very optimistic that pumping CO_2 out of the atmosphere and depositing it in contact with basaltic rocks to be turned into solid carbonates, or to dim the sun with aerosols to cool the Earth will make things better.

Even in 30 years from now, the Alps will still have the same great geodiversity. How the biological diversity will develop is more difficult to predict. For too long I had illusions about the statements and action plans that emerged from conferences. They won't change things because we don't act accordingly.

However, I am optimistic that researchers will remain motivated to learn from their results to understand alpine ecosystems and communicate their knowledge. Inspiration in education can impact future generations and make them care.

Short summary

During the Global Environmental Change Declaration Period in the last quarter of the 20th century, the ForumAlpinum emerged as a platform for addressing environmental topics in mountain regions. The 2030 UN Agenda for Sustainable Development and the IPCC's assessments highlight the possible causes and mitigation of environmental degradation and emphasize the need for targeted research. High-altitude ecological research and education, exemplified by the STEEP training program and the Leonardo da Vinci Discovery projects, delve into the interplay between geodiversity, biodiversity, and economics in mountain regions. The Jöri-Silvretta Biogeoscience Arena and the Lake Cadagno Research Station serve as hubs for education and scientific inquiry in the Swiss Alps. They contribute to our understanding of mountain ecosystems and foster stewardship in the face of environmental change challenges.

Keywords: ForumAlpinum Disentis, High-altitude ecological research, IPCC, GeoBioDiversity, STEEP program, Leonardo da Vinci Discovery projects, Lake Cadagno Research Station, Jöri-Silvretta Biogescience Research Arena

Linking bio- and geodiversity: the importance of landforms for the ecology and conservation of the Eurasian lynx (*Lynx lynx*)

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Animal communities and their habitats are shaped by different biotic and abiotic factors and processes. Habitats vary in shape and size, ranging from micro- to mega-habitats in which biota, landscape features and geomorphic processes interact and influence on animal ecology at different spatial scales. Besides providing habitat and refugia, micro-topography and landforms impact on behaviours crucial for population survival, including foraging, movement, dispersal, breeding, and resting. Large carnivores require extensive home ranges with good habitat connectivity for dispersal and gene flow within and among different populations. Consequently, most studies on their habitat use, habitat suitability or habitat connectivity modelling focus on large-scale spatial analyses (e.g. large natural areas or even continents). Such models usually also include environmental covariates, with topographic covariates often limited to general terrain characteristics such as elevation, ruggedness, and slope. Large-scale studies therefore do not usually consider the effects of microhabitat characteristics and different landforms. Previous research has shown that felids, such as cougars (*Puma concolor*), lions (*Panthera leo*), leopards (*Panthera pardus*), snow leopards (*Panthera uncia*) and Eurasian lynx (*Lynx lynx*) are attracted to rugged and inaccessible terrain, rocky areas, ridges and conspicuous landforms. However, these studies have mostly relied on low-resolution data, field mapped and/or digitized landforms, which is time-consuming and costly, resulting in low accuracy and poor data quality. With the development of advanced remote sensing technologies, high-resolution data, such as LiDAR-based digital terrain models (DTM), are now more widely available and, in combination with various (semi-)automatic methods, enable non-contact, cost-effective and accurate mapping of large, remote and densely forested areas. To investigate the impact of karstic landforms and other abiotic microhabitat characteristics on Eurasian lynx (hereafter lynx) habitat selection at a micro-scale, we used LiDAR-based DTM with 1 m × 1 m cell resolution. Specifically, in combination with GPS telemetry data, we assessed the selection of karst depressions, rocky outcrops and other terrain characteristics identified using remote sensing techniques. The use of high-resolution DTM enabled us to detect a very large number (>1 million) of studied landforms, to confirm that lynx select the vicinity of karst depressions and also regularly kill ungulate prey near these features (>50% of prey within or in close proximity to depressions). We also confirmed that lynx select rocky outcrops, steep, rugged and rocky areas, which is more pronounced for day-resting sites. In addition, we observed a functional response in the selection of rocky and rugged areas, as lynx selection of such habitats increased with their lower availability, while no such response was observed in the selection of rocky outcrops. These results highlight the advantages of integrating remote sensing techniques into ecology and show that landforms and abiotic microhabitat characteristics can play an important role in certain lynx behaviours. Findings can help to improve the management and conservation of this endangered species and show that the protection of geomorphological features (geodiversity) is crucial for biodiversity conservation.

Keywords: LiDAR, remote sensing, geomorphology, Eurasian lynx (*Lynx lynx*), spatial ecology, geodiversity, biodiversity, conservation

GRAZING & ALPINE PASTURES

CHAIR: ANDREA OMIZZOLO

Bacterial and fungal diversity of Alpine pastures

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Alpine pastures are a complex, multidimensional terrestrial habitat in which animal and plant species interact with each other and with large numbers of bacteria and fungi (*microbiota*), forming an ecological network that extends both above ground and within the soil. Although soil-, plant-, and animal-associated microbiota are known to provide fundamental services for their hosts, microbial diversity of ecosystems in general, and Alpine pastures in particular, is still largely unexplored. In addition, the extent to which climate changes in Europe and especially in the Alpine space will impact such micro-biodiversity is completely unknown. Here, we investigated changes in bacterial and fungal diversity associated with more than 900 samples of soil, rhizosphere (*Carex* spp. and *Festuca* spp.), invertebrates (nematodes, collembolans, earthworms, beetles) and vertebrates (using faecal eDNA of hares, wild ungulates and livestock) along an elevational gradient spanning 1,500 metres (a proxy for climate change). Characterization of bacterial and fungal communities of each sample was performed by targeting the bacterial 16S rRNA gene V3-V4 region and the fungal ITS2 loci as barcodes for amplicon sequencing-based meta-taxonomics. Diversity metrics of ASVs (amplicon sequence variants) and phylogenetic distances (Bray-Curtis, Unifrac) were used in redundancy analyses (db-RDA) to compare microbiota composition across sample types and elevation gradient. We found that soil, plant, invertebrate, and vertebrate microbiota were characterized by only partially overlapping bacterial and fungal communities, displaying specific associations with host, elevation, temperature, nutrient availability, and plant community composition. Faecal microbiota of wild and farmed animals revealed different patterns across bacterial and fungal microbiota, with bacterial communities being markedly shaped by host-interaction dynamics, and fungal communities showing closer associations with habitat and elevation. Analyses of fungal and bacterial taxa shared between sample types established greater overlaps between soil, rhizosphere and soil-dwelling invertebrates, compared to other invertebrates and vertebrates, highlighting above/belowground and host/habitat-specific associations in the Alpine meta-community.

Keywords: microbiota, 16S rRNA gene, ITS2, amplicon sequencing, meta-taxonomy

Connection to biodiversity conservation, connectivity, and restoration

The micro-biodiversity of Alpine pastures is almost completely unknown, yet pivotal to the definition of biodiversity conservation strategies in this characteristic agro-ecosystem in light of climate warming. In addition, evaluating the level of connectivity between bacterial and fungal communities along an altitudinal gradient hosted by Alpine soil, plants, soil-dwelling invertebrates and above ground fauna is one of the main goals of this research project.

Policy implications

By studying microbiota along an altitudinal gradient, our results provide additional insights regarding how future climate change may affect the bacterial and fungal diversity of soil and dominant vertebrate and invertebrate animal species in one of the most characteristic, species-rich, and economically and culturally important Alpine habitats. Thus, our results will have implications for management of mountain agriculture, biodiversity conservation, landscape preservation, and climate change mitigation strategies.

Climate change effects on agronomic performance and biodiversity in Alpine pastures

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Grazing management has to be adapted to an earlier start of the growing season induced by climate change to keep pastures productive and prevent shrub encroachment. To date, we lack information on how plant and insect communities respond to these changes in site conditions and management. 1) How do different livestock turnout dates affect the composition and diversity of vegetation as well as plant biomass and forage quality? 2) How do different livestock turnout dates affect the diversity of pollinators and phytophagous insects? We studied the effect of different livestock turnout dates in eight Alpine pastures in the Berchtesgadener Land Biosphere Region (Bavaria, Germany), six of them located in Berchtesgaden National Park (Northern Limestone Alps). Over the grazing seasons 2021 and 2022, we surveyed insects, vegetation (see also extended abstract of Hartung et al.), yield and forage quality in early and mid/late summer. In total, 324 vascular plant species were identified with an average of 64.9 (±20.8) plant species per plot of 9 m^2. Along two 25 m × 1 m transects, 548 (±365) inflorescences were counted on average. According to our study, cumulative plant biomass averaged 1.69 (±0.68), 1.98 (±0.8) and 1.82 (±0.7) t DM $ha^{-10}yr^{-1}$ in control, early and late treatment, respectively. Forage quality (protein, sugar content) was significantly higher in the early treatment compared to the late one. Moreover, we found that insect species richness was affected by different turnout dates mediated by vegetation.

Keywords: grazing management, vegetation, insects pollinator networks, yield

Connection to biodiversity conservation, connectivity, and restoration

Climate change causes an earlier start of the vegetation growing season. Therefore, grazing regimes need to be adapted to avoid shrub encroachment. This study contributes to biodiversity conservation by providing first evidence on how different livestock turnout dates in Alpine pastures in the Berchtesgaden Biosphere Region affect plant and insect diversity.

Policy implications

The research helps local authorities (national park administration) and farmers to adjust pasture management to climate change.

Vegetation dynamics since 1953 in a part of Stelvio National Park (Italy)

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Profound changes are occurring in the vegetation, particularly in high-alpine belts, due to the increasing temperature, reduced pasture use, and dynamics of geomorphological processes. We aim to address the following research questions: (i) How has vegetation changed in recent decades? (ii) What were the main environmental drivers behind these changes? (iii) What can we learn from community data about plant interactions mediating the effects of these drivers? We conducted a comprehensive study in the subalpine and alpine regions of Valle del Braulio within Stelvio National Park, Lombardy, Italy. The study area was already analyzed for vegetation in 1953 by Giacomini and Pignatti (Giacomini & Pignatti 1955). By resampling 42 historical plots and remapping the vegetation patterns, we studied the changes in vegetation over the last 70 years. Specifically, changes in species composition, as well as changes in total vegetation cover and species richness were quantified. Generalized Additive Models (GAM) were used to identify the potential drivers of the observed changes. The results revealed that patterns in vegetation cover largely depend on temperature, potential incoming solar radiation, convex morphology as well as soil moisture and soil chemistry. Conversely, species richness is also influenced by livestock density and flat morphology. Notably, the results indicate that climate change consequently is leading to aridization of wetland habitats as well as an acceleration of secondary succession via up-migration and range-infilling processes. Furthermore, we also observed a trend towards eutrophication in the vegetation. Finally, the results suggest that certain plant communities, particularly those found in snowbeds, are more vulnerable to environmental changes experienced over the past 70 years.

Keywords: climate change, land use change, long-term, vegetation development, high alpine environment

Connection to biodiversity conservation, connectivity, and restoration

At the scale of the study area, there was a marked homogenization of community composition and a decrease in landscape diversity. This homogenization process is consistent with the hypothesis of range expansion and observed successional dynamics driven by trees and shrubs at some lower elevations and by alpine and subalpine grassland species along the entire elevation gradient. The increase in Shannon evenness in both alpine and subalpine areas indicates that (formerly dominant species are becoming less dominant in the community structure. Our results also suggest that grazing gradients can counteract this general trend towards homogenization. Low grazing promotes species diversity, while both intensification and abandonment lead to a decrease in species richness.

Policy implications

The study shows how habitats in the alpine-nival region can be conserved in the long term. The findings can be used to develop a proactive strategy for the protection and integrated management (including agricultural use) of these habitats. However, this strategy must also reconcile the interests of conservation, tourism, the energy industry, agriculture, hunting, and protection against natural hazards. Only through a joint effort can these alpine landscapes with their high biodiversity be preserved sustainably.

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TOURISM

CHAIR: CRISTINA DEL BIAGGIO

PEMS: People experience of mountain soundscapes

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This study investigates mountain auditory environments and the influence on mountaineering experiences, through the intricate interplay between individual sounds and the overall perceived soundscapes. Research on people's perception of mountain soundscapes highlights the positive impact of natural sounds on well-being, people's experience, tourism, conservation, connectivity, and restoration. However, limited data sets do not allow generalization, transfer of knowledge or map connectivity between mountain ranges. Capturing greater quantities of accurate data (i.e. sound field recording, *in-situ* and lab soundscape assessment, and long-term monitoring) is needed to address current and future gaps. How do mountaineers perceive mountain soundscapes? How can we effectively capture mountaineers' unique listening experiences when in the mountains? What sounds are most often heard by mountaineers when in the mountains? How do soundscapes contribute to safety and navigation when mountaineering? We ran an online survey followed by a thematic analysis. Participants answered questions related to their auditory perception during mountain explorations in relation to their experience in navigation and safety in the mountains. We then extracted themes and explored the interaction between the data. We gathered data from 219 participants from 21 countries (60% male, 39% female, 1% non-binary). Most were experienced in mountaineering and scrambling. Results showed soundscapes significantly contributed to the overall mountain experiences. It helps identify wildlife, note changing seasons, and provide a sense of scale. 'Silence' and natural sounds contributed to tranquillity and enjoyment. Awareness of sounds assisted in understanding the landscape, safety (i.e., avalanches, rock falls), navigation (i.e., surroundings, territorial features) and a sense of connection with nature. Sound plays a multifaceted role in outdoor navigation, contributing to safety, emotional experiences, and effective route finding.

Keywords: soundscapes, perception, sound, safety, navigation, mountaineering, listening, auditory environments

Connection to biodiversity conservation, connectivity, and restoration

People's perception of mountain soundscapes significantly contributes to enhancing ecological connectivity. The rich and diverse soundscapes serve as aural threads connecting different habitats. Understanding soundscapes helps identify key acoustic corridors facilitating species' migration between fragmented areas. This knowledge is crucial to plan and implement ecological connectivity initiatives, enabling the creation of wildlife corridors and migration pathways. The appreciation of mountain soundscapes turns us into advocates for preserving these natural acoustic connections. Public awareness and involvement are key in supporting conservation efforts aimed at maintaining and restoring connectivity. People's perception of mountain soundscapes deepens their connection to nature and emotional engagement and fosters awareness of ecological connectivity for the preservation of biodiversity in mountain ecosystems and sustainable development in tourist destinations.

Policy implications

Mountain soundscape perception research could inform strategies aligned with local preferences, informing ecologically sound conservation measures, sustainable tourism policies, and initiatives promoting mental well-being. Specifically, integrating soundscape considerations into town planning for mountainous regions ensures that new developments prioritize preserving natural soundscapes, in line with sustainable development goals. Education initiatives accompanying these policies could ensure outdoor enthusiasts are aware of and proficient in interpreting mountain soundscapes. Integrating education into sound-related policies could reinforce the connection between environmental awareness, safety, and the overall well-being of the community and the mountains. This multifaceted approach easily aligns with the goal of sustainable development in mountainous regions, helping to create a more harmonious balance between human activities and the preservation of the unique treasures these landscapes offer.

Overtourism or inadequate dispersal – applicative testing of a new monitoring method in Lake Bohinj area, Slovenia

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The constant rise of visitors is omnipresent in the Alpine region, and Lake Bohinj, situated in the Julian Alps, is not immune to that trend. Lake Bohinj and its close surroundings, located in the heart of Triglav National Park, is on the confluence of various outdoor activities, each with its own needs, accompanying services, and environmental pressures. The Lake Bohinj area faces mounting pressures driven by climate change factors and the burgeoning influx of visitors. These pressures present formidable challenges to local residents, ecosystems, and efforts aimed at conserving biodiversity. Through an examination of visitor distribution patterns over time and space, coupled with an analysis of their impact on the area's carrying capacity, the study offers invaluable insights for the identification of site-specific visitor management measures. By identifying areas where capacity is exceeded and implementing measures to alleviate environmental degradation, the research significantly contributes to the conservation efforts around the Lake Bohinj area. However, there remains a gap in using this method for quantitative assessment of visitors as it is more appropriate to monitor visitor flows and their distribution in space and time, thus providing relevant data for the identification of measures to safeguard the region's long-term ecological health and socio-economic vitality. In our study we addressed the following research: 1) How does the temporal and spatial distribution of visitors in the Lake Bohinj area vary across pre-season, season, and post-season? 2) What implications does this have for the area's carrying capacity? 3) Is the new method suitable for assessing the number of visitors and monitoring their spatial pattern? To visualize the current area load, we analyzed data from mobile service providers. This allowed us to assess visitor distribution over space and time and identify congestion sites. Using GIS software, spatial analysis unveiled visitor transition and congestion zones, which were compared across pre-season, season, and post-season periods. Data analysis was conducted with QGIS 3.22.11, displaying results on a logarithmic scale with a classification of natural breaks. The Lake Bohinj area has become increasingly popular among visitors, despite its remote location. This trend has intensified in recent years, partly due to climate change, leading to increased pressures on mountainous regions, especially during summer. The carrying capacity of the Lake Bohinj basin was estimated to be 12,800 visitors per day under optimum conditions, rising to 15,790 when considering potential. However, during seasons, visitor numbers exceed this capacity, reaching up to 14,000 daily visitors in the Lake Bohinj basin alone and 26,000 across the entire municipality area. This congestion is worsened by non-optimal spatial distribution. Disparities in development between Lake Bohinj basin and surrounding areas are evident in the accommodation-to-population ratio. Proactive measures, including visitor management, stakeholder interest harmonization, and sustainable mobility promotion, are crucial to address these challenges.

Keywords: visitor management, mobile data, spatial distribution, spatial analysis, monitoring, monitoring

Connection to biodiversity conservation, connectivity, and restoration

The study acknowledges the increasing pressures on mountainous regions, including the Lake Bohinj area, due to factors such as climate change and rising visitor numbers. These pressures have significant implications for local residents and biodiversity. By assessing the temporal and spatial distribution of visitors and examining the impact on the area's carrying capacity, the research provided valuable insights into spatial distribution and congestion of human activities. This represents tangible input for the identification of measures for biodiversity conservation while enabling the high-quality experience of the area. Effective visitor management is essential for minimizing negative impacts on biodiversity, such as habitat degradation, disturbance to wildlife, and introduction of invasive species. By identifying areas of overcapacity and implementing measures to mitigate congestion and environmental damage, the research can contribute to the conservation of biodiversity in the Lake Bohinj area.

Policy implications

The research was used to develop public policies for natural conservation and sustainable tourism management in the Lake Bohinj area while preserving a quality living environment for the local population. Policymakers could use this method to identify measures and afterwards monitor and evaluate the effect of implemented measures. The method enables a cost-efficient tool for tracking changes (in regulations, infrastructure development, etc.). In addition, the identification of areas of overcapacity and the implementation of measures to mitigate environmental damage could contribute to the formulation of policies focused on habitat preservation and restoration. By incorporating these research findings into policymaking processes, authorities can strive to strike a balance between tourism promotion and environmental conservation, ensuring the long-term sustainability of the Lake Bohinj area.

The development of ecotourism and biodiversity conservation in the Albanian Alps

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The Albanian Alps are a beautiful and mountainous region with great value for science, ecology, culture, economy, and tourism. The Albanian Alps are 64 km long and 60 km wide, with a surface of 2,020 km². The Albanian Alps are famous for their nature-focused tourism, which includes adventure, local culture exploration, and monument sightseeing. The natural landscape is of high quality and is accompanied by warm hospitality, a unique lifestyle, opportunities to connect with the locals, delicious cuisine, and hiking trails that offer scenic beauty. These are the main competitive advantages that visitors identify with the Albanian Alps. The highly diverse nature of the Alps, with great contrasts, the pronounced isolation, and their border position, have encouraged an extraordinary biodiversity that has persisted even today after the fall of the communist regime. The purpose of this study is to explore how ecotourism development can be an effective way to conserve biodiversity in the Albanian Alps. The conservation objectives include preserving and promoting biodiversity, restoring habitats, managing biodiversity, and creating value for natural resources through ecotourism activities. The study has identified several critical conflicts related to the environment, such as habitat degradation and destruction, over-exploitation, and illegal extraction. These issues arise from the lack of a proper management strategy and from unauthorized intervention by people. Furthermore, uncontrolled tourism development also contributes to the problem. In our study, we addressed the following research questions: What is the role of local governments in sustainable ecotourism development? How is the local community involved in decision-making for ecotourism development in the Albanian Alps? How is the strategy implemented in these areas? The paper analyses the conservation of biodiversity and sustainable utilization of natural resources, which are crucial for the growth of ecotourism. Ecotourism development presents an economic opportunity to use biodiversity while ensuring its sustainability. The paper also emphasizes the need for future studies to explore options for ecotourism development. We have reviewed the literature of Albanian authors, and did more than 50 interviews with local communities, stakeholders, and other target groups. Raising awareness and educating people about biodiversity conservation is essential to effectively address conflicts. Biodiversity must be integrated into ecotourism development and linked to its management. It is also necessary to connect the ecotourism industry with conservation organizations. Ecotourism policies, conservation legislation, and the imposition of rules and regulations are crucial for achieving sustainability in the Albanian Alps. Our perception as researchers is: building capacity among institutions and stakeholders to develop and implement policies is necessary for achieving biodiversity conservation in Albania. Governance and sustainable conservation of biodiversity are essential for sustainable ecotourism development.

Keywords: biodiversity, ecotourism, conservation, sustainability, policies

Connection to biodiversity conservation, connectivity, and restoration

The paper analyses the conservation of biodiversity and sustainable utilization of natural resources, which are crucial for the growth of ecotourism. Ecotourism development presents an economic opportunity for using biodiversity while ensuring its sustainability. The Albanian Alps suffered from migration after the fall of communism 90 years ago. Now we must find ways to engage the next generation to invest in these areas and improve their well-being.

Policy implications

Government agencies should offer guarantees or fiscal incentives to encourage private organizations to provide infrastructure and services that contribute to sustainable economic development. Additionally, they should provide loans or subsidies to individuals or groups to purchase services, equipment or insurance of housing from the private sector.

BIODIVERSITY I

CHAIR: ANDREJ APIH

A century of rewilding affects mountain biodiversity on different spatial scales

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The Swiss National Park (SNP) was established in 1914 as a strictly protected wilderness area in the subalpine and alpine zone of the lower Engadine valley, eastern Switzerland. From its beginning, the SNP and its development were accompanied by intensive research and monitoring, mainly focusing on the succession of ecosystems after human activity has ceased. Thus the SNP constitutes a century-long, large-scale rewilding experiment.

Rewilding as a conservation concept involves three major ecological processes, namely trophic complexity within habitats, spatial connectivity between habitats, and the presence of stochastic natural disturbances (Perino et al. 2019). By depicting examples from the abundant research accompanying the SNP's and its region's long-term development, we elucidate how these aspects contribute to the conservation of biodiversity at the level of species and habitats. Our talk will concentrate on the aspects of the trophic complexity, touch upon interactions with the other two aspects (spatial connectivity and stochastic processes), and exemplify how landscape and biodiversity across trophic levels has changed over time. In 1914, all large carnivores and raptures, and most large ungulates native to subalpine and alpine habitats, were extinct in the wider region. Until the end of the 20th century, trophic complexity has increased over time, by natural re- establishment and population growth of red deer, chamois and golden eagle, and assisted re-introductions of ibex and bearded vulture. Especially the initially quickly rising ungulate numbers strongly shaped the landscape patterns, vegetation composition and biodiversity. In recent years trophic complexity has increased further. With occasional visits of brown bears, resident lynx, wolfs, river otters, and in 2024 golden jackal, all large carnivores have returned. In particular, the fact that in 2023 the SNP has been populated by a pack of wolfs, has the potential to introduce a real regime shift in the functioning of the ecosystems, with cascading effects through all trophic levels. This contribution will present a few examples of the multitude of research and monitoring projects, which had been started previous to the establishment of the wolf pack, and which aim at elucidating changes in the trophic network and ecosystem functioning.

Keywords: biodiversity, trophic complexity, stochastic processes, spatial connectivity, rewilding, protected area, Swiss National Park, ecology

Connection to biodiversity conservation, connectivity, and restoration

Relevant to biodiversity conservation: our input shows how the abandoned human land use and the return of large ungulates and carnivores shape the landscape and biodiversity of a mountain region over the long term.

Connectivity: movement patterns of animals across the landscape are heavily influenced by ecological connectivity, thus a focus will be laid on this, also with some remarks about the acceptance of carnivores. Restoration: natural processes are allowed, and natural dynamics restored in regulated rivers, which increases landscape complexity and geo- as well as biodiversity.

Policy implications

In the discussion on establishing additional protected areas to reach the '30 by 30' goal, the effect of different levels of protection and the long-term effect of protected areas on biodiversity needs to be taken into account. The examples of ecosystem processes and effects after re-establishment of large carnivores are important basics for the acceptance of large carnivores, as the ecological value of trophic complexity for biodiversity is neither sufficiently supported by science nor discussed at the moment.

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AtlasFloraAlpina – a new flora online atlas for the entire Alpine arc

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The idea of an online atlas for the entire Alpine flora (vascular plants), was launched in spring 2023. An international consortium *AtlasFloraAlpina* was established that brings together the existing data from national and regional data centres. Soon a common website for this atlas will be established. Online distribution maps covering a biogeographical unit across national borders of two or more countries are rare in Europe, most likely because they are challenging to realize. The data sets in 105 data centres involved are structured in very different ways, according to the needs of each data centre. Each centre tends to have its own taxonomic backbone and definitions (e.g. nativeness of a species, degree of naturalization) and their own rules on copyrights. The *AtlasFloraAlpina* consortium has formed several working groups that target specific problems and try to establish standards that allow aggregation of the data from different sources. The questions include the delimitation of the atlas, the common taxonomy, distinctions of native vs non-native, spatial and temporal scales, data exchange etc. The consortium has established thematical working groups that set up their own methods and schedules and the know-how of the various data centres is brought together. So far, the consortium has organized two international workshops with almost 30 participants from six countries. A pilot online atlas for a first set of 150 species has been developed and sets the stage for further development. Permanent technical operation of the atlas can be guaranteed by the IT infrastructure provided by the Swiss InfoFlora data centre.

Keywords: Alpine flora, data centres, online atlas, international collaboration, taxonomy, data standards

Connection to biodiversity conservation, connectivity, and restoration

The knowledge of changing species distribution in space and over time is vital for biodiversity conservation. It helps to identify hotspots or species loss in a very specific way and provides a complete overview, a complete picture of biodiversity over an entire biogeographical unit (Alpine arc).

Policy implications

AtlasFloraAlpina will collect, store and disseminate up-to-date information on Alpine flora for the needs of researchers, environmental managers and decision-makers. This tool supports public policies in the definition of strategies to combat biodiversity loss, and in their implementation. Good knowledge mobilization helps to inform and define strategies for the conservation of flora at a coherent scale, for example by revising the IUCN Red List of strictly Alpine plants.

Eastern Alpine basophilic scots pine and black pine forests in Triglav National Park, Slovenia: distribution, vegetation, and stand characteristics

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The Eastern Alpine basophilic Scots and black pine forests, referred to as pine forests, are important mid- to high-altitude forest ecosystems but cover less than 1% of Triglav National Park (TNP). They thrive on steep shallow-sandy-soiled slopes that are highly prone to erosion. These forests hold little commercial value and are largely located in semi- to strictly protected zones of the TNP. They represent the Natura 2000 habitat types 91R0 Dinaric dolomite Scots pine forests and priority habitat type 9530* Sub-Mediterranean pine forests with endemic black pines. Despite the great ecological importance, the site conditions, stand structure, and composition, as well as natural stand dynamics of these forests, have been poorly researched due to extreme conditions and difficult accessibility. In our research we wanted to explore what the key factors are that influence the distribution and diversity of the Eastern Alpine basophilic Scots and black pine forests in TNP, and how effective management strategies can be implemented to safeguard these unique ecosystems from threats such as forest fires. By combining field observations on a systematic grid of circular sampling plots, soil and vegetation analyses, and statistical models, we identified key factors shaping their distribution and stand characteristics. The inventory consisted of 23 plots in habitat types 91R0 and 10 plots in habitat type 9530*. Soil pH, nutrient levels, and climate emerged as primary factors of their distribution and diversity. Basophilic Scots pine forests thrive in alkaline and arid conditions, while black pine favours less acidity and more water. Scots pine density is relatively low at 450 trees/ha, whereas black pine stands are much denser (1,004 trees/ha). Despite their small coverage, pine forests stability within TNP presents a favourable conservation status. Challenging accessibility keeps human impact low, yet forest fires pose a significant threat. Our findings expose the importance of comprehending the ecological mechanisms governing Alpine ecosystems.

Keywords: *Pinus nigra, Pinus sylvestris,* vegetation characteristics, stand structure, Natura 2000, conservation status

Connection to biodiversity conservation, connectivity, and restoration

This research significantly contributes to biodiversity conservation by focusing on the Eastern Alpine basophilic scots and black pine forests, which are vital but scarce ecosystems in Triglav National Park. By investigating their characteristics, dynamics, and protection status, the study sheds light on their ecological importance. Factors such as soil pH, nutrient levels, and climate were identified as key drivers of their distribution and diversity, and highlight the need for tailored conservation efforts. Despite facing threats like forest fires, these forests present a favourable conservation status, emphasizing the importance of effective management strategies to preserve their ecological integrity and biodiversity.

Policy implications

This research, focusing on pine forests within Triglav National Park and special conservation areas in the Julian Alps, informs policies concerning habitat conservation, forest management, and biodiversity preservation. By highlighting ecological importance and conservation status, it guides strategies for sustainable land use, wildfire prevention, and habitat restoration. Integrated into management strategies and plans, as well as by implementing proposed management guidelines within forest management, it ensures effective management in line with national and European conservation goals.

The Long-Term Biodiversity Index (LBI) – a new tool for monitoring and planning the restoration of abandoned mining areas and landfills

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As part of an Interreg project, the *Long-Term Biodiversity Index* (LBI) approach was developed further to evaluate the effectiveness of recultivation measures in terms of biodiversity. The impact of interventions in local biodiversity is usually handled by assessing species lists, their protection or Red List status, and the estimated or measured impact on their habitat or population size. This approach usually does not take into account the biodiversity found on recultivated habitats. Secondly, absolute numbers of the species inside the affected area would depend on the regionally available species richness and this can vary significantly between arctic or tropical regions. How can the impact of a quarry on the local biodiversity at the extraction site and the overburden dump area be calculated in a comprehensible and comparable way? How can the effectiveness of recultivation measures and other biodiversity enhancing measures be evaluated in the medium and long term? The existing approach has been evaluated and been tested in four different quarries in Austria and Italy. Different extraction techniques and extracted rock materials were studied to achieve maximum effect. For each quarry, a specific scaling was applied to meet the local requirements. Quarries are classified into the extraction area and the surrounding landscape. These categories are subdivided into habitats that are homogeneous in terms of their vegetation composition and structure. The basic parameters for calculating the LBI are vascular plants and birds. Other species groups may be added to increase the significance of the index. The index shows the ratio of biodiversity in the extraction area (including recultivation areas) compared to the reference habitats in the surrounding area in a comprehensible and comparable manner. This evaluation helps to design ecologically valuable and diverse secondary habitats in the intervention areas, thereby increasing biodiversity in the long term.

Keywords: biodiversity, monitoring, restoration, recultivation, mineral extraction, impact assessment

Connection to biodiversity conservation, connectivity, and restoration

The LBI is a science-based tool to help quarry operators and conservation authorities measure the impact of the extraction process, as well as the success of restoration or other biodiversity enhancing measures. As the LBI is based on species-level assessment rather than structural indicators, the impact of extraction and restoration measures can be linked to ecologically important umbrella species, and the Red List status of each species is reflected in the calculation of the index. By using the surrounding landscape as a reference habitat, the effects of climate change on habitats inside and outside the quarries can be compensated for. High-resolution biodiversity monitoring can make an important contribution to understanding ecological processes in nutrient-poor, often dry or wet habitats in mineral extraction sites, which can serve as valuable secondary habitats for highly endangered and specialized species adapted to them.

Policy implications

Monitoring the impact of human activities on biodiversity is of great importance within the Convention on Biological Diversity (CBD), the European Biodiversity Strategy and the European Nature Restoration Programme. Many mineral extraction sites are operated by large companies that fall under the obligations of the European Sustainability Reporting Standards (ESRS). LBI can not only assess the results of restoration measures at individual quarries but can also aggregate standardized results across many extraction sites within a country, continent or globally. Within the economic framework of green taxation, the LBI can support effective and efficient reporting and help steer investment in a biodiversity-friendly direction.

Long-term changes in biodiversity of the Julian Alps – a consequence of climate fluctuations or human influence?

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The Alpine environments are sensitive to climatic fluctuations and have faced millennia of human pressure on the environment (e.g. grazing, logging, metallurgy). Archaeological excavations in the Julian Alps indicate human presence in this area since the Palaeolithic. However, the evidence of long-term environmental changes is still often understudied and/or poorly understood. In particular, it is often difficult to understand what the natural vegetation looked like because of various intervening factors (climate, human influence). The aim of our research was therefore to investigate the long-term changes in vegetation and human impact on the environment in the Julian Alps over the last 15,000 years. Multidisciplinary research including pollen and geological analyses (XRD, XRF and stable isotopes) of lake and wetland sediments at different altitudes were carried out: Lake Bohinj (526 m) and marsh at Srednja vas (580 m), a lake on Planina pri jezeru (mountain pasture by the lake) (1,430 m) and Veliko jezero (Large Lake) (1,830 m).

The combined study revealed many irreversible consequences of the continuous human/climate impact on the environment and changes in vegetation. First and foremost, the long-term changes in vegetation indicate that the 'potential natural vegetation' in this area would include more *Abies, Fagus* and especially *Picea* (and generally a higher percentage of forests), so the idea that *Picea* was introduced by humans is partially wrong. Continued human pressure and a warming climate could lead to the spread of more thermophilic taxa in the future, which would limit current biodiversity, especially if more invasive species were introduced. Furthermore, with the assumed higher precipitation, more extreme events could destabilize lake catchments and lead to more erosion and loss of biodiversity, as has been the case in the past. In addition, long-term utilization of grazing land can increase the trophic status of a lake and, in combination with climate variability, permanently affect the hydrology and chemical composition of lake sediments.

Keywords: palynology, palaeoecology, Julian Alps, long-term vegetation changes

Connection to biodiversity conservation, connectivity, and restoration

Palaeoecological research provides us with valuable information on how vegetation responds to a changing climate (with analogies of warmer and colder climate) and to long-term human impact at different altitudes. Our most important research contribution is to recognize what vegetation looked like in the past and how and why it has changed in environments that are often considered 'pristine'. With this knowledge, we can protect them in the present and in the future, especially given probably continuing human impact and climate change.

Policy implications

Our research could be used in protection policies. Conservationists and ecologists should recognize the impact of humans and climate on biodiversity and consider long-term changes in vegetation to best protect modern plant communities. By following the Alpine Convention, which states that mountain forests should be protected, it is important to include in the equation what type of forests we are trying to protect, i.e. anthropogenically influenced or natural. For example, with the increasing influence of humans (grazing, charcoal production) over the last 5,000 years, less *Abies* and *Fagus* are growing in the Alps today. Another example shows that *Picea* was an important taxon in the Julian Alps area before human influence became stronger. In addition, records from Srednja vas v Bohinju shows that *Picea* was an important taxon in the Alpine valleys in the late Holocene, as it was probably more successful than other mesophilous taxa (*Abies, Fagus*), which were more successful at higher altitudes, due to more frequent spring/autumn frosts. Furthermore, palaeoecological research is rarely (or never) included in policy implementation. Measures to increase biodiversity can include the renaturation of wetlands, which destroys the natural archives that are used for long-term palaeoecological research, and this presentation also aims to draw attention to this. Conversely, policies often fail to address these problems at all.

BIODIVERSITY II

CHAIR: ROLAND PSENNER

Saving Dinaric - SE Alpine lynx populations as contribution for lynx conservation in the Alps

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Prior to the start of the LIFE Lynx project in 2017, the Dinaric-SE Alpine lynx population was at risk of extinction. The Alpine region had no reproduction, lynx had already disappeared from the Slovenian Alps and the Dinaric part of the population was experiencing a significant decline. Through a collaborative international effort from Slovenia, Croatia, Italy, Romania, and Slovakia, the LIFE Lynx project saved the population from the brink of extinction from inbreeding by introducing new genes into the Dinaric part of the population and creating a stepping stone unit in the Alpine region of Slovenia. In the project, we addressed the genetic collapse of the lynx population due to inbreeding by translocating healthy individuals from the Carpathian population to the Dinaric Mountains. In addition, we established a stepping stone population in the Slovenian Alps by translocating six individuals to the area with the aim to help connecting the Dinaric and Alpine meta-population. The reinforcement of the Dinaric population and the establishment of the SE Alpine nucleus proved successful, as almost all individuals established their own territories and had at least one reproduction. Prior to the start of the LIFE Lynx project in 2017, the Dinaric-SE Alpine lynx population was at risk of extinction. The Alpine region had no reproduction, and the Dinaric part of the population was experiencing a significant decline.

Therefore, a collaborative international effort from Slovenia, Croatia, Italy, Romania, and Slovakia was crucial to saving the lynx population. It was necessary to introduce new individuals from the Carpathian population, which led to the adoption of national strategic documents. The success of reintroducing lynx hinged on effective communication with all stakeholders, who must understand, accept, and support their return to the wild. A pivotal factor in establishing the lynx stepping stone population in the Julian Alps was the successful collaboration with hunters who played a crucial role in the project. First, it was necessary to save the Dinaric part of the population from extinction due to inbreeding. Therefore, we translocated 12 lynx individuals from the Carpathian region into the Dinaric part of Slovenia and Croatia. For long-term conservation of lynx, it is necessary to connect the Dinaric population with other populations. Therefore, we created a stepping stone population in the SE Alps. Both the Dinaric population and the translocated individuals needed to be genetically monitored, so we conducted genetic monitoring (genotyping). All translocated lynx' were equipped with GPS telemetry collars upon release in the Dinaric and Alpine regions to monitor their movements, territory establishment, and potential breeding. Hunters were actively involved in the systematic monitoring of the lynx population by looking after camera traps in the field. Public engagement was also crucial to maintain long-term support for the reinforcement process. Within the LIFE Lynx project, we invested much effort in communication with the general public, local communities, and hunters to maintain long-term support for the conservation of this species. During the project, we translocated 18 adult individuals to Slovenia and Croatia, 6 of them to the Slovenian Alps, 6 to the Dinaric part of Slovenia and 6 to Croatia. The density and number of individuals in the Dinaric region in Slovenia has increased by ~100% by the end of the project compared to the start of the project. Currently, the minimum number of adult lynx in Slovenia is 40 and in Croatia 99.

During systematic monitoring with camera traps in the season 2022–2023, we detected a minimum of 22 reproductions. Reproduction in the Alpine region has been exceptionally successful. All released females have successfully mated, resulting in 6 recorded reproductions in this region by 2024. This is a remarkable outcome, indicating the lynx's good adaptation to the Alpine environment and holding great promise for the future of this population. Genetic monitoring of the reinforcement process revealed a dramatic improvement in the genetic print of the population, as an evident drop in inbreeding was observed. Simulations showed the inbreeding estimated from expected heterozygosity would approach 0.15 when translocated animals and their offspring formed around 40% of the population. Together with the Hunting Association of Slovenia, we educated police officers on the topic of illegal killing of wildlife and prepared manuals for hunters and foresters about how to react upon a suspicion of illegal wildlife killing. We organized conferences and public presentations for hunters and general public at the national and international level. We published numerous articles about the project and population reinforcement process, both in popular and scientific journals. In order to involve local people in the lynx conservation activities, we formed 'Local Consultative Groups', where local inhabitants were informed about the project progress, the status of lynx in their area, and were given opportunities to share their opinions.

Primary schools were also a crucial part of the stakeholders' involvement – pupils participated in the lynx releases with the animal adoptions, formed a program *The young guardians of the lynx*, participated in workshops and teachers were given the didactic materials to assist their science classes. It is essential to recognize that this project's success extends beyond just

saving the Dinaric-SE Alpine lynx population. The project represents a step toward connecting the fragmented lynx presence areas in the Alps.

Keywords: lynx, gene flow, connectivity, stakeholders' involvement, international collaboration, stepping stone population, inbreeding, population monitoring, reinforcement

Connection to biodiversity conservation, connectivity, and restoration

Reinforcement of the Dinaric population and creation of the stepping stone population in the SE Alps contribute to maintaining biodiversity through preserving a key-stone species in the ecosystem. By saving it from extinction we contributed to the conservation of the Dinaric-SE Alpine lynx population, lynx being an endangered Red List species. Without our intervention, the species would have faced extinction in the Dinaric-SE Alpine region. In addition, we established a newly created lynx population in the Alps that will connect the Dinaric and Alpine populations. Furthermore, our work includes connectivity, as we established the first official protection of green corridors in Slovenia. During the LIFE Lynx project, we prepared habitat suitability models which offer an insight into areas that would be suitable for territories of resident lynx, whereas landscape permeability prediction outlines the probable routes of dispersing animals.

Policy implications

The effectiveness of the LIFE Lynx project is largely based on the strong involvement of stakeholders and the international collaboration. The achievements are mainly a result of close collaboration among public institutions, universities, hunters' associations, local hunting clubs, national parks, local communities, NGOs, and ministries. Key stakeholders were hunters, who played a crucial role in the project activities. They were involved in all stages of lynx translocations, from the construction of the release enclosures to the care of the lynx in the enclosures and their release, and in the subsequent population monitoring by means of camera-trapping. The strong cooperation with hunters had a great effect with hunters and resulted in greater tolerance for the lynx presence as the hunters accepted the lynx as an important part of the ecosystem. This model of stakeholder involvement has proven to be very successful in lynx conservation efforts.

The impact of hybridization on *Lepus timidus* and *L. europaeus* gut microbiota in the Italian Alps

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The mountain hare (*Lepus timidus*) is a boreal mammalian species, with relict populations in the Alps threatened by climate change due to snow cover reduction and by habitat loss. An additional risk factor is hybridization with the European brown hare (*L. europaeus*), which is shifting its range to higher altitudes, once dominated by the mountain hare. Despite the recorded presence of hybrids between the two hare species in their Alpine ranges, there is a lack of information about the extent, altitudinal distribution and impact of hybridization. Since gut microbiota is known to affect mammalian health, but is also species-specific, depending on diet, physiology and evolutionary history, hybridization between the two hare species could affect microbiota composition and function, and thus species adaptability and survival. Using non-invasive (faecal pellet) samples, we investigated the altitudinal distribution of *L. timidus*, *L. europaeus* and their hybrids to evaluate the current extent of overlap of the two species in an LTSER site in the Autonomous Province of Bolzano/Bozen – South Tyrol, Italy. Using a subset of these samples, we then investigated bacterial and fungal microbiota to understand whether its diversity and composition are influenced by species and/or altitude, and how hybrid's gut microbial communities compare to that of the two species. Fresh faecal pellets were collected in the field in 2019 and 2020 at Val di Mazia/Matschertal, Italy at four different altitudes (1,000, 1,500, 2,000 and 2,500 m). A fragment of the mtDNA (D-loop) and 10 STR loci were used for individual genotyping, and the results were combined to identify species and hybrids. Gut microbiota richness and composition were investigated using amplicon sequencing of the 16S rRNA gene and fungal ITS2 regions and meta-taxonomic bioinformatics. *L. timidus* was more common at 2,000–2,500 m, but *L. europaeus* ranged across the study site, with hybrids found between 1,500–2,500 m. Gut microbiota analysis showed that bacterial alpha diversity did not differ between the two species, but there was a significant difference in fungal richness. We found a clear distinction between bacterial community composition of the two species, while both species and elevation influenced fungal composition. Interestingly, hybrid microbiota clustered more closely with that of *L. timidus*, while fungal composition did not show a clear clustering with either species. The possible impact of these results on mountain hare conservation are discussed.

Keywords: climate change, mountain hare, hybrids, STR, 16S amplicon sequencing, ITS, gut flora

Connection to biodiversity conservation, connectivity, and restoration

These results underline the precarious status of mountain hare populations in the Alps, where the species appears to be threatened by climate change in several respects. Many species are able to adapt to new temperature conditions by moving their distribution range into areas with more suitable habitats, in the case of the brown hare, into higher altitudes. Since the overlap in the distribution range of the two species will increase over time, hybridization with the brown hare may lead to a loss of both mountain hare species and its unique microorganism biodiversity. Most studies focus on the genetic basis for hybridization, while differences in the gut environment between hybrids and pure species, which can have significant impacts on their health and productivity, is still poorly considered. Gut microbiota richness and composition can impact on host fitness, as it plays a pivotal role in host immune function, behaviour and dietary supplementation. Moreover, it is an important regulator of pathways relevant for disease and energy metabolism. As a result, it can even affect demography, and adaptability of a wild population.

Policy implications

Gut microbiota has recently been recognized as having important implications for the conservation and management of wildlife species, as changes in its richness and composition can affect host health and adaptability. Our results suggest that, in the light of current climate warming and the inevitable movement of *L. europaeus* into the *L. timidus* range in the Alps, management policies should aim at preserving the unique Alpine genetic diversity of the mountain hare (*L. timidus*), also given the impact of such hybridization on its microbial communities (the disruption of which could lead to more rapid population extinction). For example, implementing differential hunting for the two species (e.g., keeping hunting open for the brown hare, while forbidding it for the mountain hare) in certain areas could be a solution for maintaining pure mountain hare populations and the highest possible densities. An alternative conservation action might be to protect areas of the mountain hare range, where the brown hare cannot access (as has already been done in Slovenia). Without rapid planning actions for its conservation, the mountain hare (like many other Alpine relict species) may be negatively affected by climate change as its altitudinal migration is limited by the height of the mountains.

Conservation and sustainable management of the Alpine ibex in the cross-border area of the Julian Alps

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The Alpine ibex (*Capra ibex*), an endemic species in the Alps, once presumed extinct in the Julian Alps by the end of the 17th century, has been successfully reintroduced since the mid-20th century. Reintroduction initiatives began in Slovenia in 1964 and in the Friuli-Venezia Giulia region of Italy in 1978. These efforts aimed to restore the Alpine ibex population in its endemic habitat. Presently the Alpine ibex population is thriving on the Italian side of the border, while facing stagnation or decline on the Slovenian side. The management of Alpine ibex faces numerous challenges, including low genetic variability, inbreeding, human activities, such as tourism and agriculture, habitat changes and fragmentation, limited adaptability to climate change, and differences in species management between countries. How can the conservation and sustainable management of Alpine ibex in the cross-border area of the Julian Alps ensure ecological connectivity, considering the influence of diverse policy, legal, and institutional structures, and the need for harmonized cross-border management approaches? Recent research (AlpBioNet2030, DINALPCONNECT, CIBIOGO) addresses the Julian Alps challenges by analyzing population status, habitat characteristics, and connectivity. Methods involve participatory workshops, stakeholders' consultations, preparation of cross-border management documents to engage stakeholders and foster collaboration. We assessed Alpine ibex management, proposing adaptations for population improvement and broader ecological connectivity. Since 2017, we have held four cross-border workshops with stakeholders, drawing up a comprehensive management concept. The expert group devised a vision and a strategy to ensure long-term conservation. It outlined goals, objectives, measures, and indicators regarding legislation, monitoring, habitat enhancement, communication, education. Stakeholders endorsed an action plan, prioritizing proposals for transboundary wildlife management. The highlight was on the harmonized legal status of Alpine ibex on both sides of the border.

Keywords: ecological connectivity, cross-border management concept, participative process, wildlife management, conservation, protected areas, Julian Alps

Connection to biodiversity conservation, connectivity, and restoration

Our research significantly contributes to biodiversity conservation by focusing on Alpine ibex management and proposing adaptations to enhance population conditions and ecological connectivity. By conducting cross-border workshops and engaging various stakeholders, including hunters, landowners, and conservationists, we ensure comprehensive management of Alpine ibex and its habitat. This approach promotes collaborative decision-making and prioritizes proposals for cross-border wildlife management, thus effectively conserving biodiversity across the area. Furthermore, our strategy for Alpine ibex aims at long-term conservation and sustainable management within the cross-border area, addressing key aspects such as legislation, habitat improvement, and awareness rising. Ultimately, our efforts transform the pilot region into a model area for ecological connectivity, contributing significantly to biodiversity conservation, connectivity, and restoration in the Alpine ecosystem.

Policy implications

This research could inform the development of public policies related to cross-border wildlife management and biodiversity conservation. Specifically, it can contribute to the formulation of policies aimed at harmonizing wildlife management practices across borders, enhancing ecological connectivity, and promoting sustainable land use in the Alpine region. Policymakers could utilize the insights gained from stakeholder consultations and workshops to design regulations that prioritize the conservation of Alpine ibex populations and their habitats. Additionally, the proposed wildlife management strategy could serve as a blueprint for policymakers seeking to implement comprehensive conservation measures and foster cross-border cooperation. By incorporating the findings of this research into relevant policies, governments can effectively address the challenges of managing wildlife in transboundary areas while promoting biodiversity conservation and sustainable development.

More than meets the eye: unravelling anthropic land use impacts on skin microbiota of an opportunistic amphibian species

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As amphibians register population declines worldwide as a result of human-driven habitat modifications and emerging diseases, their skin microbiota has attracted major interest as a means of adaptation to the changing environment and a barrier against pathogens. A substantial body of research has been published on the characterization of the bacterial taxa found on amphibian skin, or their variation between species and/or life stages, as well on the interaction between amphibian skin microbiota and potential pathogens, especially the fungus *Batrachochytrium dendrobatidis*, showing how bacterial skin communities can influence the resistance of amphibian wild populations to this pathogen. However, the diversity of amphibian skin mycobiota and its potential interaction with the bacterial component of microbiota is still largely unexplored. This study aimed to characterize the diversity patterns of both bacterial and fungal communities living on the skin of *Bombina variegata* (Linneaus 1758), and to highlight the associations between these patterns with biotic and abiotic parameters of their habitats, including the microbiota of the wetland itself. Skin swabs of about ten individuals were collected from populations of four habitat categories, with varying degrees of human impact. Alpha and beta diversity indices were calculated for both communities from the 16S (bacteria) and ITS1 (fungi) amplicon variants (ASVs) retrieved. Differences across habitats were statistically tested, as well as the influence of abiotic factors and that of one community on another. We found a clear association between skin and water microbial communities in terms of relative abundance of bacterial and fungal ASVs shared between the two microbial communities. Both alpha and beta diversity indices calculated from *B. variegata* skin swabs were found to be statistically different across habitats, although different patterns were found for bacterial and fungal diversity. Beta diversity indices also showed close clustering of water and skin communities for each habitat and sampling site. Water pH, temperature and dissolved oxygen proved to be statistically significant factors affecting both bacterial and fungal diversity, but, again, with different patterns between alpha and beta diversity.

Keywords: amphibians, skin microbiota, land use, anthropic impact, pathogens

Connection to biodiversity conservation, connectivity, and restoration

This study contributes to biodiversity conservation, as amphibian skin microbiota has an important role in both adaptation to the changing environment and as barrier against pathogens. This research is one of the first focusing on both bacterial and fungal diversity, providing relevant insights into this relatively unexplored component of wild population biodiversity. In fact, we highlighted complex, and sometimes opposing, trends, which will require more studies to be fully understood. These first promising results also support the hypothesis that human activities contribute to shaping amphibian skin microbiota. We also demonstrated the existence of a strong association between skin and environmental microbial communities. Overall, we argue that conservation strategies for B. variegata, and amphibians more in general, should be based on a better understanding of the aquatic/environmental microbiota and the impact of anthropogenic activities in these environments.

Policy implications

This study highlighted that some habitats, such as farm ponds or agricultural water tanks, can be important breeding sites for the target species. Therefore these sites could benefit from small interventions or ad-hoc management practices like constructing wooden fences that do not allow cattle to enter the farm pond and disturb the water.

BIODIVERSITY AND CULTURE & HISTORIC CHANGES

CHAIR: CHRISTIAN ROHR

Landscape features as the cornerstones of landscape character, identity and biodiversity

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Landscape features are one of the basic components of landscape character. Whether of natural origin or man-made, they have a positive effect on landscape heterogeneity and, consequently, on landscape identity and biodiversity. Several studies have addressed the interconnection between landscape heterogeneity and biodiversity (Duelli 1997; Benton et al. 2003; Fahrig et al. 2011; Batáry et al. 2015, Redlich et al. 2018), emphasizing landscapes' natural aspects. The second group of research focused on landscape character (Tveit et al. 2006; Ode et al. 2008) and landscape identity (Stobelaar & Pedroli 2011; Ramos et al. 2016, 2019), which also includes cultural landscapes. Landscape features proved to be an overlooked cornerstone of all concepts, from biodiversity (Penko, Seidl & Golobič 2020) to identity (Penko Seidl et al. 2021) and character (Golobič et al. 2022). The question we wish to address in this research is: How do landscape features – the smallest elements in the landscape, e. g. individual trees and hedges, hay stacks and shepherds' huts, ponds and marshes – contribute to three important aspects of the landscape: landscape character – the image of the landscape, landscape identity – the meaning of the landscape, and biodiversity – the function of the landscape? We approached this question in two steps: 1) Field mapping, desktop mapping and automatic/machine learning mapping for landscape features inventory and definition; 2) Landscape features evaluation in terms of their contribution to biodiversity, identity and character of Alpine landscapes. The results of the presented research are: 1) An inventory of landscape features and their evaluation in terms of (i) image – their role in building the character of landscapes; (ii) meaning – their importance for the identity of landscapes; and, (iii) function – their contribution to biodiversity conservation or enhancement. 2) Guidelines for holistic landscape protection, management and planning, which are applicable at the level of landscape features. 3) A discussion on relevant instruments (e.g. spatial planning, sectoral policies) that need to be adopted for better protection, management and planning of (Alpine) landscapes.

Keywords: landscape features, landscape image, landscape meaning, landscape function, landscape identity, biodiversity, landscape character

Connection to biodiversity conservation, connectivity, and restoration

The research contributes to: (1) Biodiversity conservation. According to several researchers (Duflot et al. 2014; Lomba et al. 2014; Tscharntke et al. 2005), 50% of all species live in extensively managed agricultural landscapes. An inventory of landscape features that are considered important for biodiversity along with guidelines for their protection and management is crucial for protection and/or enhancement of agricultural landscapes' biodiversity. (2) Landscape and ecological connectivity. Several, especially linear, landscape features (e.g. riverine vegetation, hedges, drywalls, etc.) contribute to structural landscapes (Fahrig et al. 2011) as well as functional/ecological (Beger et al. 2022) connectivity. Whereas the first concept is important in terms of landscape structure and character, the second one is crucial for species movement across landscape, since they provide shelter and/or corridor within human dominated landscapes.

Policy implications

The results of the research could be applied in: (1) *Common Agricultural Policy* (CAP). As the previous research (Penko Seidl & Golobič 2018) has shown, CAP measures are often too general to embrace the diversity of European landscapes. Adopting the measures to local content (e.g. measures for protection and management of locally specific landscape features) would have a positive effect to all three aspects of the landscape: its image, meaning, and function. (2) *Protected areas management*. Several Alpine landscapes are under some (natural or cultural heritage) conservation regime. Management plans would therefore benefit from input data on landscape features and their importance for landscape management. (3) *Landscape policy*. Landscape features are crucial in landscape inventories, landscape character assessments and landscape monitoring. A standardized list of features, combined with a list of landscape patterns, offers a starting point for landscape characterization, where each area is assessed individually, but with unified methodology.

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Study Circles to reinforce existing values of biodiversity

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For thousands of years, humans have recognized the multifaceted value of biodiversity, appreciating its utilitarian aspects as a source of food, materials, and labour. Values, in this context, encompass the conscious or subconscious *preferences, principles*, or *virtues* held by members of society or society as a whole. In order to develop effective solutions for preventing and halting biodiversity loss while considering the needs of both people and nature, it is essential to enhance our comprehension of the cultural importance of biodiversity. Despite evidence indicating that people genuinely care about and value biodiversity, there exists limited understanding of how these culturally mediated values can effectively prevent and mitigate biodiversity loss. What are the diverse values attributed to biodiversity in the rural area of Tolmin, Slovenia, and how do these diverse perspectives contribute to our understanding of the significance of biodiversity in the region? We employed the Study Circles approach, engaging a group of adults in regular meetings over almost a year. Cultural values on biodiversity explored during the Study Circle meetings were assessed through various social valuation methods, including questionnaires (distributed at the first and the last meeting), and interviews with the Study Circle participants. The results of this social experiment induced transformative changes in values related to biodiversity and facilitated the dissemination of knowledge within participants' networks, spanning family, colleagues, friends, and the wider community. Study Circles have successfully pioneered initiatives to enhance public engagement in discovering biodiversity through different approaches, such as: 1) promotion of Citizen Science through actions within the *Birds Around Us* initiative; 2) development of bird nesting boxes and acquisition of *My Bird Buddy* feeder tools for bird watching and increased awareness on avian species; and 3) transformation of the community garden into an outdoor classroom, to create a vibrant space that fosters environmental education and connection with the surrounding ecosystem. Study Circles, recognized as an innovative form of adult education, provided a collaborative space for learning about biodiversity, with the overarching aim of fostering societal change.

Keywords: adult education, biodiversity, cultural values, learning in nature, shared Green Deal, Study Circles, Slovenia

Connection to biodiversity conservation, connectivity, and restoration

While our research may not have a direct impact on biodiversity conservation, we aspire for our results to create a lasting influence on the preservation of biodiversity. In order to help put Europe's nature on a path to recovery by 2030 by leveraging the *inextricable link* of biodiversity in rural and urban areas, we explored how the values and perception of biodiversity are embedded within a community and transferred through stories, narratives and observations. To do this, we engaged a group of adults to explore if there is variation in values upon biodiversity in a rural area. The central dimension of our social experiment is inherently linked with biodiversity and learning.

Policy implications

Informed by our research, public policies can be strategically developed to align with the EU Biodiversity Strategy 2030. By placing local communities and the general public at the forefront, policies can emphasize community engagement and education, addressing *item 3.3*. of the strategy. Furthermore, our findings contribute directly to the European Green Deal, aiding the transformation towards a prosperous society with economic growth decoupled from resource use. This supports a just and inclusive transition, particularly through the active involvement of vulnerable populations. Moreover, our research lends itself to advancing Sustainable Development Goal 15 (Life on land) within the 2030 Agenda for Sustainable Development. It also aligns with the objectives of the Convention on Biological Diversity (CBD), specifically targeting Article 13 on public education and awareness. In sum, our study offers a comprehensive foundation for policy development, promoting biodiversity recovery, sustainable development, and social inclusivity in line with these influential EU and global strategies.

Dynamics of ecosystem services in response to land use and climate change: a case study in the Italian Alps

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In recent decades, socio-economic drivers have led to an increase in forest coverage in the Alps. This study focused on the evolution of ecosystem services provided by the forest in the area of Paneveggio forest in the central Eastern Alps (Italy) since 1954. Initially, forest growth could be considered a re-naturalization, but, after the 1990s, this trend caused loss of landscape and habitat diversity. The Vaia windstorm in 2018 triggered extensive damage, highlighting the need for robust ecosystem service quantification. This study used a spatio-temporal approach, recognizing the complexities of ecological, social, and economic drivers shaping contemporary landscapes. Gathering information from several data sources is advocated by many authors as most appropriate to develop an evidence-based management strategy tailored to local situation. Understanding past ecosystem dynamics can help to develop long-term strategies to cope with a changing climate and society. The aim of this work is to quantify some of the ecosystem services provided by the forest over time following the Common International Classification for Ecosystem Services (CICES). We used a previously developed set of maps of forest coverage, derived from historical maps and aerial images, and conducted spatial analysis with GRASS GIS and QGIS. Data on provisioning services, such as cattle numbers, timber, and wildlife trends, were collected from various literature sources. Carbon stock and protection from erosion were calculated, the latter was assessed with the Revised Universal Soil Loss Equation (RUSLE). Aesthetic preferences were assessed by evaluating the sales of postcards depicting the same landscape over time. Forest coverage steadily increased from 1950s to 2018 and with it all the services linked directly to trees: timber carbon stock and protection from erosion. Biodiversity, however, presented a more complex pattern, with losses in open areas affecting priority habitats while benefiting forest-dwelling species. Aesthetic preferences also showed a fluctuating pattern, suggesting a preference for a balanced landscape of grass and trees. After 2018, some services were reduced, including protection and aesthetics, because of fallen and standing dead trees and the building of avalanche defence systems to cope with deforestation. Some fallen areas became open-air laboratories and opportunities for multi-species forest development, even attracting disaster tourism for raising climate change awareness.

Keywords: historical data, protection forest, landscape, Vaia storm, RUSLE, carbon stock

Connection to biodiversity conservation, connectivity, and restoration

Forest landscapes will continue to evolve and cannot be restored to a moment from the past. We advocate for a holistic approach to forest management that can adapt to climate change while preserving biodiversity, services, and people value. Our research can contribute to creating a broad, inter-disciplinary, and more comprehensive vision of historical landscape changes in the Alpine environment and ecosystems. This spatial vision, which includes the visual and temporal perspectives, is crucial to allow for a different approach in mountain landscape planning and management, an approach that favours biodiversity conservation in a difficult moment for many species endangered by climate change and anthrophization, by highlighting the importance of ecosystem connectivity and restoration from different spatial and temporal points of view.

Policy implications

In order to promote resilience through mountain landscape diversification while preserving ecosystem services, forest management should concentrate on a strategy that incorporates the impending climate challenges into a larger landscape vision of the ecological issues related to forest production and sustainability, human and wildlife coexistence. With the help of our method, it will be feasible to tell a story about landscape changes that policymakers and members of the general public will find it easier to comprehend. This can be applied at various stages of the planning process for forest management, but it can also promote inclusive methods and the acceptance of novel ideas that consider the ecosystems, culture, and landscapes of the past.

The Alps: green or colourful? From early-modern to post-modern attitudes to meadows

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Species-rich hay meadows are biodiversity hotspots, essential components of healthy cultural landscapes, providing ecosystem services for humans. In the 20th century, they have almost disappeared from most of Western, Northern, and Central Europe; in the Alps, their loss has been progressing quickly. Thomas (1987) focuses on human attitudes to plants and animals in England between the 16th–19th centuries. Vogl-Lukasser et al. (2006) present historical farmers' interest in grassland biodiversity in the Alps. McKittrick (2015) synthesizes the environmental history of farming since the Green Revolution. Willett et al. (2019) present the environmental footprint of the global food system and call for action to feed the world sustainably. Magda et al. (2015) bridge the divide between agronomy and nature conservation. No study has so far presented human attitudes towards meadows in the Alps in the long run, from 1500 CE to the present. The paper explores (1) how and when the general human attitude towards living beings in hay meadows in the Alps changed from the 16th century to the present; (2) what message the human civilizing process should take from the intersection of (a) the changing human environmental footprint in meadows, and (b) the degree of society's fairness to farmers; (3) long-term evidence-based best practices linking the economic, environmental and social pillars of sustainability in hay meadow management. This interdisciplinary paper links the findings from a selection of 16th- to 20th century historical sources from the South Eastern Alps, such as manuscripts kept in archives, *belles-lettres*, oral-history interviews, Elias' study of the human civilizing process since the Middle Ages, recent fieldwork, and discussions with farmers. The findings are contextualized based on the publications listed above, the UN-initiated Global Agenda for Sustainable Livestock's 2021 report, the World Economic Forum's report *The Future of Nature and Business*, Dietl's & Lehmann's ecological meadow management, and an Austrian results-based nature conservation plan. Until the Green Revolution, most farmers were interested in keeping the functional role of biodiversity – species with evident favourable impact on milk quality, quantity or on livestock's health were valued. Meadow management largely corresponded with today's land-sharing in environmental conservation. Nonetheless, before the 19th century, cruelty towards many grassland animals was common. Farmers' attitudes toward meadow fauna underwent an evolution with two major turning points: increased compassion with them since the 19th century progress of the civilizing process, and an increase in cruelty of indifference with industrialized farming intensification. Adequate human society's (not only farmers') attention to species-rich grasslands in post-modernity is a logical next step in the civilizing process. However, this requires fundamental changes in human values, consumer behaviour, agro-environmental policy, and business. Some history-inspired best practices of grassland management are relevant.

Keywords: biodiversity, hay meadows, Alps, environmental history, historical ecology, farming, society-nature relations

Connection to biodiversity conservation, connectivity, and restoration

This paper contributes to biodiversity conservation and, potentially, restoration. Species-rich meadows are the most favourable environmental arrangements of livestock farming. 50 to 65 or more plant species usually occur on 50 m^2 of a non-fertilized meadow, 35–50 species in moderately fertilized meadows, where mowing timing allows for seed dispersal every second year at least. Animal diversity is also very high (it can reach more than a thousand species living in a meadow complex), non-fertilized meadows in particular are often inhabited by many specialists with a narrow ecological niche. This paper identifies several long-term evidence-based good practices of sustainable species-rich meadow management.

Policy implications

This research can be used in the development of (1) agro-environmental and (2) trade policies.

Agro-environmental policy: there are huge inequalities in agro-environment schemes between Alpine countries. Introduce well-considered result-based or hybrid (not management-based) schemes of equitably high agro-environment payments for colourful meadows based on brochures with target species to be identified and monitored by farmers (and controlled by a specialist no more than once per policy period), where such schemes do not exist yet (Slovenia!). Ensure agro-ecological education for interested farmers and farm advisors – many educated farmers will get interested in the agro-ecosystems if financially stimulated. Stimulate research identifying what payment will be equitable for farmers managing which kinds of species-rich grasslands – a parameter not known in several Alpine countries. Bridge the farming-nature conservation divide by making moderately fertilized meadows (cut at the time enabling seed dispersal every second year at least) eligible for agro-environment payments.

Trade policy: Ensuring that consumers and investors "*are able to make informed decisions that, in turn, reinforce responsible production*" is one of the key mechanisms to foster sustainable production. Since "*the trend for greater transparency and accountability continues to rise*" (The Future of Nature and Business), it is high time to introduce transparent trade policies enabling the consumer to know which milk and meat products are based on species-rich (moderately fertilized, non-fertilized)

grasslands. Consumers are massively misled by the labels, like *organic, from hay milk, selected quality*, which often have nothing to do with species-rich grasslands. Marketing 'wording' allowed outside the product specification is another problem. All these prevent a fair price for actual products from species-rich grasslands and contribute to their swift abandonment or intensification, and with it to the 6th mass species extinction in the planetary history.

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NEW TECHNOLOGIES

CHAIR: LEA REUSSER

Unlocking nature's secrets – Digital Twins, eDNA and AI in nature conservation – a glimpse into the BioMONITec project

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Synergies between cutting-edge technologies, including drones, digital data capture, artificial intelligence, and advanced genetic methods enable transformative approaches in nature conservation. Remote sensing, camera traps, acoustic sensors, and genetic methods aid the holistic collection of big data from remote regions, unveiling new insights into the dynamics of ecosystems and wildlife behaviour. Integrating new technologies into existing monitoring efforts remains a major challenge. Another major challenge is developing a monitoring scheme that ensures long-term results and covers aspects such as data availability, quality, comparability, and a high likelihood of securing funding. To what extent can conservation technologies be integrated into existing biodiversity monitoring programs, and how can the development of new programs be optimized? Pilot actions established an overview of state-of-the-art technologies and their workflows for conservation. Workshops were conducted with conservationists from around the globe. The knowledge gained was used in writing a monitoring guideline and the development of an online monitoring configurator. BioMONITec (Biodiversity Monitoring Technologies – Transfer of disruptive engineering technologies into conservation practice) case studies revealed how integrating drones, digital data acquisition, genetic methods, and automated data analysis is changing biodiversity monitoring. We developed a conceptual framework for biodiversity monitoring programs, with application across spatio-temporal scales. The online monitoring configurator helps managers to find suitable monitoring tools. It can also be used to share important information and best practices between conservationists. BioMONITec demonstrated the potentials of technology to support management activities, underlining the need for uniting technological innovation with conservation expertise to protect our planet's irreplaceable biodiversity.

Keywords: biodiversity, monitoring, new technology, nature conservation

Connection to biodiversity conservation, connectivity, and restoration

BioMONITec was established to improve the processes of monitoring biodiversity, a necessary first step towards improving conservation outcomes. BioMONITec pilot actions provided direct experience on how to pair multiple state-of-the-art approaches to conduct a holistic monitoring strategy, highlighting in particular the relative ease of making data-driven management decisions. Collaboration with local stakeholders, protected area managers, and international scientists allowed the development of a comprehensive monitoring guideline, describing step-by-step how to establish effective monitoring programs. The guideline's depth of information allows it to be used in all aspects of management, not only to conservation and habitat restoration, but also to bringing together diverse stakeholders to achieve acceptance of a new or revised management plan.

Policy implications

The most recent global biodiversity policy with high impact is the Global Biodiversity Framework (GBF), signed in December 2022. The GBF outlines four global biodiversity goals and includes targets that call for significant restoration efforts and effective management of conservation areas. This agreement is already influencing policy alignments across the globe. The BioMONITec global monitoring guideline – supported by the highly visible global conservation network IUCN WCPA – provides a roadmap for the design and implementation of effective biodiversity monitoring programs in conservation areas. The guideline will reach a wide audience that must adhere to the targets of the GBF, guaranteeing a large impact.

Remote sensing for monitoring restoration efforts in Alpine areas

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The global loss of biodiversity is one of our biggest current challenges. A quantitative and objective monitoring system assisted by remote sensing is needed especially for inaccessible mountain regions in order to identify areas of restoration needs and also to monitor the impact of restoration efforts. Mountain regions like the Alps are known biodiversity hotspots, but, at the same time, the rough topography and harsh climate make frequent and wall-to-wall assessments in the field difficult and expensive. Earth Observation (EO) techniques have been applied to monitor land cover, vegetation, and other environmental factors over time in an efficient manner, but their use for biodiversity assessment and restoration monitoring is not yet fully exploited. Which EO data and methods are useful to provide wall-to-wall data on restoration needs and success? How well can indicators derived from various EO data sets be used to monitor impacts of the Nature Restoration Law? High-resolution LiDAR data is used to determine the restoration of previously disturbed forest areas using foliage height diversity (FHD) as an indicator. For grassland monitoring, we use optical satellite time series images and *in-situ* data to derive indicators like mowing intensity and grassland types. Existing data on structural landscape features in agricultural areas is used to compare regions and identify areas with a high restoration need. FHD is a useful indicator to monitor forest restoration after disturbance events like bark beetle outbreaks. Instead of only evaluating the re-closure of canopy cover, FHD also integrates the vertical structure, thus giving a much more realistic assessment. Tests in an area heavily affected by bark beetles revealed that, based on the FHD, almost 65% of the area was not yet fully restored. For agricultural areas, we used data from two sources: Copernicus Small Woody Features (SWF) layer and a Habitat Type Assessment (HTA) done some 10 years ago. Our assessments found that highest detection rates (62% compared to 45% HTA and 31% SWF respectively) were achieved when combining the data sets because of the complementarity for many of the structural features. For example, 26% of all hedges were detected both by SWF and HTA, but combining them led to a detection rate of almost 44%.

Keywords: restoration, grassland, forest, LiDAR, remote sensing, monitoring, structure

Connection to biodiversity conservation, connectivity, and restoration

In our project RestorEO we employ EO data in combination with field assessments to provide information about ecosystem restoration and degradation in order to support Austria's National Restoration Plan. Compared to previous attempts targeting only administrative areas, given the nature of the basic data which allow only statistical assessment, RestorEO can pinpoint areas in need of restoration or where restoration efforts have failed. The exemplary analysis of structural elements highlighted some agricultural areas with a potential for improvement. These structural elements could also serve as basic data for connectivity analysis on a local scale. Forest fragmentation was also assessed using Copernicus forest layers, which are potentially useful for connectivity assessments.

Policy implications

The results from the analysis of structural landscape features in grassland-dominated cultural landscapes in Austria can be used to pinpoint areas with poor structural diversity and target restoration efforts in these areas. Additionally, the structural features can be used as stepping stones for habitat modelling, although additional information might be needed for this purpose. Monitoring the increase or decrease in abundance of these features over time can give regional managers information on trends in restoration success or failure, as well as warning of ecosystem degradation. The forest-related structural feature FHD derived from airborne LiDAR data can be used for a better insight into the vertical structure of restored forests in order to move from pure forest/non-forest assessments to a more realistic and meaningful indicator.

Conceptualizing the management of conservation areas: the launch of IPAM Toolbox 2.0

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Conservation areas (CAs) are public facilities aimed at long-term biodiversity and ecosystem service preservation. Current European and global agreements will require tools to enhance management capacities. The Kunming-Montréal Global Biodiversity Framework sets ambitious biodiversity goals. Large amounts of project funding are available, yet little is invested in institutional capacities. CA management bodies must sustainably secure biodiversity and ecosystem services. Management faces multiple demands: navigating aporetic conflicts while maintaining structured approaches to deliver conservation outcomes, operating in dynamic societal environments and seeking new funding streams. The deluge of scientific insights and practical guidance further increases the challenges. The authors developed a toolbox for use in planning, designating, managing, expanding, connecting, and de-gazetting CAs. Relevant questions are: 1) What common issues exist for planning and management? 2) How can general principles be structured? 3) How can experiences be provided to key stakeholders? The IPAM 2.0 toolbox was first developed between 2003 and 2005 and is now being relaunched. It shows the development of CAs as a lifecycle comprised of specific stages called Fields of Activity (FoAs) to expand management structures. Key information is available online on an interactive planning platform. The CA lifecycle is structured into 29 FoAs, beginning with the initial vision of the CA to its de-gazettement. These include planning and designating a site, long-term site management (core processes, governance, administration), repeal and termination, and management beyond borders (buffer zones, corridors, networks). The toolbox offers a comprehensive perspective on CA development. With a self-assessment tool, CA managers can evaluate the development status of their conservation area, and the IPAM toolbox suggests appropriate measures and tasks. Currently, the toolbox is available online as a demonstrator (http://ipam.mca.tools/), with further development and a broad public launch planned.

Keywords: Kunming-Montréal Global Biodiversity Framework (GBF), management of conservation areas, lifecycle of conservation areas, UNESCO designated sites, conservation outcomes, European Restoration Law, OECMs (Other Effective Area-based Conservation Measures), European Green Deal

Connection to biodiversity conservation, connectivity, and restoration

To achieve the GBF goals – managing 30% of the earth's surface for conservation purposes – several actions are required: 1) restoring destroyed ecosystems; 2) establishing new CAs; 3) enhancing and expanding existing CAs; 4) maximizing connectivity between CAs. These goals may raise societal, political, economic, and cultural conflicts. From a conservation perspective, these processes rely on a consistent and transparent framework. The IPAM lifecycle takes individual CA development from isolated consideration and identifies commonalities among the 300,000 conservation areas worldwide. This will enable better exchange of knowledge and clearer assessment of management effectiveness. Goals thus improve justice, fairness, respect for rights and interests of the indigenous population, and support for political decision-makers. The IPAM lifecycle concept highlights the scale of the task, providing a framework for building institutional capacities and professional management.

Policy implications

IPAM Toolbox 2.0 explicitly addresses the public sector, focusing on usability by administrators and managers of CAs, NGOs, planners, and consultants. Its user interface is easy to use. The toolbox provides crucial support for key European policies, particularly the Restoration Law, Green Deal, and the Birds and Habitats Directives. Internationally, the toolbox can contribute to GBF and the Convention on Biological Diversity. Efforts are underway at the UNESCO Chair on Sustainable Management of Conservation Areas to foster collaboration with other UNESCO sites and institutions, with a focus on field-testing the IPAM toolbox. The toolbox and its lifecycle concept are integrated into relevant postgraduate curricula, particularly within the international Master's program in Management of Conservation Areas (www.cuas.at/unesco-chair) at Carinthia University of Applied Sciences. This way, the toolbox shall be applied more widely in professional settings in future.

Digital trails: harnessing outdoor and fitness app data for sustainable tourism management in sensitive ecosystems

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As the popularity of outdoor and fitness apps continues to grow, a rising number of visitors of natural areas rely on these platforms to plan, navigate, and track their journeys. Our analysis explores how harnessing outdoor and fitness app data can guide conservation areas towards sustainable tourism management. While outdoor and fitness apps empower users to share their routes, the proliferation of unofficial trails poses a challenge, particularly in ecologically sensitive mountain regions. In a recent online survey from Mangold et al. (2024), 131 conservation area (CA) managers were interviewed across 46 countries. Around 42% of park managers perceive digitization as problematic, causing off-trail behaviour and higher visitor load in sensitive areas. While 70% envision digital visitor monitoring and management as a future task of CA management, there are still obstacles such as financial and staff resources to targeting this activity. What are the regional, country-specific, and user-driven variations in the use of outdoor and fitness apps of visitors of the Karawanken-Karavanke UNESCO Global Geopark? How can information from outdoor and fitness apps be used by park management to identify frequently used unofficial trails within the Karawanken-Karavanke UNESCO Global Geopark? From June to October 2023, a visitor survey was carried out in the Karawanken-Karavanke Geopark. A statistical analysis gives insights into visitors' use of digital outdoor and fitness apps for planning and navigating their outdoor activities in the area. Furthermore, a geostatistical analysis of digital trail data from Outdooractive, Trailforks, Strava, and Komoot gives insights into the number and statistics of promoted hiking and mountain biking trails in the areas of Hochobir and Mt. Petzen/Peca. Of 258 respondents, 42% planned to use apps or digital devices for orientation and/or tracking their activities. Mountain bikers were most likely to use apps and digital devices (60%), followed by hikers (36%) and pedestrians (20%). While the most frequently used apps of mountain bikers are Trailforks and Strava, hikers and other groups mainly used Komoot and Strava. Only 2 respondents used Outdooractive for planning, orientation, or tracking their routes. In the analysis of digital trail data for Hochobir and Petzen/Peca, a catalogue and map representations of unofficial trails were created to inform the Geopark management about currently promoted digital trails and digital user activities on outdoor and fitness apps.

Keywords: digital visitor monitoring, digital visitor management, conservation technologies, digital ranger, outdoor and fitness apps

Connection to biodiversity conservation, connectivity, and restoration

This research contributes primarily to biodiversity conservation efforts. By analyzing outdoor and fitness app data, it helps to identify and manage human impact on ecologically sensitive areas, thereby promoting the conservation of biodiversity. Understanding visitor behaviour through digital trail data aids in mitigating threats to biodiversity hotspots, ensuring their long-term preservation.

Policy implications

The findings of this research can inform the development of policies related to sustainable tourism and conservation management. For instance, governments and park authorities can utilize insights about visitor behaviour and digital trail data to formulate regulations guiding outdoor activities in natural areas. Policies focused on regulating trail usage, promoting responsible outdoor behaviour, and allocating resources for conservation efforts can be developed based on the research outcomes, fostering sustainable tourism practices while safeguarding biodiversity.

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Datafication in outdoor recreation and tourism – emerging potential of Big Data for sustainable management of nature trails in the context of bio- and geodiversity

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Digitalization, connectivity and datafication are key features characterizing current society, frequently described as digital society. The rapid technological development affects many aspects of our daily life, including habits related to outdoor tourism and recreation. Increased usage of digital devices and technologies, such as smartphones, smart wearables, and GNSS-based navigation while planning and visiting outdoor leisure settings, generates significant amount of data. Those new high-resolution data resources related to human mobility and spatio-temporal distribution in nature destinations may greatly support planning and management of ecologically sensitive sites. The main objective of this study is to explore the utility of digital data resources for understanding the public's demand for nature and its potential for sustainable management of nature trails in the context of bio- and geodiversity. Our study is based upon empirical data collected in forests located within the metropolitan area of Vienna, Austria. Part of those forests geographically belongs to the Alps (e.g. Wienerwald), others are designated protected areas (e.g. Donau-Auen National Park). Various data sources, including Volunteered Geographic Information (VGI), mobility data of outdoor apps, along with representative socio-empirical observations based on an online panel survey (n = 3,089), were analysed using Geographic Information Systems (GIS) and statistical approaches (SPSS & R). The preliminary findings provide insights into patterns of human mobility in the Vienna metropolitan area, showing how forests serve as a source of relaxation and connection to nature for urban residents. Additionally, we explore what kind of *digital traces* are being left during leisure forest visits and what the differences are between various visitor profiles in terms of planning and navigating trips, as well as sharing trip experiences in social media. Our study points out the overall significance of technology use related to outdoor recreation activities in society. Yet, not all visitor groups use technology in the same way. Young visitors tend to demonstrate more digital skills than older generations and therefore also *produce* more digital content related to outdoor activities, although on average they spend less time outdoors. Therefore, these differences must be considered when analyzing large digital datasets, such as VGI, outdoor app data. These findings were used in our project to calibrate maps of spatial distribution of recreational use in the forest areas studied. Validated big data patterns may thus provide a reliable basis for further impact research and evidence-based management of bio- and geodiversity in ecologically valuable environments, such as the Alps.

Keywords: nature trails, tourism, recreation, Big Data, digital society, forests, protected areas management, recreation ecology

Connection to biodiversity conservation, connectivity, and restoration

Our research plays a crucial role in biodiversity conservation, providing advanced methods to measure and map the usage of sensitive natural areas for recreation and tourism. By leveraging big data from digital devices and social media, we obtain high-resolution insights into human activity patterns within these environments. This data is vital in identifying potential stressors that impact on biodiversity. It aids in the design of strategies that balance human recreation with the preservation of natural habitats. Understanding visitor behaviour and preferences also supports efforts in ecological connectivity and restoration. Our findings can inform decisions about where to focus restoration efforts and how to develop nature trails in a way that minimizes ecological disturbance while maximizing the enjoyment and educational value for visitors.

Policy implications

Our study's outcomes are particularly relevant to several targets of the Kunming-Montreal Global Biodiversity Framework. Specifically, our research contributes to Target 1 by providing data to manage areas for outdoor recreation in a way that conserves biodiversity and ecosystem services. It aligns with Target 3 by offering insights for minimizing the negative impacts of tourism on biodiversity. Furthermore, our findings can inform policies under Target 12 by guiding sustainable use and management of natural resources in forested and protected areas. By advancing the understanding of the interplay between human activity and nature, it also supports Target 19, which focuses on knowledge sharing and capacity building. Lastly, our approach contributes to Target 21 by enabling the integration of biodiversity values into planning and development processes, ensuring that recreational use of nature is sustainable and contributes positively to the conservation and restoration of biodiversity.

WATER RESOURCES & GEODIVERSITY

CHAIR: LEOPOLD FÜREDER

Let's go! Valorization of spring habitats in an inner-Alpine region

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Springs are an important source for drinking water for humans and animals and are influenced in many different ways by human activities. At the same time, they are sensitive habitats that provide unique environmental conditions for specialized and endangered species. Scientific data on spring ecology in the Alps is often gained from projects conducted in protected areas. Besides the scientific basis, biodiversity conservation depends on the willingness of society to invest in protection measures. Currently, knowledge and awareness of the relevance of springs as valuable habitats in inner-Alpine regions is still very limited. In areas heavily impacted by tourism, the use of spring water as a resource is much more obvious. Applied spring research uses scientific data to raise people's awareness and wants to contribute to a better conservation of ecologically valuable springs. Lepomis gibbosus In 2023 we developed two nature trails in the highly touristic community of Samnaun. The major goals of this approach are (a) to get people into contact with springs in different ways, and (b) to educate them in a playful way to use water as a resource sustainably. Potential springs along common hiking trails were first mapped and documented photographically. A qualitative sampling of the macro-invertebrates complemented this survey. In a second step, 13 springs suitable for the nature trails were selected. For each spring, we worked out certain topics, such as *springs as drinking water supply*. Despite the high utilization pressure in the region due to skiing tourism and agriculture, many springs in Samnaun are still in a good structural condition. Some are even inhabited by highly endangered and rare species like the stonefly *Nemoura undulata*. The developed nature trails are suitable for tourists and also locals older than 10 years. Along the nature trails, hikers get to know springs actively and playfully. The visitors experience a personal concern and get encouraged to act more respectfully and sustainably in the future. The trails are supported by the community of Samnaun and the conceptual design based on QR codes is currently developed by DialogN. The trails will be implemented in summer 2024.

Keywords: nature trail, spring ecology, spring protection, sustainability

Connection to biodiversity conservation, connectivity, and restoration

The research greatly contributes to biodiversity conservation as it raises an awareness of springs within a conflict of being irreplaceable habitats and important drinking water resources. The nature trails will help to sensitize the young generation and to encourage people towards a more sustainable way of life. This will help to enhance biodiversity conservation in the future. Moreover, our research project yielded important results for further spring research in a high Alpine region, which seems to be rich in natural springs inhabited by rare spring specialists.

Policy implications

Research on Alpine springs and their response to climate change can provide policymakers with essential information for developing effective policies to protect these critical ecosystems and to engender support in the communities that depend on them. Education-based programs with a strong focus on Alpine springs play a significant role in the development of public policies related to environmental conservation, water resource management, and climate change adaptation. Within the project, we also developed recommendations for possible future support programs and protection measures. We contribute to better spring protection in the future and to more sustainable touristic services for the community of Samnaun. The capacity of local communities and institutions to manage and protect Alpine springs effectively will be enhanced. Furthermore, this kind of research can empower stakeholders to advocate for policies that protect and sustainably manage Alpine springs.

Long-term research on springs and spring brooks the UNESCO Biosfera Engiadina Val Müstair

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Global climate change is threatening freshwater ecosystems worldwide. For Alpine headwaters, a shift in the discharge regime and rising water temperatures are predicted. This will have severe impacts on freshwater biodiversity in the Alps. Springs are relatively stable habitats with low temperature and discharge variability. They are partly inhabited by specialized species adapted to environmental stability. Evidence-based data on how Alpine headwaters react to climatic changes are rare and mostly exist for glacial-fed headwaters and not for groundwater-fed springs. Increasing water temperature might cause a species range shift, and a changing discharge regime might be especially critical for spring-adapted taxa like water mites. A long-term research was implemented in 2019 at 15 springs, seven spring brooks, and three brooks in the UNESCO Biosfera Engiadina Val Müstair. The goal is to gain empirical data on hydro-ecological aspects over several decades to understand whether 1) the environmental conditions in groundwater-fed headwaters change over time, and 2) how these changes influence species composition. Water temperature loggers were installed at every site. Other abiotic parameters, such as electrical conductivity and discharge, are measured thrice a year; the substrate composition is documented twice a year. The meio- and macrofauna was sampled in 2019–2021 with a semi-quantitative approach taking all substrates into consideration. The next faunistic sampling will take place in 2025. First results confirm overall environmental stability typical for groundwater-fed systems. A certain seasonal variability of discharge and water temperature possibly indicates an influence of permafrost or snow meltwater. The species assemblages differ significantly between sites and stay relatively constant over time. Elevation and the availability of wood have a significant influence on the species composition. In springs and spring brooks above 2,000 m, Trichopteran species adapted to Alpine headwaters are found, while in springs below the treeline, spring specialists such as certain water mite species are more common. We now have a solid baseline on groundwater-fed headwaters in the Central Alps, which is needed for a proper interpretation of changes identified on a long-term basis.

Keywords: groundwater-fed headwaters, spring ecology, long-term research, environmental stability, spring specialists

Connection to biodiversity conservation, connectivity, and restoration

Our long-term research on springs and spring brooks in the UNESCO Biosfera Engiadina Val Müstair highly contributes to biodiversity conservation. With the data we gain over time, we will be able to better understand how species restricted to certain environmental conditions react to changes of these respective conditions. We will see which species are particularly threatened by climatic changes and will need specific protection in the future. Moreover, natural springs are generally threatened by anthropogenic influences, and biosphere reserves do have a great responsibility for habitat protection and therefore biodiversity conservation.

Policy implications

Our long-term research on springs and spring brooks will help to understand future threats for spring habitats in the Alps, which will be intensified by a common pressure on springs due to water scarcity. This information is important for the development of water resource management policies. The research on Alpine springs can provide critical data on how these ecosystems are responding to climate change. With this knowledge, adaptation policies could be developed to enhance resilience to climate change impacts. Moreover, decision making in tourism and landscape management in the Alps should include the protection of valuable spring habitats.

Warming Alpine streams: differential vulnerabilities of aquatic invertebrates

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Mountain freshwater ecosystems face accelerated warming during summer, and aquatic communities are generally considered sensible to such changes, while their vulnerabilities have barely been evaluated.

Moreover, the real-time changes within such aquatic habitats, such as mountain streams, remains poorly understood. Individual species or species groups are expected to respond differently depending on their adaptations, traits, or distributions, but this has not yet been distinguished, so that population shifts as a climate change consequence are difficult to predict. Moreover, multi-year observations of aquatic communities during warming periods in mountain rivers are missing, and consequential population dynamics remain theoretical. In this study, we examined the climate change vulnerability of European Ephemeroptera, Plecoptera, and Trichoptera (EPT) species and i) compared their vulnerability across diverse ecoregions, including Alpine endemics, to elucidate differences in species pools, ii) contrasted the vulnerability between insect orders, iii) investigated the altitude-vulnerability relationship within the European Alps, and iv) monitored benthic invertebrate communities in 18 Alpine study streams to compare these theoretical expectations with real-time observations. We used available climate change vulnerability scores for European Ephemeroptera, Plecoptera, and Trichoptera (1,899 taxa from 48 families) and compared their vulnerability i) between European ecoregions, ii) between insect orders, and iii) correlated vulnerability with other species traits (altitudinal distribution, saprobic index, temperature preferences). For the empirical part, we monitored different study streams in Hohe Tauern National Park annually (abiotic parameters) and additionally in 2011, 2014 and 2015 (for biotic parameters) during summer months. We identified 50 Alpine Plecoptera and Trichoptera species categorized as highly vulnerable to climate change effects (= 31% of all highly vulnerable European species), with highest proportions in species inventories of Alpine endemics and high-altitude waters (51% of high-altitude species are classified as highly vulnerable). The ccvs-analysis specifically for mountain waters shows that a disproportionately high number of Alpine species, and particularly Alpine endemics, will be affected by climate change, and suggests that Ephemeroptera may be better prepared than Plecoptera and Trichoptera. Thus, this trait-based evaluation suggests that mountain stream invertebrate communities are undergoing disproportionate restructurings in response to climate change effects – more than lowland communities. For the observed mountain streams, we revealed that the EPT insect orders remained stable or increased only marginally, while cold-adapted species (i.e., Diamesinae) unexpectedly expanded their dominance over the observed years – findings that remain hidden in space-for-time substituted study designs. In particular, however, within the next years it is the aquatic fauna in smaller rivers that will experience the greatest summer warming and consequential changes.

Keywords: climate change, mountains, protected area, sensitivity, macroinvertebrates

Increasing population trends of non-native fishes in rivers of the Eastern Alps

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The immigration of non-native species has become one of the major threats for aquatic biodiversity worldwide, and freshwater fishes are among the taxonomic groups that appear particularly vulnerable to non-native invasive species. Such invasions are mostly associated with threats to the native fish communities and economic costs.

While fish invasions have been extensively studied and managed in streams and lakes around the world, there has been a notable lack of attention given to special ecoregions like mountain regions, with the exception of some research on North America or Himalaya. Their occurrence and spread in mountain regions and associated population trends are insufficiently known, which has hindered effective management of non-native species so far. With the exception of studies focusing on high-altitude lake ecosystems, knowledge of the presence and spread of introduced and non-native fish species in aquatic ecosystems within the European Alps remains largely insufficient. It was generally hypothesized that there has been an increase in the establishment of non-native species during the study period in the Alpine region of South Tyrol, and it was assumed that trends varied among different river types. This study analyzed over 1,300 electrofishing surveys in 650 sites across a 7,400 km² area in the Eastern Alps to quantify non-native species occurrences and to predict their foraging in distinct river types. Additionally, population sizes and biomass trends were estimated for sites that were fished multiple times between 2000 and 2020 (>150 sites). Among the 42 fish species in the study region, 11 are non-native. Two invasive species of union concern, *Lepomis gibbosus* and *Pseudorasbora parva,* increased their population sizes in recent decades by 8% and 9% per year, supposedly supported by increasing water temperatures. Among the non-native species relevant for recreational fishing, *Oncorhynchus mykiss* populations have significantly increased (+7 +3% year^{-1}), *Salmo trutta* populations have remained stable, while *Salvelinus fontinalis* populations have significantly decreased (-7.4 ±3% year^{-1}). The variation in their population trends may be due to different stocking intensities, with *S. fontinalis* being stocked minimally compared to the others. Our study found that non-native and invasive fish species are a relevant part of fish communities in mountain rivers. Non- salmonid non-natives thrive in warm rivers at low elevations, while salmonid non-natives consolidate in steeper habitats.

Keywords: South Tyrol, pumpkin seed, stone moroko, fish stocking, brown trout

Connection to biodiversity conservation, connectivity, and restoration

Since rising temperatures and fish stocking in mountain rivers will accelerate the spread and growth of these species, this first quantification of the current extent will improve fish management strategies in mountainous areas.

Mountain pasturing and quality of water sources in the Kamnik-Savinja Alps

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Mountain livestock farming, often considered environmentally benign, faces scrutiny. EU policies emphasize sustainability. We preliminarily monitored four active water slurries in livestock farming areas of the Kamnik-Savinja Alps. Research on mountain livestock grazing unveils critical gaps: 1) a lack of comprehensive studies quantifying its impact on water quality, including specific pollutants, 2) a need to explore spatial variability in water quality across diverse grazing intensities, 3) opportunities to enhance mitigation strategies for sustainable livestock production, 4) investigation into climate change effects on grazing-water quality dynamics, 5) a future focus on ecological impacts, including effects on biodiversity and downstream users. Monitoring water resources in mountain agricultural areas is crucial due to their vulnerability. We surveyed water slurries in the Kamnik-Savinja Alps, vital for livestock. Droughts heightened their importance. Our research assesses water quality and land use impacts to improve the actual regulation. Our interdisciplinary approach merges geography and ecology to assess land-water dynamics. Using GIS and open data, we assessed land use impact on water quality. Our fieldwork measured key indicators, and lab tests assessed nitrate and Biochemical Oxygen Demand (BOD) levels. Environmental data enriched our analysis. Our study examined mountain streams crucial for livestock drinking water, considering natural settings and legislation. We monitored: Mala (WS1) and Gojška planina (WS2) on Velika planina plateau, Lemonska planina (WS3) on Menina plateau and Gostečki stan (WS4) on Golte plateau, in three seasonal periods in 2022–2023: 1) before grazing (winter/spring), 2) during grazing (summer), and 3) after grazing period (autumn/winter). Despite extensive grazing, water quality issues arise from runoff and erosion. Field measurements revealed fluctuating BOD levels, suggesting organic pollution risks. Nitrates remained below 2 mg/l at each sampling site. Further research integrating livestock impact data is essential for a comprehensive assessment.

Keywords: mountain agriculture, extensive farming, livestock grazing, water ecological conditions, water quality, Kamnik-Savinja Alps

Connection to biodiversity conservation, connectivity, and restoration

Livestock grazing research informs policies crucial for biodiversity conservation, ecosystem connectivity, and restoration efforts to ensure water resource sustainability. Key connections include: 1) Biodiversity Conservation: Understanding grazing impacts on water-dependent ecosystems informs policies to protect biodiversity hotspots. Strategies like grazing restrictions in sensitive habitats and promoting rotational grazing maintain ecological balance. 2) Connectivity: Studying grazing effects on water sources highlights the importance of linking aquatic and terrestrial ecosystems. Policies may establish buffer zones along waterways to mitigate grazing impacts and enhance wildlife corridors. 3) Restoration: Research identifies degraded areas impacted by grazing, guiding policies to prioritize restoration. Actions may include riparian restoration projects and promoting regenerative grazing practices to improve ecosystem health and water quality.

Policy implications

Integrating livestock grazing research into policy can foster sustainable agriculture, safeguarding water resources and farmer livelihoods. It informs policies in various ways: Water quality regulations: Insights into grazing impacts inform revisions to agricultural regulations, safeguarding water quality. Water allocation policies: Understanding grazing's water consumption guides equitable water rights allocation. Conservation programs: Identifying grazing impacts on sensitive ecosystems informs restoration efforts, such as fencing off areas, or implementing rotational grazing. Subsidy programs: Livestock subsidies may hinge on adherence to environmental standards from research findings. Land use planning: Research guides decision-making by identifying areas where grazing supports water quality and where it poses risks. This informs zoning, conservation, and land management plans for sustainable resource use.

Valuing geodiversity in Alpine environments: selected case studies from Slovenia

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Mountainous environments are site-specific in terms of their geodiversity mainly because of their high ruggedness values and elevation ranges between the highest peaks and the valley floors (Stojilković et al. 2023). Areas with mountains are considered the ones with high geodiversity index values. However, that is mainly due to the terrain ruggedness component which affects the geodiversity index values in two ways (Stojilković 2022): it adds up the value as steepness and elevation rise, and it contributes to high dynamics of erosional and depositional processes. Hence, it is imperative to make the ruggedness factor equal to other geodiversity components (e.g. geomorphological, hydrological, and others) when making quantitative evaluations (ibid.). The presentation aims to show where the most heterogeneous abiotic environments in the mountainous regions are if ruggedness is integrated into the index as an equal element to other elements. The study areas contrasted in the presentation are the Topla Valley (Stojilković 2021) in the Karavanke Mountains and the Logar Valley in the Kamnik-Savinja Alps (Stojilković 2022). To answer the research question, we applied two methods to the study areas and compared the results. Both work on the block statistics principle, where the study areas are divided into the same size blocks. The first method multiplies the terrain ruggedness values with the sum of other geodiversity elements per block (Serrano & Ruiz-Flaño 2007), whereas the second one sums the classes of the ruggedness index values with other elements (Stojilković 2022). The methods contrasted in the two study areas identified the micro-areas that are more geodiverse than the others. However, the differences became obvious if too much stress was put on the ruggedness component (Stojilković 2022). When valuing surface geodiversity (i.e. lithosphere, hydrosphere, and cryosphere), all of the components should be equally represented (Stojilković et al. 2023). This presentation brings a novel method that integrates the latest methodological research, which has so far shown that most geodiverse areas of mountainous environments are at the junction of slopes and their level and nearly level parts, which is also beneficial for geodiversity-biodiversity evaluations (Muellner-Riehl et al. 2019). The method's general advantage is that it can be easily applied to other areas worldwide.

Keywords: spatial analysis, geodiversity index, geodiversity, terrain ruggedness, Topla Valley, Logar Valley, Alps, Slovenia

Policy implications

Presently, no relevant policy in Slovenia even mentions geodiversity, whereas the Nature Protection Act (ZON 1999) considers only some of its aspects, but does not mention the term 'geodiversity' explicitly. This paper presents a method that could be applied to any area in Slovenia to objectively and automatically evaluate its geodiversity characteristics and (based on the results) determine the areas that need additional protection or other attention due to its intrinsic characteristics (e.g. geotouristic, geo-educational).

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SPATIAL PLANNING

CHAIR: HUBERT JOB

Alpine spatial planning perspectives: Green infrastructure, energy and spatial development

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The *Alpine Spatial Planning Perspective* paves the way towards a common spatial vision for the Alpine region. This process is part of the mandate of the Working Group on Spatial Planning and Sustainable Development of the Alpine Convention and helps to facilitate the dialogue between a variety of actors and sectors. Alpine spatial planning is embedded in a highly complex context. The pan-Alpine level brings together eight nation states, including more federal or centralized systems, EU and non-EU countries, as well as large and small states. All these countries are organized on multiple levels, from European to regional and local levels. Furthermore, spatial planning and development has to cover several dimensions. This includes, first, the gradient of harder planning in a formal and legally binding sense, and softer instruments. Second, rather technical planning has to be differentiated from more strategic formats that address cross-sectoral coordination. The question is how Alpine spatial planning can contribute in the fields of green infrastructure and energy without having a pan-Alpine mandate in the technical sense. Based on process reflections, we discuss challenges, instrumental perspectives, and policy options. Our arguments refer systematically to the relevant scientific and grey literature, defining the link between spatial planning/development, green infrastructure, and energy. Spatial planning has an important role to play in the implementation of green infrastructure and energy issues. In this context, cross-sectoral coordination is a key concern. Understanding and balancing competing needs is a complex challenge – for example, nature conservation vs. tourism, renewable energy production vs. biodiversity, transport infrastructure vs. ecological networks. In parallel to the vertical challenge in the multi-level system, the horizontal challenge is cross-border cooperation. Effective measures require collaborative efforts across political boundaries in order to implement protected areas or habitat restoration.

Keywords: spatial development, spatial planning, Alpine Convention, sustainable development, green infrastructure, energy, Alpine Spatial Planning Perspectives

Connection to biodiversity conservation, connectivity, and restoration

We position the sectoral instruments of nature conservation and connectivity towards the spatial planning instruments. This is discussed against the background of spatial development policies in a broader sense.

Policy implications

Our contribution is based on the second input paper that paves the way towards an *Alpine Spatial Planning Perspective*. This draft paper series is part of the mandate of the Alpine Convention's Working Group on Spatial Planning and Sustainable Development (WG SPSD). The WG SPSD has initiated a process aiming at a long-term perspective for spatial planning and development. This Alpine Spatial Planning Perspective has to be seen as a process rather than just a document. The current mandate phase of the Working Group (2023/24) provides important elements with three draft papers that undergo diverse feedback loops. At the end of the 2-year-process, a synthesis report will provide the first draft of the *Alpine Spatial Planning Perspective*.

A tailored and trans-scalar approach to face the Alpine region challenges

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The Alpine region is a key player in the global climate crisis. Open spaces and Green and Blue (G&B) infrastructures are major concerns. A challenge for this complex region is adopting a comprehensive approach to spatial planning to safeguard and improve them. This requires a powerful operational toolkit that integrates comprehensive strategies and operative spatial policies, by tailored and trans-scalar tools. Assuming that the transnational G&B infrastructure system is mainly based on Natura2000 areas, Strategic Alpine Connectivity Areas and international protected areas, a coherent trans-scalar chain should be created between planning instruments at different spatial levels (transnational, national, local) for their effective functioning from the large scale to the local level. So far, this has not happened due to a fragmented and uneven planning and administrative competence framework in the Alpine region. Emphasizing the multifunctionality of G&B infrastructures is crucial for achieving climate goals at local and transnational level throughout the Alpine region. This can be achieved by starting with the EC definition (2013) and improving upon it in trans-scalar spatial planning. G&B networks should be designed to fit the different territorial features, specificities, and policy competencies. Due to the complexity of the region, a variable-geometry method is proposed, involving a *push method* relying on voluntary cooperation and soft planning tools. Incentive measures and territorial cooperation instruments used to develop a coherent, shared, and useful system, tailoring the concept of multifunctionality of G&B to diverse territorial needs and characteristics. The ongoing activities are expected to yield results in the short term. These transnational initiatives are linked to projects that aim to translate into spatial planning policies, with a focus on G&Bs. The EU Strategy for the Alpine Region (EUSALP) Macro Regional Strategy Joint Paper of Spatial Planning (2022), protocols on G&B and land use (Alpine Green Infrastructure … 2017), and the Alpine Spatial Planning Perspective being prepared by the Alpine Convention (2024) serve as reference frameworks for this effort. The Target Analysis InTerAlp of the European Observation Network for Territorial Development and Cohesion, ESPON, has just begun. It delves into the spatial dimension to analyze specific phenomena beyond administrative and statistical boundaries. The Alpine Space project PlanToConnect involves partners with scientific, academic, and practitioner expertise and develops the G&B concept through pilot cases involving local stakeholders who will apply the concept concretely in plans and actions.

Keywords: G&B multifunctionality, G&B infrastructure, spatial planning, trans-scalar approach, EUSALP, Alpine Convention

Connection to biodiversity conservation, connectivity, and restoration

The research contributes to the implementation of the concept of multifunctionality of the G&B infrastructure according to the definition of the EC 2013. It develops the relationship between the G&B infrastructure in term of scientific/technical instrument/concept and spatial planning instruments employed by territorial authorities. The research faces the issue of connectivity in planning instruments and potential conflict of uses.

Policy implications

The research is strictly linked to activity within the Alpine Convention, EUSALP and different territorial actors involved in the Alpine Space Territorial Cooperation Programme. The concept of multifunctionality of the G&B infrastructure is part of an activity involving pilot cases of the project PlanToConnect (Interreg Alpine Space).

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Planning without planning: do renewable energy projects endanger open spaces in the Alps while undermining spatial planning frameworks?

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Alpine open spaces are characterized as contiguous landscapes that are little developed, and to a large extent free of technical infrastructure. Due to their remoteness, mostly noise-free situation and less anthropogenic land use, they have been hardly present in the public consciousness and on the political agenda. If these open spaces become usable resources, this potentially has serious impacts on the environmental quality of Alpine ecosystems. Currently this observation is changing massively, as exactly these Alpine open spaces get a lot of interest as potential sites for the installation of large-scale solar plants and wind parks. The urgency to utilize these open spaces for energy transition is increasingly acknowledged against the background of the overall European policies and considering the Ukraine crisis. This recently led to major policy shifts to address energy shortfalls in Europe. The unprecedented speed of these decisions to a certain extent bypasses environmental impact assessments, established planning procedures and thereby also public participation and consultation. This contribution deals with two important questions: Do renewable energy projects endanger Alpine open spaces? How far does the energy transition challenge the balancing of various public interests in spatial planning and development? Our contribution is not intended as a representative empirical study, but as an up-to-date discussion of current trends and challenges in the context of renewable energy transitions, leading to the identification of certain shortcomings for spatial planning governance. We use the European Alps as a case study to illustrate currently debated examples in Austria, Germany, and Switzerland covering solar, wind, and hydropower. The urgency of accelerating the energy transition is undisputed. However, the extent to which the necessary expansion can only be achieved at the expense of landscape-scale conservation, biodiversity, and landscape aesthetics is controversial, as shown in the selected examples from Austria, Germany, and Switzerland. Particularly critical attention in this respect is given to large isolated facilities developed in protected areas. For a rapid implementation of renewable energy facilities, there is a need to move more quickly towards integrated coordination approaches to halt the existing trend of ruling out planning processes and instruments. Concepts for wind, water, and solar energy can be important foundations for the adaptation of regional spatial planning instruments. At the same time, fundamental policy mechanisms should be maintained, as well as basic principles for efficient spatial development (concentration of development, weighing of interests, participation).

Keywords: European Alps, biodiversity, energy transition, landscape-scale conservation, open spaces, renewable energy, spatial planning

Connection to biodiversity conservation, connectivity, and restoration

The article has an important connection to biodiversity conservation as it addresses a central threat to ecologically vulnerable Alpine open spaces: The expansion of renewable energy infrastructures in alpine landscapes. At the same time, the article recognizes the importance of expanding renewable energies and so contributing to the reduction of GHG emissions and therefore the mitigation of climate change. The weighing up of public interests as a task of spatial planning in the specific case of land-use planning is at the centre of the underlying considerations to find balanced solutions for Alpine territorial development.

Policy implications

This research is very closely related to current debates and developments in the fields of energy, spatial planning, and biodiversity conservation policy, from the UN, European, to the national and regional level. The central question here is how important principles and quality standards of spatial planning procedures can be maintained while at the same time the energy policy framework conditions and processes are changing rapidly. The article attempts to consider the requirements of the energy transition and biodiversity conservation, which are particularly important in the Alps, and to provide an impetus for integrative solutions.

Monitoring tourism flow to high-altitude mountain and protected areas in the Alps: A cartographic and spatio-market planning methodology

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While spatial accessibility characterizes and identifies high-altitude mountain and protected areas in the Alps, monitoring the number of visitors is still largely grounded to the accommodation facilities and/or transport links in the bordering valleys/municipalities. The local spatial planning instruments which might permit a change in tourism bed-density as a key indicator, e.g., municipal space and landscape plans, have a fundamental impact on the surrounding near-natural areas. Yet, the pattern of the non-technical visitor flow (trails) in high-altitude areas is not fully monitored or analyzed. In fact, several recent studies focus on the visitor counting methods utilized at observation-based points for the monitoring of tourism flow, i.e., visitor count per hour per point, without equally elaborating on methodologies to identify these points – apart from selection criteria. Thus, this paper addresses, quantifies, and geo-visualizes the question of: What points-of-eco/cultural-interests (POIs) of a mountain landscape are being consumed as a commodity – for the monitoring of tourism flow and multi-purpose impact surveys for policy-testing? The POIs are subjected to a profound temporality as a result of the change in landscape consumption, i.e., through the promotion of clusters of POIs. Founded on the cartographic theory and field landscape documentation surveys in Trentino-Alto Adige/Südtirol (and the Alps), this paper introduces a cartographic and spatio-market planning methodology and indicator to answer the above question. It spatially segments the POIs in the high-altitude mountain and protected areas, based on accessibility and topography, and land cover and feature type (characteristics/geodiversity), and analyses the connectivity clusters of the POIs (preference). All destinations, i.e., nodes (ultimate POIs), within the boundary of a particular high-altitude mountain and protected area, are identified through cross-referencing all available sectoral/industry sources, where the total POIs on all possible routes to a specific node form a single preference (connectivity) cluster. The clusters overlap to create low/medium/high frequency POIs. Thus, the methodology funnels the landscape into a pattern of multiple frequency consumption POIs (quantification) of specific characteristics for the monitoring of tourism flow in actual market terms, and maps these preference (connectivity) clusters for use in local/regional spatial planning instrumentation (protected area and municipal plans), i.e., geodata tool (geo-visualisation).

Keywords: landscape consumption, spatio-market planning, tourism flow, geodata, connectivity clusters, high-altitude areas, protected areas, spatial planning instrumentation

Connection to biodiversity conservation, connectivity, and restoration

The methodology has formative and comparative implementation in high-altitude mountain and protected areas in the Alps, namely, with regards to conservation and area connectivity. The impact of visitors along the trails is assessed by an impact indicator, i.e., through the aggregation of the multiple frequency POIs into multiple frequency unit areas (localized grid). As an ultimate result, the indicator 'Impact Density of Tourism Flow', equals the number of medium/high frequency unit areas per particular high-altitude area (total area). The geo-visualization of this indicator acts as a management tool to identify medium/high frequency unit areas for monitoring the tourism flow. The latter is mentioned in terms of unit areas, not POIs – because within each of the unit areas, there might be several medium/high frequency POIs, where only one POI (highest frequency) will be used as a monitoring point to avoid any visitor double-counts. Thus, the monitoring would occur based on both the patterns of the POIs inside each unit area and the unit areas across a particular high-altitude mountain and protected areas – while factoring in the geodiversity (characteristics) of the landscape as a unique offering identified at the POIs level (competitive advantage/economy of difference).

Policy implications

The monitoring of tourism flow through the implementation of the spatio-market methodology and the use of the indicator: 'Impact Density of Tourism Flow' – directly facilitates the cooperation between the supralocal stakeholders: nature protection and tourism associations, and businesses, municipalities, etc. The identified and quantified POIs and unit areas are associated with the Sustainable Tourism Management policy in the study-area, namely, nature conservation, beyond the approach based on the accommodation facilities and/or transport links in the bordering valleys/municipalities. Hence, nature conservation is 1 out of 15 key issue areas addressed by the Sustainable Tourism Observatory of South Tyrol, part of the data-driven long-term UNWTO-INSTO International Network of Sustainable Tourism Observatories. Moreover, this policy is aligned with the Alpine Convention's Tourism protocol, Article 8 on Controlling Tourists Flows, particularly in protected areas, and ALPARC's Alpine Parks 2030, recommendation 10 on Direct and Concentrate Touristic Impact.

Climate change and the Alpine quality of life: questioning the status quo of spatial planning in the Alps and its functionality to tackle long-term water security

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The (peri-)Alpine population is steadily increasing, as are the overall mean temperatures, and with it the use of vital resources such as water. With locally decreasing drinking water levels locally increasing flood risks and generally changing water thresholds in the Alpine region, it is a prime example of how climate change is affecting the landscape and life in it. Looking at the UN Sustainable Development Goals Nr. 2, 6, 13 and 15, changes in landscape use and management are deemed necessary to ensure and secure a certain quality of life. The current state of the art in spatial planning for water protection centres on issues of climate adaptation and landscape protection. Research on spatial planning and water management in Europe exists mainly with a focus on the Netherlands (cf. de Vriew & Wolsink 2009; Hendriks & Buntsma 2009), presenting a great range of best practice of how the two sectors can be intertwined, or focuses on rather politically generated frameworks, such as the EU Water Framework Directive (cf. Moss 2012; Carter 2007; Liefferink et al. 2011), that target mainly policy-makers and views spatial planning and water management more from a generalized perspective. A specific focus on the Alpine Convention perimeter is yet to be done, as this space serves as the major water supplier for the whole Alpine and fringe areas bordering north and south of the Alpine Convention area. Therefore we pose the following three research questions: How do spatial planning systems within the Alpine space deal with water management and landscape protection? Do we need a different perspective for spatial planning to tackle water security following a concept of monofunctionally used *central* open spaces in the Alps? How effective are spatial planning systems across the Alpine states already in dealing with land use conflicts about water availability and further landscape developments? To answer the research questions, we first conduct a thorough literature review trying to define how *open spaces* in the Alps can be defined and how they serve water management as an instrument of spatial planning. To find out where those *open spaces for water protection* should be and how they are challenged by landscape and climatic developments will be analysed using GIS. In order to understand the functionality of existing spatial planning instruments for water protection, we conduct expert interviews with local stakeholders to gain further perspectives on different regions and spatial planning systems. What we expect to achieve is a systematic and quantitative overview of the existing literature on open spaces, as well as spatial planning and water management within the EUSALP perimeter. We aim to get a first overview of the definition for open spaces and their service for landscape and water protection. We will carry out initial GIS analyses and produce maps from them that represent key data and developments of the existing water resources, putting it into perspective with our initially gained results. Building on this, further results are to be obtained in order to further develop and review the *concept of central open spaces* with the help of instrument analyses and qualitative interviews.

Keywords: climate change, Alpine water security, spatial planning, biodiversity, threats

Connection to biodiversity conservation, connectivity, and restoration

This research aims to contribute to biodiversity conservation. With protecting water bodies, monitoring glacier development and other cryosphere-related habitats in the context of climate change, budgeting and planning water usage (e.g. in form of hydropower stations, cooling systems for businesses e.g. in the Po Valley, and drinking water supply across all Alpine areas, as well as water's climate regulating functions) is a key aspect in guaranteeing the safety and quality of life in the Alpine states.

Policy implications

The research could be used in spatial planning policies, highlighting the need for spatial planning itself and the need for changes regarding landscape water use in the face of climate change. The way in which directives, instruments and frameworks with the aim of landscape protection function can be integrated into the often existing multi-level governance systems within spatial planning. However, the main added value lies in the potentially new perspective of open space functions on a potential effectiveness of monofunctionality. This might enhance stricter processing of land use conflicts giving priority to biodiversity goals.

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ECOSYSTEM SERVICES & CONNECTIVITY

CHAIR: DANIELA RIBEIRO

Microplastics contamination in high mountain lakes – the case of Triglav National Park

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Microplastics (MP) have been found in all environments. However, its presence is less studied in environments that are more distant from the influence of human activities, such as high mountain areas. The objective of this study is to investigate the presence and concentrations of MP particles in high mountain lakes, specifically in Dvojno jezero (Double Lake) and Veliko jezero (Large Lake) in the Triglav National Park. In Slovenia, numerous studies have already been conducted on the presence of MPs in different environments – rivers (in freshwater fish, Bogdan et al. 2022), lakes (e.g. Lake Bled, Centa 2016), drinking water (Centa 2016) and even hail (Kozjek et al. 2023). Surprisingly, no study or research has yet been conducted on MP contamination of Slovenian high mountain ecosystems. Given this research gap, the aim and objective of this research was to determine whether MP particles are present in two high mountain lakes - the Double and the Large Lake in the Triglav National Park and to assess their quantity and type. Can we identify MPs in Alpine lakes? The research is based on the analysis of MP presence in (i) sediment samples from the coastal zones of both lakes and (ii) digestive tracts samples of arctic charr (*Salvelinus alpinus* Linnaeus) caught in Double Lake. MP were extracted from sediment samples by first drying them for 14 days at a temperature of 40°C. From the dried samples, 10 g of dry sediment was taken, sieved through 125 µm sieves into glass containers, and organic matter was removed using a wet oxidative digestion method, i.e. by adding a 30% H_2O_2 solution to the sample, which was heated and stirred at a specific temperature and stirring speed. To isolate the MP, a density separation method was used by adding $ZnCl_2$ to the samples, causing polymers with low density to float while denser particles settled. After 72 hours, the supernatant water from the samples was filtered using vacuum filtration to obtain the extracted MPs. We attempted to extract MPs from fish digestive tracts through the chemical breakdown of organic material in three ways: alkaline degradation, Fenton reaction, and enzymatic reaction. However, we encountered difficulties due to incompletely removed organic substances that could interfere with further analysis. Therefore, we did not proceed with the analysis of the remaining digestive tracts. As an exception, in one case, we successfully obtained results using the enzymatic method, and particles were further analyzed. MP identification was performed using two methods: (i) stereomicroscopy – extracted MP particles were examined using the Leica DMS 1000 digital stereomicroscope, and their colour and length were analyzed with Leica Application Suite software, and (ii) the chemical composition (identification) of the particles was determined using FT-IR spectroscopy. 12 MP particles were identified in sediment samples from both lakes, 10 particles in the sediment of Double Lake and 2 particles in the sediment of Large Lake. The predominant form of MP were fibres (5) and films (4 particles), 2 fragments and one pellet were also found. The fibres suggest their origin from textiles, while the films, fragments, and pellets indicate plastic packaging materials (such as foil and plastic bottles). The colour of MP fibres from Double Lake was mostly blue. The average length of MP fibres was 3.00 mm (long fibres), suggesting that the sources of these particles could be locally generated. The stereomicroscopic analysis of particles from the fish digestive tracts discovered 3 fibres, whereas the chemical analysis (FT-IR spectroscopy) showed that they were all of natural origin. Chemical analysis was performed on all particles identified by stereomicroscopy in the sediments. However, due to the small size of the particles, we were not able to determine the composition of the fragments, films, and 18 fibres, even after repeated attempts using FT-IR spectroscopy. The fibre analysis revealed that detected fibres in Double Lake had both cellulose and semi-synthetic (rayon) origins and the fibres in Large Lake were of cellulose origin. The composition of a larger portion of fibres could not be analyzed (undetermined source: 40% from Double Lake, 60% from Large Lake). The pellet from Double Lake was identified as polypropylene (PP).

Keywords: microplastics, mountain lakes, sediments, arctic charr (*Salvelinus alpinus* Linnaeus), stereomicroscopy, FT-IR spectroscopy, Julian Alps, Slovenia

Connection to biodiversity conservation, connectivity, and restoration

The study shows the occurrence of microplastic in two mountain lakes in the Julian Alps. The area is heavily polluted by visitors. One of the lakes is not only heavily polluted by microplastic, but also by historical mistakes, such as the introduction of species that were not part of the original ecosystem. Future measures aimed at restoring the ecosystem to a good condition are of great importance.

Policy implications

It can be used as one of the data showing the current state of the respective ecosystem, which obviously needs measures to improve it.

Priority ecological connectivity areas for spatial planning interventions – an in-depth analysis of a potential ecological network and of human barriers in the EUSALP area

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Ecological connectivity (EC) plays a fundamental role for the protection of biodiversity, but regional administrations have not yet fully and adequately included ecological network concepts in Alpine spatial planning systems. Harmonization problems arise at national and regional borders. The Econnect project (2011) devised a functional model with target species within the Alpine Convention area to respond to the demand for cross-border actions. Several studies then identified the main structural ecological connectivity of many parts of the Alps (Ferretti & Pomarico 2013; Staccione et al. 2022). The first structural connectivity model for the whole EUSALP area was developed in the AlpBioNet2030 project (2019) but without addressing specific interventions for improvement and intervention priorities for spatial and landscape planning purposes. The main research question is: How can more detailed priority areas for ecological connectivity that are useful for spatial planning purposes be identified on a pan-Alpine scale? Consequently, which linkages contribute most to the coherence of the overall ecological network? Which of these are at risk by urbanization?

A pan-Alpine ecological network scenario based on studies of Plassmann et al. (2019) was set up using least-cost paths. To prove their plausibility, they were cross-checked with existing national and regional connectivity concepts. The network model permitted investigating the centrality of linkages, the minimum spanning tree, bottlenecks, and barriers. This allowed elaborating more detailed intervention priorities with GIS, based on the importance of the linkage for network coherency and the risk of them getting lost, which was missing before. Results show that 8.1% of areas with the lowest anthropogenic pressure in the Alps (ecological conservation areas) are not protected and most of them occur in Switzerland. 953 potential ecological linkages were mapped, of which 640 linkages fulfil criteria for creating a coherent network. One third of these linkages are passing through bottlenecks caused by urbanization and thus are at risk of getting lost. In total, 150 motorway barriers were identified, most of them in France, Germany, and Austria. More than half of the potential linkages are passing through areas of intensive agriculture, with the most problematic situations in the Po Valley and in Lower Austria. To date, only ten linkages have been seriously impaired by solar panel fields, but 194 are already affected by this upcoming barrier.

Keywords: ecological connectivity, priority areas, spatial planning, GIS model, Alps

Connection to biodiversity conservation, connectivity, and restoration

The devised GIS model contributes to identifying the most important areas for general ecological landscape connectivity in the Alps and uses a structural approach that avoids the selection of target species. The general assumption for identifying these areas is that the absence of human activities has a positive effect on landscape permeability for wildlife. The study seeks to determine potential ecological linkages between areas with the lowest anthropogenic pressure in the Alps, searching for the shortest paths with the fewest and weakest anthropogenic barriers, and which can therefore be restored with the least effort. This can contribute to developing recommendations for spatial planning practices to counteract landscape fragmentation. The study could also contribute to reaching the goal of protecting 30% of the EU's land area through the identified ecological conservation areas that still need a protection.

Policy implications

Regional and national spatial planning administrations can use the model for cross-border ecological network harmonization actions and for realizing interventions to implement a coherent ecological network in the Alps. The identified bottlenecks caused by settlement development should in any case be protected by spatial planning offices through regional and municipal development programmes and landscape plans, as well as by land use plans at local level. The identified 170 linkages, which are important for the network coherence and at the same time are threatened by urbanization, should have the highest priority for spatial and landscape planning offices. Administrations like transport infrastructure offices should focus on overcoming motorway barriers on linkages which are identified as important for the network coherency. They can dismantle motorway barriers or guarantee the permeability for wildlife species when it comes to, for instance, new transport infrastructure.

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Can the concept of ecosystem services help in the management of protected areas?

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The management of protected areas (PAs) can often be contentious, and it has been suggested that applying the Ecosystem Services (ES) lens may help. The aim of the NatGuidES project – i*dentification, assessment and mapping of ecosystem services in valuable nature conservation areas in Slovenia* – was to develop a protocol for mapping and assessing ES in Slovenian PAs. PAs are an important tool in nature conservation and increasingly the concept of ES has been included in conservation efforts to garner political support, aid expert decisions and planning, and address conflicts. Its capacity for bridging different disciplines is still seen as key. However, practical applications are still lagging due to issues with standardized classifications, indicators, as well as ethical misgivings and differences in common understandings of the concept among different stakeholders and experts. Who are the main stakeholders influencing the use and provision of ES in Logar Valley Landscape Park and a similar non-protected area (Matkov kot)? Which ES are used by them or influence their provision? Which ES are considered important in which area? Researchers explored stakeholder roles through interviews, conversations, workshops, surveys, and field visits in Logar Valley Landscape Park as a pilot area and Matkov kot as a reference area (without PA status). Nine types of stakeholders influencing the availability of ESs and 11 types benefitting directly or indirectly from ESs were identified. The stakeholders with the greatest impact on the availability of ESs in the PA were district foresters and landowners; the most prominent beneficiaries include landowners, visitors, tourist workers, and the park manager. While the ES selected as important and their associated beneficiaries and *providers* were similar, there were some differences. Notably, the PA demonstrated a slightly stronger emphasis on provisioning ES (wood and water) and especially cultural ES (recreation/tourism). Results for regulating ES were mixed, with somewhat more importance in the reference area.

Keywords: ecosystem services, protected areas, stakeholders, mapping and assessment, management

Connection to biodiversity conservation, connectivity, and restoration

This research relates to the selected topics indirectly by addressing how people engage with nature and which competing uses of nature appear in the same space. Understanding the relationships between people with regard to the use of natural resources is important to address these competing interests.

Policy implications

The research could help in improving conservation and land-use policies by improving the inclusivity of the governance of natural resources. It could be used both in achieving consensus at higher levels of governance (EU, national) and garnering support for local management plans from landowners and other stakeholders.

Finding open spaces: a consensus-based mapping for Swiss mountain regions

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As mountain areas experience a proliferation of tourism, transportation, energy, and agricultural development, the need to manage landscape fragmentation and maintain aesthetic qualities becomes ever more important. This research presents a novel methodological framework that engages experts in a collaborative consensus-building process to map these remaining open spaces in mountain environments. Previous mapping efforts have primarily utilized qualitative methods, expert-based factor identification, or quantitative approaches focusing on physical landscape attributes. However, these methods have limitations in terms of scalability and/or in capturing the nuanced definition and nature of the open space concept. Our study aims to fill this gap by combining qualitative and quantitative methods, leveraging machine learning to integrate broad expert knowledge for more comprehensive open spaces mapping. Given the broad and multifaceted nature of the concept of open spaces, particularly in mountain regions, this study seeks to explore the integration of quantitative data and expert perceptions to develop a nuanced understanding and mapping of open spaces. Our innovative approach combines the strengths of a Delphi survey, which elicits expert knowledge and facilitates consensus-building, with machine learning techniques to develop a shared and legitimized delineation of open spaces, which recognizes the multiple qualities that characterize these regions. This methodology aims to capture both physical attributes and subjective expert perceptions. The study demonstrates that the Delphi approach, with its iterative process of knowledge (de)construction, facilitates a collective and shared understanding of open spaces and their delineation in the landscape. The incorporation of the survey findings into the machine learning process led to a robust prediction over the entire study area, providing a new open spaces map of Swiss mountain regions. This outcome offers a robust and legitimized tool for the sustainable management of mountain regions. Indeed, by incorporating diverse expert perspectives, this participatory process and the resulting map not only improve understanding, but also foster acceptance of future land-use planning decisions.

Keywords: open spaces, mountains, machine learning, Switzerland, Delphi

Connection to biodiversity conservation, connectivity, and restoration

This research indirectly contributes to topics of biodiversity conservation, connectivity, and restoration. By accurately mapping open spaces in Swiss mountain regions, we facilitate the identification of areas that are largely unaffected by human influence and others where the landscape is shaped by infrastructure and impactful land uses. Thus, while the primary focus is on mapping, the implications of this research extend to supporting broader environmental conservation and restoration goals.

Policy implications

This research is important for the design of public policies that address the complex balance between development and conservation. This novel map offers a basis for land-use planning in Swiss mountain regions and provides empirical insights into the delineation of open spaces. It offers additional knowledge for approaching the construction of renewable energy infrastructure, an issue of growing importance. This refined approach helps to identify areas where conservation efforts are most needed and where development can occur with minimal environmental impact, thus ensuring sustainable management of mountain landscapes.

POSTER SESSION

Detection of forest stress from European spruce bark beetle attack in northern Italy through remote sensing techniques

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Animal communities and their habitats are shaped by different biotic and abiotic factors and processes. Habitats vary in shape and size, ranging from micro- to mega-habitats, in which biota, landscape features and geomorphic processes interact and influence animal ecology on different spatial scales. Besides providing habitat and refugia, micro-topography and landforms impact on behaviours crucial for population survival, including foraging, movement, dispersal, breeding, and resting. Large carnivores require extensive home ranges with good habitat connectivity for dispersal and gene flow within and between different populations. Consequently, most studies on their habitat use, habitat suitability, or habitat connectivity modelling focus on large-scale spatial analyses (e.g. large natural areas or even continents). Such models usually also include environmental covariates, with topographic covariates often limited to general terrain characteristics, such as elevation, ruggedness, and slope. Therefore, large-scale studies usually do not consider the effects of micro-habitat characteristics and different landforms. Previous research showed that felids, such as cougars (*Puma concolor*), lions (*Panthera leo*), leopards (*Panthera pardus*), snow leopards (*Panthera uncia*) and Eurasian lynx (*Lynx lynx*), are attracted to rugged and inaccessible terrain, rocky areas, ridges, and conspicuous landforms. However, these studies have mostly relied on low-resolution data, field mapped and/or digitized landforms, which is time-consuming and costly, resulting in low accuracy and poor data quality. With the development of advanced remote sensing technologies, high-resolution data, such as LiDAR-based digital terrain models (DTM), are now more widely available and, in combination with various (semi-)automatic methods, enable non-contact, cost-effective and accurate mapping of large, remote, and densely forested areas. To investigate the impact of karstic landforms and other abiotic micro-habitat characteristics on Eurasian lynx (hereafter lynx) habitat selection on a micro-scale, we used LiDAR-based DTM with 1 m × 1 m cell resolution. Specifically, in combination with GPS telemetry data, we assessed the selection of karst depressions, rocky outcrops, and other terrain characteristics identified using remote sensing techniques. The use of high-resolution DTM enabled us to detect a very large number (>1 million) of studied landforms to confirm that lynx select the vicinity of karst depressions and also regularly kill ungulate prey near these features (> 50% of prey within or in close proximity to depressions). We also confirmed that lynx select rocky outcrops, steep, rugged, and rocky areas, which is more pronounced for day-resting sites. In addition, we observed a functional response in the selection of rocky and rugged areas, as lynx selection of such habitats increased with their lower availability, while no such response was observed in the selection of rocky outcrops. These results highlight the advantages of integrating remote sensing techniques into ecology and show that landforms and abiotic micro-habitat characteristics can play an important role in certain lynx behaviours. Findings can help to improve the management and conservation of this endangered species and show that the protection of geomorphological features (geodiversity) is crucial for biodiversity conservation.

Keywords: European spruce bark beetle, sentinel-2, remote sensing, forestry, NDVI

‘I need this water as a driving force’ Introduction of hydro-electric infrastructure in the villages below the Karawanks, 1904–1908

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At the beginning of the 20th century, the question of broader electrification became a pressing issue throughout the Austro-Hungarian Monarchy, with the utilization of hydropower of Alpine rivers taking centre stage. In the context of increased public debate and the ongoing nationwide electrification campaign, the question of wider electrification also became a burning issue in the Carniola region in present-day Slovenia. However, the use of the water potential of Alpine rivers triggered conflicts between local, regional, and national stakeholders. The existing literature deals with the development of hydropower and the introduction of electricity in the Austrian part of the Dual Monarchy and specifically with hydropower in the Austrian Alps between 1873 and 1918. The works on the development of hydropower infrastructure in the territory of present-day Slovenia were mostly published by experts in hydropower, with some exceptions from the field of historiography. The authors focus on the electrification process and the construction of hydropower plants, mainly from a technical point of view, leaving out the role of the local population in the discourse surrounding the construction of hydropower plants. In the course of obtaining the necessary water rights and acquiring the ownership rights to the land required for the construction of the hydropower infrastructure, complications and conflicts arose, including with the local population. By answering the question of what the reasons for the resistance of the local population to the construction of hydropower infrastructure were, the poster deals with the social aspects of hydropower and aims to shed light on subaltern agency in the construction of hydro-infrastructure on the Završnica stream in the Carniola region. Focusing on the involvement of local actors in the construction of new infrastructure in Carniola, the chosen research method was an analysis of archival sources. These consisted mainly of letters and reports from the local population living in the villages at the foot of the Karawanks in the Carniola region. The analysis of the preserved archival sources reveals the local perspectives on the new hydropower infrastructure. At the beginning of the 20th century, the main party interested in using the water power of the Završnica stream to generate electricity was the Ganz et. Co. machine factory from Leobersdorf (Austria). When concluding the purchase agreements for the water rights and the land, the factory was confronted with opposition to the project from the local population. An analysis of the archival sources shows that the resistance to the construction was based, on the one hand, on a lack of knowledge about the hydroelectric infrastructure, as most of the peripheral areas of the Carniola region were not yet electrified and the inhabitants of the villages were unaware of the advantages and disadvantages of the new infrastructure. On the other hand, the resistance to the hydropower plant can be linked to the different interests in the use of water resources, as the locals needed the stream’s water power to operate facilities such as mills and as drinking water for themselves and their livestock.

Keywords: water power, hydroelectric system, Karawanks, Završnica stream, Carniola (1904–1908)

Footprints in the Julian Alps: identifying hiking hotspots

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The numerous positive effects of hiking and the experiential quality of the natural environment encourage an increase in the number of hikers (Higham et al. 2015). Despite several counters established in Triglav National Park, there is no monitoring of visitors in the Julian Alps. In this study, we identify visitor concentrations at hotspots in the Julian Alps based on spatial analysis with Strava data. More crowded areas are often referred to as hotspots due to their high visitor numbers (Jacobsen et al. 2019; Schirpke et al. 2018). Hotspots tend to attract large numbers of visitors and the term implies that popularity is not always desirable if you want a good recreational experience, as increased visitor numbers can lead to negative impacts and overcrowding (Jacobsten et al. 2019, Kohlhard et al. 2017). The increasing concentration of visitors and the rising number of accidents in the mountains underline the importance of addressing the issue of hiking also in the Slovenian Alps (Statistics… 2024), where it has not yet been comprehensively addressed. This study fills the research gap with a methodological contribution to the identification of areas with higher visitation rates, so-called hotspots. Where are the hiking hotspots in the Julian Alps? The aim of this study is to identify the areas with higher visitation rates or hiking hotspots in the Julian Alps. The hotspots are identified through a spatial analysis based on Strava data. We used data on the activity of hikers in the Julian Alps by analyzing user-generated data from Strava. We examined the frequency and popularity of hiking routes based on the number of recorded activities for the Julian Alps area with spatial hotspot analysis using ArcGIS Pro. The data was verified by comparison with additional sources. We collected data from the counters in the Triglav National Park and compared it with Strava data. The data obtained from Strava was interpreted to identify hiking hotspots in the Julian Alps. The result of the spatial analysis is a heat map of hiking activity in the Julian Alps. We have identified clusters of popular routes and highlighted the respective peaks. This is a relatively new and innovative approach to monitoring outdoor recreation visitor numbers, which is why we obtained control point data from other sources. We analyzed the accuracy of the data and the possibility of using the database in further studies of outdoor recreation with a focus on hiking. The application of this type of method represents a methodological contribution to the study of outdoor recreation and is at the same time the first attempt to determine hiking visits at the Slovenian level.

Keywords: hiking, visitation rates, GPS tracking, natural areas, spatio-temporal pattern

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Second homes and resilient communities in Alpine resorts – A geographical approach to multi-local inhabitant footprints in France, Switzerland, Italy, Austria and Slovenia

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This doctoral research aims to characterize the use of second homes and to identify public responses to support sustainable living conditions in resort communities that are facing great tourism intensity and real estate pressure. Many municipalities subject to high seasonal tourism intensity are faced with the challenge of maintaining a year-round population with a binary paradigm opposing permanent and second homeowners (Hall & Müller 2004). Tourism functions predispose municipalities to a greater or lesser extent to accommodate permanent, seasonal, and secondary residents that are difficult to distinguish through censuses due to multi-local dwelling patterns (Elmi & Perlik 2011; Back 2020). An empirical approach in the context of Alpine resorts has been little studied which is why this research has been implemented. What is the inhabitant footprint of second home owners? What are the factors and levers that strengthen living conditions of local life with a high level of tourism intensity? To what extent can the use of second homes and public action contribute to year-round living in Alpine resorts? The PhD study is based on eight case studies of Alpine resorts (Les Belleville, Montvalezan, La Clusaz, Les Deux Alpes, Nendaz, Kitzbühel, Alta Badia, Kranjska Gora) that are very attractive to tourists. We carried out mapping analyses, a survey of secondary residents (1,178 respondents), statistical analyses, and interviews (115). Secondary residents can have greatly differing profiles and residential practices. A small proportion of secondary residents are intermittent inhabitants who contribute to the year-round life dynamics of the resort communities, and some have become permanent residents over time. The occupancy rate of a second home depends on the characteristics of the owners, the accommodation, and the Alpine resort. Incentive policies can contribute to a better occupancy rate. The presence of jobs and services throughout the year in the resort seems to be a determining factor in mitigating the seasonal effect, as much as ensuring a supply of accommodation for permanent use. The research suggests various recommendations depending on the characteristics of mountain resorts.

Keywords: second homes, Alpine resorts, public responses, year-round living, inhabitants' footprints, multilocality, housing

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The potential of OpenStreetMap for proactive, digital visitor guidance in ecologically sensitive areas

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In the realm of digital outdoor and sports platforms like Komoot, Strava, and Outdooractive, OpenStreetMap (OSM) serves as the base map, crafted and updated by a volunteer community. This research delves into leveraging OSM modifications, to guide visitors effectively in Donau-Auen National Park. In recent years, digital visitor guidance has gained in importance as technology gradually becomes an integrated part of outdoor recreation, using tools like navigation and way-finding (Taczanowska 2023; Horst et al. 2023). There is little research on adapting digital tools like OpenStreetMap for managing visitor access in sensitive ecological zones. This creates a gap in effectively using digital platforms for sustainable environmental management. How can modifications to the community-driven OpenStreetMap effectively guide visitors through ecologically sensitive areas, considering its widespread use as the base map on various outdoor and navigation platforms? Direct editing of OSM through the OSM editor, beginning in 2023, constitutes the implementation strategy. Evaluation of these modifications' efficacy relies on analyzing movement data from outdoor apps. The objective is to determine whether these adjustments aid in successful visitor management and the conservation of sensitive natural areas. Analysis of movement data reveals a decline in unauthorized movement within Donau-Auen National Park in recent years. Biking on permitted paths increased from 79.6% in 2019 to 89.8% in 2023, after the first proactive editing. Hiking and running on official trails rose from 94.9% to 96.2%. Discussion: Next to monitoring OSM content, it would be advisable to observe other possible influencing factors, such as changes in signage on-sight, information campaigns for visitors, or NP ranger activities. Additionally, regular surveys of visitors' awareness of NP regulations and behaviour would complement our research.

Keywords: protected areas, visitor management, outdoor navigation, OpenStreetMap, recreation

Connection to biodiversity conservation, connectivity, and restoration

This research contributes to the theme of biodiversity conservation. By focusing on the modification of OpenStreetMap (OSM) to display only officially designated paths in ecologically sensitive areas like Donau-Auen National Park, it addresses the critical need for sustainable visitor management in protected natural environments. The advancements in digital visitor guidance, as reflected in this research, show a proactive approach towards minimizing human impact on biodiversity. The implementation of OSM modifications and subsequent analysis of movement data from outdoor apps indicate a reduction in unauthorized access to sensitive areas. This approach helps in preserving the natural habitat and biodiversity by directing visitors away from vulnerable regions and towards designated paths, reducing the likelihood of disturbance to wildlife and sensitive ecosystems. The increase in adherence to permitted paths, as evidenced by the movement data, underscores the effectiveness of digital tools in enhancing biodiversity conservation efforts.

Policy implications

This contribution can inform public policies focused on environmental conservation and sustainable tourism. It showcases how digital tools like OpenStreetMap can effectively manage visitor access in ecologically sensitive areas. The findings can guide the development of policies that integrate digital navigation and mapping tools for real-time monitoring and management of visitor movements in places like Donau-Auen National Park. Such policies could help balance tourism activities with environmental conservation, ensuring protection of sensitive ecosystems while allowing responsible recreation. The research can also underscore the need for policies to ensure that digital mapping tools accurately reflect official trail regulations and environmental restrictions to prevent unauthorized access to protected areas. This approach can significantly aid in biodiversity conservation and habitat protection.

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Plant communities of mountain pastures in the Berchtesgaden region

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Due to its geography and cultural history, the Berchtesgadener Land Biosphere Region encompasses large areas of mountain pastures. Plant community types are an important basis for balancing productivity and biodiversity in the face of climate warming. Alpine pastures include many rare plant species that respond to natural site conditions, such as climate and bedrock geology, as well as anthropogenic interferences, like grazing and fertilization, resulting in a diverse mosaic of ecosystems. Information about plant communities of Alpine pastures in the region is currently scattered across several vegetation databases. In the course of a field experiment comparing different management strategies with regard to climate change, new vegetation data were gathered on eight pastures (see also extended abstract of Panassiti et al.). A synthetic analysis of existing databases is required to identify natural and anthropogenic factors driving composition, diversity, and conservation value, and to assess the representativeness of the experimental plots for the biosphere regions. The following research questions were addressed: What are the distinct plant communities found within the mountain pastures of the Berchtesgaden region? How relevant are the plant species compositions of mountain pastures for nature conservation? How do site factors affect the establishment of the plant communities? Is the vegetation of experimental plots representative and are findings transferable to other pastures of the larger region? Eight mountain pastures were selected in the biosphere region, six of them located in Berchtesgaden National Park. Overall, 13 vegetation relevés were recorded on each pasture over the grazing season 2021. Two reference databases from the larger region were used to ordinate and classify the vegetation relevés and to investigate the relation between plant species composition and site factors. In total, 28 plant vegetation types were detected in the mountain pastures of the Berchtesgadener Land Biosphere Region. The most commonly found plant communities (alliances) were *Cynosurion, Seslerion albicantis, Nardion, Caricion ferrugineae, Adenostylion alliariae, Rumicion alpinae, Mesobromion erecti* and *Poion alpinae*. Alpine pastures are structured by gradients of thermal climate, soil moisture, and soil fertility, which is driven by bedrock and pasture management. Plants of protected biotopes are common at oligotrophic sites and in the periphery of pastures. Comprising both productive, mesotrophic (*Cynosurion*, 37%), as well as less productive, oligotrophic, pastures of acidic (*Nardion*, 25%) and calcareous sites (*Mesobromion*, 27%), the experimental pastures represent the vegetation of the biosphere region quite well.

Keywords: mountain pastures, plant communities, Berchtesgadener Land Biosphere Region, Northern Calcareous Alps

Connection to biodiversity conservation, connectivity, and restoration

The study describes the plant communities that occur on Alpine pastures in the Berchtesgadener Land Biosphere Region. This can support measures that help to preserve this large variety of plant communities.

Policy implications

The research helps local authorities (national park administration) and farmers to adjust pasture management to climate change.

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