Universität für Bodenkultur Wien
Department für Raum, Landschaft und Infrastruktur

Universität für Bodenkultur Wien
Department für Integrative Biologie und Biodiversitätsforschung

WSL

"Healthy Alps"

Alpine landscapes under global change:

Impacts of land-use change on regulating ecosystem services, biodiversity, human health and well-being

Final Report

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Authors and project members:

Thomas Frank, Johann Zaller, Ronnie Walcher, Raja Imran Hussain, David Brandl, Ines Jernej (Institute of Zoology, Department of Integrative Biology & Biodiversity Research, BOKU - University of Natural Resources and Life Sciences Vienna)

Kerstin Michel (Forest Ecology and Soil, Austrian Research Centre for Forests, BFW).

Leopold Sachslehner (Büro für Naturschutzpraxis und Forschung).

Arne Arnberger, Renate Eder, Brigitte Allex, Martin Ebenberger, Sarah Böhm (Department of Spatial-, Landscape-, and Infrastructure-Sciences, Institute of Landscape Development, Recreation and Conservation Planning, BOKU - University of Natural Resources and Life Sciences Vienna).

Hans-Peter Hutter, Peter Wallner, Georg Wanek (Public Health, Medical University of Vienna).

Nicole Bauer, Mathias Hofmann (WSL, Switzerland).

Andreas Bohner (Higher Federal and Agricultural Research Centre Raumberg-Gumpenstein, Austria)

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1. Introduction

Changes in agricultural practices and policies, low farm income and depopulation of rural areas have resulted in the abandonment of traditionally managed mountainous landscapes globally and across the Alps (Bürgi et al., 2010; Hersperger & Bürgi, 2010; Arnberger & Eder, 2011; Schönbrodt-Stitt et al., 2013). However, such historic landscapes, e.g. alpine pastures and meadows, harbour a high biodiversity (Boschi & Baur 2008; Tocco et al. 2013; Komac et al. 2014), attract tourists and may even positively influence human health. Today's western societies are faced with a growing incidence of poor health because of mental stress and sedentary lifestyles. Natural landscapes are increasingly seen as restorative settings, compensating for negative psycho-physiological effects on humans (e.g. Laumann et al., 2003; Hartig & Staats, 2006; van den Berg et al., 2010; Tyrväinen et al., 2014). The extent of these positive effects, however, may depend on the landscape quality. While previous landscape ecology research has documented the effects of the aforementioned landscape changes on biodiversity, restorative research on the link between human health/well-being and landscape has neglected the role of such mountainous landscapes for human health. Therefore, the ecosystem services of these landscapes cannot be fully considered in political decision making and in the design of agro-environmental, public health and nature conservation policies and measures. If cultural landscapes of biosphere reserves are specifically effective in providing restorative effects, then such benefits can be used for regional development by exploiting the natural-cultural capital for new health-related commercial offers in a sustainable way, thereby preserving such valuable historic landscapes.

Healthy Alps investigated for the first time possible linkages between cultural ecosystem services, biodiversity and regulating ecosystem services (pollinator activity, soil decomposition rate, greenhouse gas emission) and human health and well-being in mountainous landscapes.

1.1 Linkages between ecosystem services and biodiversity

Ecosystems provide services beneficial to mankind and human well-being. Biodiversity plays a key role as an underlying condition that is required for delivering ecosystem services, like provisioning services (e.g. fresh water, biological products) or regulating services (e.g. climate regulation, water flow regulation) (Millenium Ecosystem Assessment MA, 2003). But relating to cultural ecosystem services, little is known about the linkages between the (level of) biodiversity of a certain landscape type and its effects on human health and well-being (Keniger et al., 2013); nor it is evidenced whether there is a linkage at all. Restoration research has shown that natural environments achieve higher outcomes concerning the improvement of the psychological and physiological state of humans than urban or built environments (e.g. Ulrich et al., 1991; Parsons et al., 1998; Staats et al., 2003; van den Hartig & Staats, 2006; Lee et al. 2009; Berg et al., 2010; Tyrväinen et al., 2014; Wallner et al., 2018). In this context the impression and/or the experience of nature and natural elements were found to be important drivers for restoring the cognitive functions of humans (Berman et al., 2008, 2012; Berto, 2005; Kaplan & Kaplan, 1989) and their physical and mental health (Bratman et al., 2012; Keniger et al., 2013).

While there have been very few efforts investigating relationships between biodiversity and human health and well-being, there exists a pile of studies investigating relationships between biodiversity and landscape preferences of humans. These studies resulted in divergent findings. Qiu et al. (2013), for example, found that high biodiversity did not positively relate to landscape preferences as half-open park areas were preferred to areas of more complex vegetation. On the other hand, a greater aesthetic appreciation for more diverse plant communities were found elsewhere (Lindemann-Matthies et al. 2010a,b). Home et al. (2010) showed that people have a higher preference for more complex and ecologically diverse residential environments compared to tended lawns if they were considered as safe and were accessible to the public. Gobster et al. (2007) concluded that aesthetic preference of landscapes does not always relate positively to ecological quality, e.g. a neatly tended countryside may be considered beautiful but lacks in ecosystem health, while a biologically rich wetland may be seen as unattractive.

Surveys are rare, which clearly bring the degree of biodiversity of green spaces and their impact on human health and well-being together. Velarde et al. (2007) stated that only few studies exist that distinguish natural environments concerning biodiversity and their influence on human health and well-being. Moreover, only few studies tested the relationships between human health and well-being and natural environments with varying levels of biodiversity of one landscape type.

Most studies on relationships between biodiversity and human health and well-being were carried out in the urban context, often focussing on urban forests and urban parks. Martens et al. (2011), for example, investigated the effect on self-rated well-being after a walk through „wild“ (not managed for six years) and „tended“ (managed) forest conditions in a Swiss urban forest. Results indicate that well-being increases stronger in the silviculturally used forest stand than in the natural setting with relatively high amount of dead wood and undergrowth. In order to test the relation between ecological and psychological factors, Carrus et al. (2013) identified five different typologies of urban green space in Italy, ranging from minimum to maximum degree of naturalness. Perceived restorativeness increased significantly as a function of the level of naturalness. In another study focusing on psychological benefits and biodiversity (plant, butterfly and bird species richness) in urban green spaces, psychological benefits were shown to increase with the species richness of urban green spaces (Fuller et al., 2007). Both Carrus et al. (2013) and Fuller et al. (2007) used independent samples of participants.

Emotional and physiological responses to different states of biodiversity in temperate decidious broad-leaf peri-urban forests in Sweden were conducted by presenting images of biotopes with a low, an intermediate and a high degree of biodiversity, which differed in tree species composition and diversity of shrub and herb layer (Johansson et al., 2013). Although the participants had a rather correct perception of biodiversity levels, emotional appraisal showed a preference for an intermediate degree of biodiversity and higher brain activity for a low degree of biodiversity. Dallimer et al. (2012) investigated the relationship between actual plant, butterfly and bird species richness and the self-reported psychological well-being of urban green space visitors. Across all of the taxonomic groups, well-being was positively related to the participants´ perceived species richness. In contrast, when the relationship between actual species richness and measures of psychological well-being were quantified, there were no consistent patterns. Although well-being increased with higher levels of bird species richness, well-being declined with greater plant diversity, and there was no pattern with butterfly species richness.

Summarizing, few studies have analysed the relationships between biodiversity and human health and well-being. All of these studies were carried out in the urban context. Thus, effects of alpine landscapes on human health and well-being are unknown. In addition, most of these studies relied on independent samples of participants. However, dependent samples of participants, visiting all sites under investigation, allow for a more controlled comparison between the site effects. Several studies performed in the urban context measured only psychological effects, and not physiological effects. The studies correlating biodiversity and human health could not provide a clear picture. None of these studies used soundscapes as measures for biodiversity and recreational quality indicators, and biodiversity indicators were limited to few species, not integrating regulating ecosystem services delivered by cultural landscapes.

1.2 Study objectives and hypotheses

“Healthy Alps” investigated whether there are relationships between regulating services (pollinator activity, soil decomposition rate, greenhouse gas emission), biodiversity, and human health and well-being as well as cultural ecosystem services (recreational quality and landscape aesthetics), and whether these relationships are subject to land-use changes (Figure 1). “Healthy Alps” links ecosystem services, land-use changes and human health and well-being as a basis for the development of sustainable health-related tourism and recreational offers in cultural landscapes of biosphere reserves. These objectives were studied in alpine meadows differing in land-use intensities in two biosphere reserves and one LTER-site across the Austrian and Swiss Alps.

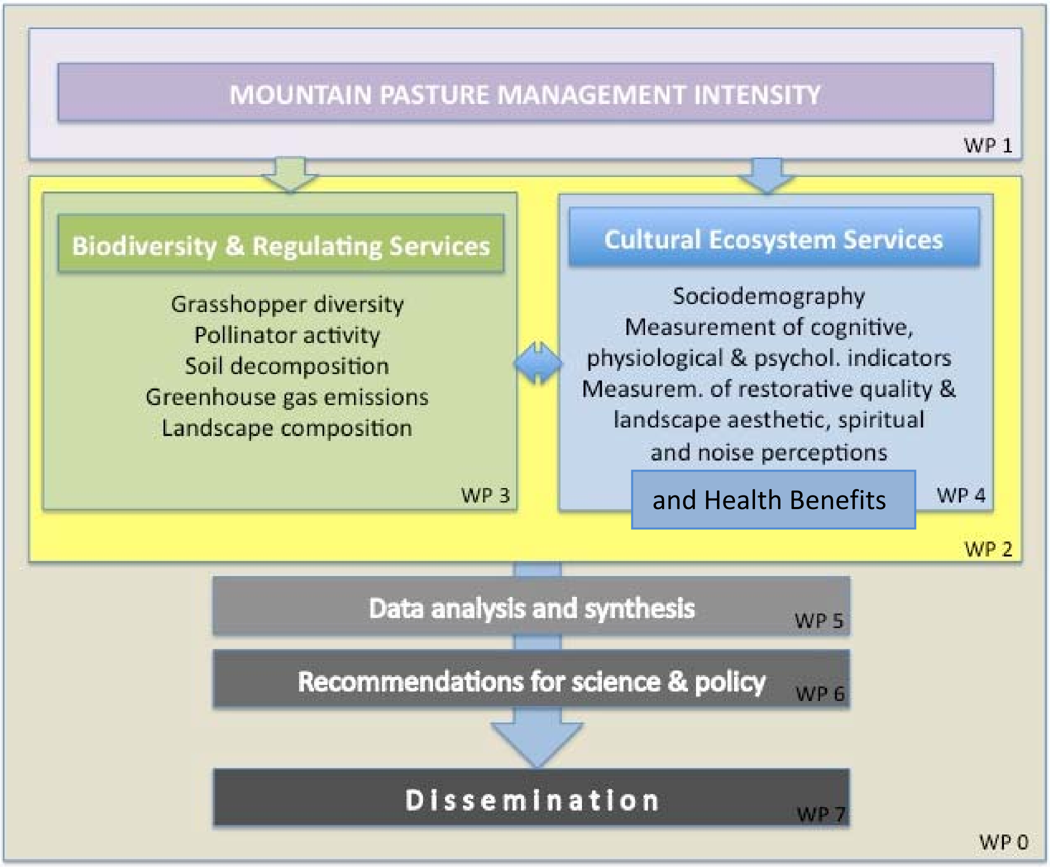

Figure 1. Conceptual model on how relationships between biodiversity and regulating ecosystem services will affect cultural ecosystem services and human health as assessed by the Healthy Alps project (WP refers to the project workpackages).

"Healthy Alps" specifically examined whether and to what extent

1) regulating ecosystem services, biodiversity, human health and well-being are connected,
2) land-use intensities and land-use abandonment of cultural landscapes have an impact on human health and whether these differently managed landscapes are perceived as restorative by visitors,
3) soundscapes are useful tools for measuring linkages between biodiversity and human health.

We hypothesized that

(i) there is a close positive correlation between regulating ecosystem services and human well-being and that more diverse meadows will receive a psycho-physiological appreciation by visitors than meadows with lower diversity,

(ii) a decrease in management intensity (i.e. from properly managed meadows to abandonment) and associated changes in landscape composition will result in a decrease in human health measures,

(iii) acustic surveys (soundscapes) are cost-effective tools to describe connections between different categories of ecosystem services (i.e. regulating vs. cultural ecosystem services).

Addressing these topics is urgently needed because biosphere reserves aim in being a role model for nature-based health-related offers. Unfortunately, information on restorative effects of landscape types such as alpine meadows subject to different level of land-use change is missing, while at the same time these traditionally managed meadows are disappearing. Demonstrating health effects resulting from a stay in biosphere landscapes will raise public awareness about the valuable natural-cultural capital of the area, which can assist in maintaining natural and historic-cultural landscapes and supporting the biosphere reserve idea. Findings may also support the role of a biosphere reserve for the well-being of its local residents and visitors.

2 Methods

2.1 Selection of study sites

Three study regions across the alpine range from Central Austria to Switzerland (Eisenwurzen LTSER-region, Großes Walsertal Biosphere Reserve, Val Müstair Biosphere Reserve (Switzerland)) were considered in the project. Within each study region 6 study sites were selected (3 abandoned and 3 extensively managed (mowed once a year, no fertilizer input) semi-dry meadows) measuring richness, abundance and species assemblages of wild bees (including bumble bees), hoverflies, grasshoppers and bugs leading to a total of 18 study sites. Furthermore, vegetation assessments within each study site were conducted and soil parameters (greenhouse gas emissions, decomposition rate) were measured. The study sites were selected in agreement with local land owners and tenants and according to a criteria list developed by the team members in several meetings. The list of criteria comprised management of meadows, field size, surrounding landscape composition, altitude, exposition, accessibility, parking lot for bus, distance from accommodation to study site, comparable access from bus parking lot to study site, similar views on the mountain landscapes.

For the assessment of human health effects, 8 study sites were needed. Two of the six alpine meadows per study region were selected representing two different levels of land-use: one extensively managed meadow per study region (in total 3 managed meadows) and one 1 abandoned meadow per study region (in total 3 abandoned meadows). All meadows had a similar accessibility within each study region. In addition, an urban, built up site was selected (Vienna) as a contrast to the alpine natural environments and as a reference for examining health effects. To contrast blue with grey (urban) and green spaces (meadows), a river (the Lutz River in the Großes Walsertal Biosphere Reserve) was added to the study site list.

The study sites were selected in the first months of the project from April to June 2015. According to a developed criteria list potential study sites within the three study regions were preselected based on analyses using web-based GIS-Data (DORIS, VOGIS, geo.admin.ch), printed maps and information provided by local stakeholders (e.g. Biosphere Reserve Management, land owners, forester, scientists).
The land owners were sufficiently informed about the objectives and aims of the project in short meetings. After permission to access the meadows was obtained by the land owners, the study sites were inspected on site on several days in April, May and June. Those sites which fulfilled the points of the criteria list were final-selected in the beginning of June 2015. The selection of the sites in the LTSER-region Eisenwurzen and in the Biosphere Reserve Großes Walsertal was conducted by team members of the Institute of Zoology (BOKU) and the Institute of Landscape Development, Recreation and Conservation Planning (BOKU). Support for selecting sites in LTSER-region Eisenwurzen was given by Dr. Andreas Bohner from the Higher Federal and Agricultural Research Centre Raumberg-Gumpenstein. Sites in Switzerland were selected by members of the WSL (Dr. Mathias Hofmann, Swiss Federal Institute for Forest, Snow and Landscape Research). Mathias Hofmann was supported for selecting the study sites by Jörg Clavadetscher, who works in the municipality Valchava (Val Müstair) as district forest ranger.

For achieving permission for collecting animals and plants within the three study regions local competent nature conservation authorities were contacted and informed about the aims and objectives of the project. The allowance to collect wild bees, hoverflies and bugs and the withdrawal of several plant species was achieved before starting the field work in June.

2.2 Measuring instruments and data collection

2.2.1 Measuring regulating ecosystem services and biodiversity

2.2.1.1 Methods used for measuring regulating ecosystem services and biodiversity

Before preparing measuring instruments a standardised measurement approach for animal and plant species richness and for measuring soil parameters (soil greenhouse gas emissions, decomposition rate) was defined and a list of tools was elaborated. The preparation of measuring instruments and elaborating a measurement plan allowed for a strict standardised comparison between the study sites.

Measuring instruments for assessing wild bees, hoverflies and bugs

Species richness and abundance of wild bees, hoverflies and bugs were assessed using sweep net method. Within each study site 90 sweeps were conducted approximately in the middle of each site along 3 transects. The sweep net had an opening diameter of 40 cm with a bar lenght of 1 m. Additionally a sweep net with opening diameter of 20 cm and a bar length of 1 m was used for single catches (wild bees and hoverflies). Collected insects were treated with acetic ether (killing fluid) and Formol ® to avoid mold formation.

The sweep net method was tested on several days in May 2015 in the surrounding of Vienna to get familiar with the method for optimal conduction during the field work.

Measuring instruments for assessing grasshoppers

Grasshopper species richness was measured by using soundscapes. Survey of grasshoppers was conducted by using 6 Olympus LS-12 studio record devices which are equipped with two integrated microphones at the front end of the device. Additionally a bat detector (Batbox III D) was linked to the record devices for enhancing signals of especially grasshopper species vocalising more silently and to achieve the record of these species in a certain way. Several adjustments on the devices were conducted previously to achieve an optimal recording result. Before applying this method in the field work, the devices were tested by subcontractor Dr. Leopold Sachslehner and PhD-student Ronnie Walcher on several days in June and July 2015 to figure out optimal conditions for the records.

Measuring instruments for greenhouse gas emissions

Greenhouse gas emissions were detected by the closed chamber method. Tools for measuring greenhouse gas emissions was provided by the sub-contractor Dr. Kerstin Michel from the Institute of Forest Ecology and Soil, Austrian Research Centre for Forests, (Austria). To get familiar with this method an introduction was given by Kerstin Michel and the method was tested on one day in May 2015 at the .

Measuring instruments for soil decomposition rate

The newly developed Tea Bag Index (TBI) was applied for measuring soil decomposition rate using commercially available tea bags. Two sorts of tea bags were used, green tea and rooibos tea. The tea bags consisted of synthetic material, so only the organic material in the tea bags was decomposed. Before the method was applied, literature about application of the TBI was sufficiently operated.

Assessing vegetation

The vegetation cover in the study sites was assessed by using a ceptometer (Sun Scan, Canopy Analysis System) which measures the Leaf Area Index (LAI). The ceptometer consists of the probe head equipped with light sensitive photodiodes and a connection to a measurement device.

2.2.1.2 On-site measurements of regulating ecosystem services and biodiversity

Investigation of indicators representing biodiversity and regulating ecosystem services of the 18 selected study sites. The investigations were carried out in June and August 2015 and 2016. Grasshoppers' soundscapes as measures for biodiversity have been used. Measures for ecosystem services were soil decomposition rate using the newly developed tea bag index, soil greenhouse gas (GHG) emissions, and pollinator activity (wild bees and social bees, hoverflies, butterflies).

Sampling dates

June 2015: LTSER-region Eisenwurzen: 8.-10.6., Großes Walsertal Biosphere Reserve: 30.6., Val Müstair Biosphere Reserve: 1.-2.7.

August 2015: LTSER-region Eisenwurzen: 24. and 27.8., Großes Walsertal Biosphere Reserve: 20.-21.8., Val Müstair Biosphere Reserve: 22.-23.8.

June 2016: LTSER-region Eisenwurzen: 8.6.,10.6., and 14.6.

August 2016: LTSER-region Eisenwurzen: 16.-18. 8.

Hereinafter the methods applied for measuring regulating ecosystem services and biodiversity are described in detail.

Data collection (wild bees (excluding bumble bees), hoverflies, bugs)

Species richness and abundance of wild bees, hoverflies and bugs were surveyed once in June and once in August 2015, and once in June and August 2016 in Eisenwurzen. Within each study site wild bees, hoverflies and bugs were recorded by sweep netting (Fig. 2) conducting 90 sweeps per study site. Moreover, four 2 m² plots for wild bees and hoverflies were observed each for 15 minutes counting and determining all individuals occurring within each observation plot. Sampling was only carried out at suitable weather conditions (dry vegetation, slight wind, temperature >20°C, sunshine) and approximately in the middle of each study site.

Bumblebees were observed on four 20 m² plots each for 15 minutes. The use of a field determination key for bumblebees made it possible to determine almost 80 % of individuals occurring in the field on species level. Prior to field work Ronnie Walcher visited a course for determination of bumblebees, given by Dr. Johann Neumayer. Additionally, field training was conducted on several days in April, May and June 2015.

Fig. 2. Sweep net used for bumblebee and bug collection (40cm opening diameter) with bar (bar length: 1m). Photo: © R. Walcher

Data collection (grasshoppers)

Grasshopper diversity expressed as number of species was surveyed once in August 2015 using record-devices (Olympus LS-12) recording grasshopper sound production. For signal enhancement, a bat detector (Batbox III D) was linked with the recorder. The recorders and the bat detectors were placed 80 cm above the soil surface on a self-made wooden platform (Fig. 3), which ensured to record grasshopper sound production in a range of 30-40 m. The sampling time ranged from 10 a.m. to 5 p.m. leading to a total recording time of 7 hours per study site. Sampling was carried out at dry weather conditions with temperatures above 20°C and only slight wind. The recorded grasshoppers are identified to species level by sub-contractor Dr. Leopold Sachslehner (Büro für Naturschutzpraxis und Forschung, Vienna) at his office. For a method comparison of record-devices with the transect method, grasshoppers were surveyed with both methods once in August 2016 in Eisenwurzen.

Fig. 3. Experimental setup for recording grasshopper sound production in a managed meadow in the Großes Walsertal (Austria). Photos: © R. Walcher

Measuring greenhouse gas emissions and soil parameters

Gas samples were taken once in June and once in August 2015 to gain an insight into the dynamics of greenhouse gases (GHG) CO_2, CH_4 and N_2O. Gas sampling was carried out by using the closed chamber method. The chambers (steel cylinders) were inserted 5 cm into the soil to gain a closed atmosphere in the chamber. Plants growing on the plots were removed before inserting the chamber into the soil. The chamber was closed after insertion and gas samples were taken using syringes at 0, 5, 15 and 30 minutes. The samples were injected into evacuated glass vials and stored in a cool place. Additionally the surrounding temperature, the soil temperature on three plots adjacent to the chamber and the temperature within the chamber was measured.
The concentration of the greenhouse gases was determined using a gas chromatograph equipped with a flame ionization detector (CO2, CH4) and an electron capture detector (N2O). Analysis of the gas samples was carried out at the BFW by the sub-contractor Kerstin Michel and members of the BFW. The usage of the closed chamber method was previously tested at the under supervision of the sub-contractor Kerstin Michel before applying the method in the field.
Within each study site approximately 0.5 kg soil samples were taken randomly. The analysis of the soil samples should provide insight into soil activity by analysing the amounts of functional groups (gram+ and gram- bacteria, fungi, mycorrhiza). The analysis of the soil samples was carried out at the BFW..

Vegetation assessment

Within each study site the vegetation was assessed on four randomly chosen 1 m² plots. The plants within each plot were determined at species level and ¼ of each plot was harvested to investigate the total above ground biomass, the composition of functional groups (proportion of graminoids, non-legume herbs, legumes) and the proportion of living biomass and necromass.

Soil decomposition rate

The soil decomposition rate was assessed between beginning of June and end of August 2015 , and beginning of June and mid-August 2016 in Eisenwurzen, using the newly developed tea bag index (TBI). This provides a well-standardised and cost-effective method to measure soil decomposition rate by using commercially available tea bags (rooibos and green tea). The tea bags were weighed before being buried in the soil. Within each study site 20 tea bags (10 rooibos tea and 10 green tea) were buried in the soil in a depth of 8 cm and left into the soil for about 50 to 80 days. In August the tea bags were excavated and weighed again. The weight loss of the tea bags is a measure of the soil decomposition activity. The acquired Tea Bag Index (TBI) consists of two parameters describing decomposition rate and litter stabilisation factor. In 2015, altogether 120 tea bags were buried within each study region (6 sites x 20 tea bags), and 160 tea bags were used in the study region Eisenwurzen in 2016.

2.2.2 Measuring cultural ecosystem services and health benefits

2.2.2.1 Methods used for measuring cultural ecosystem services and health benefits

Healthy Alps used a method-mix and relied on methods from different disciplines such as environmental psychology and recreation research to measure human health and well-being and cultural ecosystem services at the study sites. In a first step, a sampling design for a standardised measurement at all study sites was developed to survey effects on human health and well-being and cultural ecosystem services including a strict timetable to ensure the same procedure for each measurement day during the field trip. Tools for measuring cognitive (attention test), physiological (pulse and blood pressure) and psychological indicators (e.g. emotional well-being, psychological resilience) of human health and well-being were prepared.

A list of selection criteria for probands according to medical aspects ensuring a homogenous sample (e.g., age class, non-smokers, no disease influencing measurement results, like cardiac disease or low/high blood pressure) was developed. For the field trip, an energy-efficient touring coach was hired. Accommodations for 22 probands and the supervising team, specific transports within the areas, meals etc. were organized before the field trip. An exact route planning including bus parking opportunities was requested to be in time and to use routes which are accessible by a bus. All measurements devices were pretested.

Survey instruments proven in the fields of medicine, (environmental) psychology and recreation research were selected to measure the restorative effects of natural and urban study sites on human health and well-being. A short description of the used methods is given below.

Daily constitution („Tagesverfassung")
Each morning of the research expedition a questionnaire was handed out to the probands to record their constitution in order to avoid possible influences, which may affect the performance and the concentration measures and the medical tests (pulse and blood pressure). Participants evaluated their actual health state, mental and physical constitution and their mood, as well as the quality of their sleep in the previous night.

Health, noise and landscape perceptions
The psychological health benefits (i.e. attention restoration, stress relief and wellbeing) were assessed using single-item 5-point answer scales. Participants were asked whether their stay at the study site had restored their attention (1 = very well, 5 = not at all), reduced their stress level (1 = very well, 5 = not at all), and changed their psychological wellbeing (1 = improved, 3 = unchanged, 5 = declined).
The questionnaire addressed perceptions of the scenic beauty of the surrounding landscape and of the study site itself, sound perceptions and awareness of background sound, perceptions of naturalness and biodiversity, using 5-point answer scales. Landscape and site beauty were assessed by an answer scale which ranged from 1 = very high to 5 = very low. The answer scale of the perceived sound level ranged from 1 = quiet to 5 = very loud; perceived background sound ranged from 1 = very pleasant to 5 = very unpleasant. Participants had to rate the suitability of each site for recreation purposes (1 = very useful, 5 = absolutely not), and whether they

would revisit this site for recreational purposes on a scale ranging from 1 = definitely yes to 5 = definitely not.

The Perceived Restorativeness Scale (PRS; Hartig et al. 1997) was used to measure the perceived restorative quality of the study sites. The PRS consists of 16 items and measures four qualities of a restorative environment: being away, fascination, coherence and compatibility. These items were rated on a scale from one (I totally agree) to seven (I totally disagree). A tested German translation of the PRS was used and slightly adapted to the context of the study.

Emotional well-being

Emotional well-being was measured with the so called "Eigenzustand – Skala" (EZ) by Nitsch (1976). A short version of the Nitsch-scales with 27 items belonging to 5 factors (willingness to make an effort, mood, tenseness, fatigue, sleepiness) were administered to the subject four times per study site visits. The items were assessed on a 6-point scale ranging from 1 (hardly) to 6 (completely), negative items were recoded accordingly (leading to inverted scales for the factors fatigue and sleepiness). The measures took place before departure at 8:30 AM, [T1]. Participants arrived near the study site by bus, after a journey time between 25-30 minutes, and filled the scales again [T2]. On arriving at the study site, after an easy and 10-minute walk in flat terrain or a short shuttle transport of about 10 minutes, participants sat and observed the scenery for 15 minutes, after which they filled in the scales again [T3]. Participants then walked back to the bus and after returning to their accommodation by bus they filled the scales a fourth time [T4b]. The same procedure was used for the afternoon measurements at the meadows.

Blood Pressure and Pulse

Study sites were located in cultural landscapes across the alpine range, so that surveys were conducted outdoor and in rough terrain. These circumstances required measuring instruments easy to apply. To test physiological parameters of the cardiovascular system (pulse and blood pressure) in a practicable, full-automatic and non-invasive method self-inflating blood pressure cuffs (boso medlife S) were used. Pulse rate and blood pressure were measured four times per study site visit. Before departure at 8:30 a.m., participants measured their pulse rates and blood pressure [T1]. Participants arrived near the study site by bus, after a journey of between 25-30 minutes, and measured their pulse rates and blood pressure again [T2]. On arriving at the study site, after an easy 10-minute walk in flat terrain or a short shuttle transport of about 10 minutes, participants sat and observed the scenery for 15 minutes, after which they measured pulse rates and blood pressure again [T3]. Then they observed the scenery again for some minutes and filled in several survey forms, dealing with perceptions of sound, aesthetics, and perceived health benefits. Participants then walked back to the bus and measured pulse rates and blood pressure [T4a] before returning to their accommodation by bus. Cuffs were put on proband`s wrist of the non-dominant hand and pulse and blood pressure were measured three times (12 times per study site). This process was standardized (e.g. fixed time table, same body posture, cuff at the same height as the proband`s heart) and the same procedure was used for the afternoon measurements at the meadows.

Cognitive performance

In order to survey cognitive performance before [T2] and after each study site-visit [T4a] a standardized test to measure power of concentration was used: the "3DW

Dreidimensionaler Würfeltest" by Gittler (1990). The "3DW" is a one-dimensional Power-test based on the "Items-Response-Theory" and applied for aptitude and performance diagnostics. The long version consists of 18 tasks. In each task, a proband is asked to check if a given cube (3 sides are visible containing different figures) matches with one cube out of six alternatives (Figure 4). There is also the possibility to reduce the number of tasks but to keep the main test characteristics, so that short versions enable an efficient use of the "3DW". For this project a specific version with eight tasks was developed to test probands power of concentration.

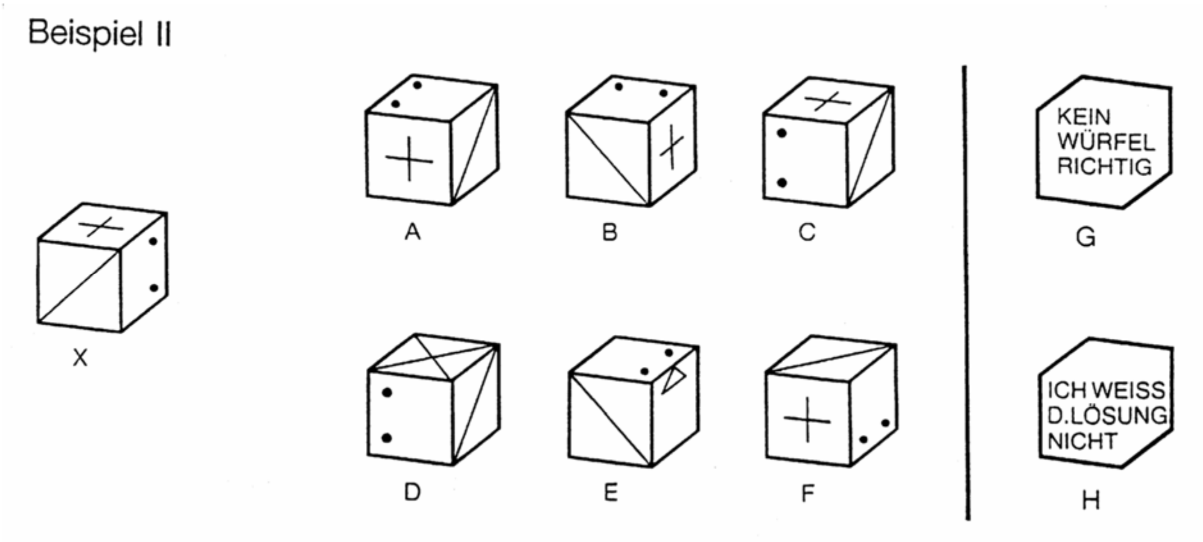

Fig. 4. Example of one item of the 3 DW-Tests.

Psychological resilience

Psychological resilience is considered to be the ability of a human being to cope with extraordinary requirements and challenging situations in everyday life through personal and social, passed on resources and to use it for individual development at the same time (Welter-Enderlin, 2006). This psychological concept explains why some humans handle daily strains better and are less vulnerable than others. Measuring this ability helps to understand if staying in a natural environment over several days leads to an improvement of the resilience of the probands and if there are differences between study regions and the type of land use (managed and abandoned). For this project a shortened version (RS 11) of the original "resilience-scale" developed by Schumacher et al. (2004) was used and handed out to the participants two times [T1, T4b – in afternoon only] per day.

2.2.2.2 On-site measurements of cultural ecosystem services and health benefits

A sample of 22 voluntary and healthy participants (12 females, 10 males), and of a fairly homogeneous age (age mean = 26.7, SD = 4.1, ranging from 22 to 36 years), was used for the field trip to assesses human health and well-being and cultural ecosystem services per study site. Exclusion criteria were: smoking, heart diseases, medication for blood pressure, pregnancy, and age over 45. Participants were recruited on a voluntary basis by distributing flyers at different universities and research institutions and personal contacts. The sample consisted of working people and students from various universities. Before the trip, participants filled in a baseline questionnaire asking them about their employment and health status, attitudes towards travelling in a group, nature orientation, and landscape preferences. Respondents received a small remuneration for their efforts. Each participant was assigned a code number, and participants used their code during the whole experiment. All ethical aspects were considered.

The 11-day field trip took place between August 17 and August 27, 2015 (Figures 5-8). The 22 participants visited all study sites in a standardised manner. Each measurement day started at 8:30 a.m. and the experiment lasted 2.5 hours per study site visit. Each site visit strictly followed the same procedure (i.e. same time of the day; similar physical activity level, and length of stay) during the entire research trip. Each meadow was visited twice (morning/afternoon). Visits to the meadows were rotated in terms of time depending on land-use intensity (managed/abandoned). The river was visited only once, while the urban site was the start and the end of the field trip.

Figure 5. Measurement at the urban site © A.Arnberger

Figure 6. Soudscape measurement at one meadow © A.Arnberger

Figure 7. Measurements at the abandoned meadow in the LTSER-region Eisenwurzen © A.Arnberger

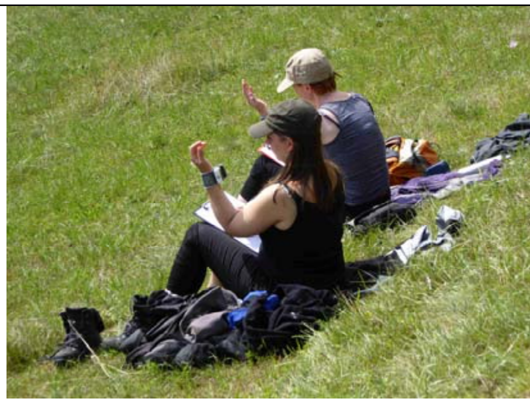

Figure 8. Measurement at the managed meadow in the Val Müstair Biosphere Reserve. © A.Arnberger

2.3 Analyses

Biodiversity data were checked for normal distribution graphically by creating QQ-plots, and statistically using Shapiro-test. Homogeneity of variances (homoscedasticity) was tested applying Bartlett-tests. Ecological count data (e.g. number of individuals or species) were not log-transformed to satisfy parametric test assumptions but rather analysed using generalized linear models (GLMs). Hence, in order to assess the effects of the two habitat types, managed and abandoned meadows, on species richness and abundance of bumblebees, heteropteran bugs and grasshoppers, GLMs with Poisson distribution were applied with management and region as explanatory variables. Data were tested against over- and underdispersion by applying the function *dispersion.test()* in R (R-package „AER“ 1.2-4). Many of the datasets were overdispersed or underdispersed, and it was therefore corrected by specifying quasi-poisson errors. In order to summarize different conditions among the three study regions (e.g. altitude, precipitation), region was treated as block. Differences between managed and abandoned meadows concerning trophic levels and overwintering strategy types of heteropteran bugs, tongue length of bumblebees and suborders of grasshoppers were also analysed using GLMs. To test the effects of plant parameters (plant species richness, vegetation cover, flower frequency, flowers with hidden and open nectar) and surrounding landscape structures on the three insect groups linear regressions were performed. To test for significant associations of bumblebees, heteropteran bugs and grasshoppers between managed and abandoned meadows, the point-biserial correlation coefficient r_{pb} for each species was calculated. To investigate associations of bumblebee, heteropteran bug and grasshopper species with study sites, the strength and the significance of the association was computed using the R-functions *strassoc()* and *signassoc()* in R (R-package „indicspecies“ 1.7.5). Significance of the associations were assessed with two-sided permutation tests and confidence intervals were calculated by bootstrapping data 999 times.

To assess differences in species assemblages of bumblebees, heteropteran bugs and grasshoppers between managed and abandoned meadows, a principal coordinate analysis (PCO) based on a resemblance matrix of Bray-Curtis similarity measure was carried out. A permutational ANOVA (PERMANOVA) was computed to test for significant differences in species assemblages between managed and abandoned meadows. P-values were obtained using an appropriate permutation procedure for the factors management and region. Residuals were permuted 9999 times under a reduced model. In order to exclude the factors that do not differ in their dispersion, the PERMDISP-routine was conducted in analogy to homogeneity test before applying an ANOVA. The test was performed on the basis of distances to centroid with 9999 permutations. P-values were obtained by using permutation of residuals.

In addition, the SIMPER-routine (similarity percentages) was conducted to look at the role of individual species in contributing to the differences of managed and abandoned sites, which decomposes average Bray-Curtis dissimilarities between all pairs of samples into percentage contributions from each species. PCO, PERMANOVA, PERMDISP and SIMPER routines were conducted using the software Primer, version 6.1.13 with PERMANOVA+ (PRIMER-E Ltd., Plymouth, UK). All other statistical tests were performed in R-Studio, version 3.1.3 (R Core Team 2015).

General Linear Models with repeated measures were used to analyse differences in pulse rates, blood pressures and perceived health effects, noise and landscape perceptions such as scenic beauty between the study sites. Time and site for pulse and blood pressure analyses, and site for psychological measures were the within subject factors. The third (most reliable) measurement of pulse and blood pressure was used for analyses. ANOVAs with repeated measures are susceptible to the violation of the assumption of sphericity. We therefore used Mauchly's tests of sphericity to evaluate whether the variances of the differences were equal. If violations of sphericity did occur, we used the Greenhouse-Geisser correction factor from analyses that encompassed more than two measures to produce a more valid F-value. Bonferroni post-hoc contrasts were used to identify differences between the visits. Pearson correlations were used to analyse relationships between SBP, DBP and pulse, and other items. A significance level of $p \leq 0.05$ was chosen. During the measurements at each site, noise levels were permanently monitored using a standard noise measurement device (Voltcraft SL-451) recording noise levels at a 1-second interval. Based on 30 minutes of observation, an average noise level was calculated.

3. <u>Results</u>

3.1 Regulating ecosystem services and biodiversity

3.1.1 Abandonment of mountain meadows affects plant diversity, vegetation structure, litter decomposition and nutrient cycling but impacts vary between different regions

Abstract: Extensively managed, annually mown, mountain meadows are among the most diverse vegetation types in Europe. However, due to socioeconomic pressures many of these meadows are abandoned and not cut any more. This study investigated whether (i) abandonment of extensively managed mountain meadows affects plant diversity, litter decomposition and nutrient cycling and (ii) effects differ between different regions. Three meadows cut once a year were compared with three abandoned meadows in three study regions located along a 500 km west-east gradient in the Eastern European Alps in Switzerland and Austria. At each site plant species composition (vegetation relevés) and above-ground plant biomass, litter decomposition (tea bag method), efflux of soil CO_2, CH_4 and N_2O gas (chamber method), soil microbes (phospholipid-derived fatty acids, PLFA) and soil temperature and moisture was measured. Across regions, abandonment led to a 45% decreased plant species richness, to an altered composition of plant species, functional groups, rosette types, strategy types and indicator values for light availability and soil humidity. The 20% increased litter decomposition rate, the increased soil N and C:N ratio in abandoned meadows was mainly the result of accumulated plant necromass. Abandonment neither affected soil microbes nor the efflux of greenhouse gases. Significant interactions between grassland management and regions indicate no general effect of abandonment on plant diversity or ecosystem functions. We conclude that annual mowing is essential for conserving the high plant diversity and ensuring the qualitative provision of soil-based ecosystem services in our study regions.

Results

Plant diversity

Among regions, species richness was lower in V. Müstair than in C. Ennstal ($P < 0.001$) and G. Walsertal ($P < 0.028$), but Shannon-Index and Eveness were similar. Abandonment reduced species richness (29 species/m² on managed, 16 species/m² on abandoned meadows), Shannon-Index and Eveness (Table 5.1.1.1, Table 5.1.1.2) and increased vegetation cover, total above ground biomass, living biomass and necromass (Table 5.1.1.1, Table 5.1.1.2). Species richness was negatively correlated with NH_4^+ concentrations in the soil in June ($\rho_{species,NH4+}$ = P = 0.020) and the litter decomposition rate k ($\rho_{species,k}$ = P = 0.003). Species composition was significantly affected by management (PERMANOVA, P = 0.001) with significant effects in all regions (G. Walsertal: P = 0.016; Val Müstair: P = 0.017; C. Ennstal: P = 0.001). Among regions, composition of plant communities was similar (PERMANOVA, P = 0.288). The dominant matrix species in managed meadows was the grass *Bromus erectus* (frequency = 83%, mean cover = 17%). In contrast, the grasses *Brachypodium pinnatum* (frequency = 90%, mean cover = 32%) and *Molinia caerulea* (frequency = 40%, mean cover = 10%) were the dominant species in abandoned meadows whereas *B. erectus* played a subordinate role (frequency = 35%, mean cover = 2%).

Abandonment also affected plant functional diversity. The proportion of competitors was significantly higher in abandoned sites ($P < 0.001$) with a significant effect in V. Müstair and proportion of ruderals was significantly lower in all regions ($P < 0.001$). The proportion of stress-tolerators, however, was inconsistent with significantly higher proportion in abandoned sites in G. Walsertal and significantly lower proportion in V. Müstair. Abandoned sites showed significantly more erect growing plants in all regions ($P < 0.001$) and less hemi-rosette plants in G. Walsertal and C. Ennstal ($P < 0.001$). Proportion of rosette plants was inconsistent with significantly lower abundance in abandoned sites in V. Müstair but significantly higher abundance in G. Walsertal.
Abandonment led to significantly smaller proportions of legumes among functional groups with significant effects in G. Walsertal and V. Müstair, to significantly smaller proportions of forbs with significant effects in V. Müstair and C. Ennstal and to significantly higher proportions of necromass with significant effects in all regions (Table 1, Fig. 9). The proportion of grasses remained unaffected in all regions (Table 1, Fig. 9).
Abandonment lowered the Ellenberg indicator value for light availability significantly in all regions with averaged 7.1 in managed and averaged 6.8 in abandoned sites. Indicator value for soil humidity was significantly higher in abandoned (average 4.8) than in managed sites (average 4.1) with significant effect in G. Walsertal (Tables 1,2).

Soil abiotic, chemical and biochemical parameters
Across regions, soil temperature was significantly lower, C_{org} higher, C:N ratio higher, NH_4^+ in June higher and litter decomposition rate and litter stabilization factor higher on abandoned sites than on managed sites. Decomposition rate and stabilization factor correlated with each other ($P = 0.015$) and both correlated with necromass ($\rho_{k,necromass} = 0.638$, $P = 0.006$; $\rho_{S,necromass} = 0.521$, $P = 0.030$) but not with the proportions of legumes ($\rho_{k,legumes} = -0.099$, $P = 0.446$; $\rho_{S,legumes} = 0.212$, $P = 0.422$). Stabilization factor correlated with N_{tot} ($\rho_{S,Ntot} = -0.537$, $P = 0.022$).
Concentration of C_{org} was significantly higher in abandoned sites in C. Ennstal and G. Walsertal. Abandonment increased the decomposition rate significantly in G. Walsertal and V. Müstair. Stabilization factor, C:N ratio and NH_4^+ in June were not significantly affected in single regions. All other soil abiotic and chemical parameters were unaffected by treatment but most differed significantly between study regions. Plant available nitrogen in the soil was significantly higher in August than in June (NH_4^+: $P < 0.001$; NO_3^-: $P < 0.001$).
The sum of all phosphor-lipid fatty acids (Sum PLFA) was higher in abandoned sites (219.2 ± 102.4 nmol g^{-1} DM) than in managed sites (173.3 ± 86.85 nmol g^1 DM) but effect was not significant. Microbial communities were bacteria-dominated in all sites with Gram-negative bacteria contributing the largest proportion. Proportions of specific groups in the community differed significantly between regions but were not affected by abandonment. . The sum of PLFAs correlated closely with concentrations of C_{org} ($\rho_{sumPLFA,Corg} = 0.900$, $P < 0.001$), N_{tot} ($\rho_{sumPLFA,Ntot} = 0.887$, $P < 0.001$), soil moisture ($\rho_{sumPLFA,moisture} = 0.805$, $P < 0.001$) and concentrations of NH_4^+ ($\rho_{sumPLFA,NH4+} = 0.789$, $P < 0.001$) and NO_3^- ($\rho_{sumPLFA,NO3-} = 0.663$, $P = 0.003$) in August. The content of vesicular-arbuscular-mycorrhiza (VAM) correlated with the cover of *Molinia caerulea* ($\rho_{VAM,cover\ Molinia} = 0.649$, $P = 0.004$).
CO_2 contributed most to the overall efflux of GHG. In June, CO_2 emissions were significantly lower in V. Müstair than in the other regions. Abandonment had no effect on the effluxes of GHG. In June, emissions tended to be higher in managed sites in

all regions but differences were not significant (Online Resource Table GHG). The CH_4 efflux was highly variable but a net sink was measured in most cases (Online Resource Table GHG). N_2O emissions were very low in all samples.

Table 1 ANOVA and Kruskal-Wallis results for the effects of management and region on vegetation structure and plant (functional) diversity.

	Treatment		Region		Treatment x Region	
Variable	$F_{1, 78}$	p	$F_{2, 77}$	p	$F_{2, 77}$	p
Vegetation cover (%)	**41.921**	**<0.001**	**39.440**	**<0.001**	**6.846**	**0.002**
Species richness	**135.320**	**<0.001**	**12.962**	**<0.001**	**3.196**	**0.047**
Shannon-Index	**84.779**	**<0.001**	1.621	0.205	**3.456**	**0.037**
Eveness	**56.534**	**<0.001**	0.580	0.562	**5.575**	**0.006**
Ellenberg light indicator	**40.322**	**<0.001**	1.994	0.143	1.722	0.186
Ellenberg humidity indicator	**5.714**	**0.019**	1.978	0.146	0.437	0.648
Functional groups						
Total above ground biomass (g)	**25.451**	**<0.001**	**5.807**	**0.005**	2.242	0.113
Necromass (g)	**34.853**^{x}	**<0.001**	2.631^{y}	0.268		
Living biomass (g)	**5.054**	**0.028**	**18.099**	**<0.001**	1.241	0.295
Legumes (%)	**27.984**	**<0.001**	**4.974**	**0.009**	**8.107**	**<0.001**
Forbs (%)	**13.670**	**<0.001**	**6.190**	**0.003**	**4.340**	**0.017**
Graminoids (%)	0.055	0.815	**4.812**	**0.011**	0.492	0.614
Necromass (%)	**65.861**	**<0.001**	**4.649**	**0.012**	**5.394**	**0.007**

Table 2 Species richness, vegetation cover, biomass and Ellenberg indicator values in response to management. Means ± SD, n = 12 (Großes Walsertal, Val Müstair), n = 16 (C. Ennstal).

Parameter	Treatment/ Region	Managed	Abandoned
Species richness	G. Walsertal	30.8 ± 3.6 a	13.7 ± 2.4 b
	V. Müstair	25.0 ± 5.1 a	12.6 ± 3.1 b
	C. Ennstal	31.3 ± 7.1 a	20.3 ± 6.1 b
Vegetation cover (%)	G. Walsertal	43.5 ± 4.3 a	79.8 ± 18.4 b
	V. Müstair	42.2 ± 18.2 a	54.2 ±11.0 a
	C. Ennstal	73.8 ± 14.0 a	85.6 ± 9.2 b
Total above ground biomass (g m^{-2} DM)	G. Walsertal	391.8 ± 138.3 a	559.8 ± 116.0 a
	V. Müstair	298.1 ± 81.1 a	428.5 ± 219.0 b
	C. Ennstal	520.5 ± 115.2 a	560.4 ± 112.8 b
Living biomass (g m^{-2} DM)	G. Walsertal	258.2 ± 57.9 a	266.2 ± 61.6 a
	V. Müstair	143.4 ± 40.4 a	166.6 ± 83.6 a
	C. Ennstal	189.9 ± 66.8 a	248.1 ± 63.6 b
Necromass (g m^{-2} DM)	G. Walsertal	4.1 ± 2.3 a	27.9 ± 35.7 b
	V. Müstair	2.3 ± 2.8 a	95.4 ± 78.6 b
	C. Ennstal	12.0 ± 21.2 a	63.5 ± 55.5 b
Ellenberg light indicator	G. Walsertal	7.2 ± 0.2 a	6.7 ± 0.2 b
	V. Müstair	7.2 ± 0.1 a	6.8 ± 0.5 b
	C. Ennstal	7.1 ± 0.2 a	6.8 ± 0.2 b
Ellenberg humidity indicator	G. Walsertal	4.1 ± 0.2 a	4.4 ± 0.4 b
	V. Müstair	4.1 ± 0.2 a	4.2 ± 0.4 a
	C. Ennstal	4.3 ± 0.5 a	4.4 ± 0.4 a

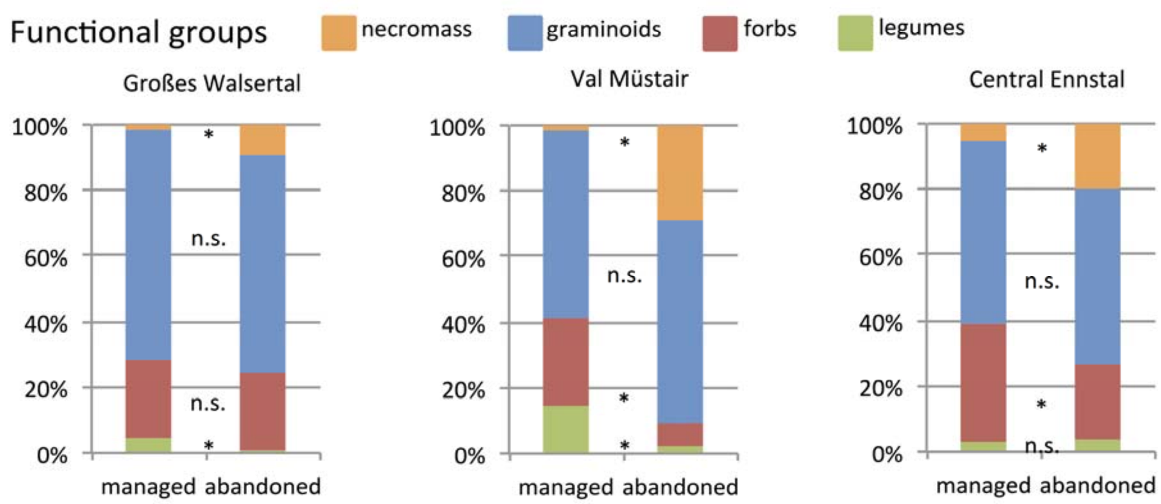

Figure 9. Proportion of various functional groups between managed and abandoned meadows.

3.1.2 Diversity of bumblebees, heteropteran bugs and grasshoppers maintained by both: Abandonment and extensive management of mountain meadows in three regions across the Austrian and Swiss Alps

Abstract: Abandonment of extensively managed meadows is an ongoing global challenge in recent decades, particularly in mountain regions directly affecting plant diversity. However, to what extent plant diversity affects associated insect pollinators or herbivores is little investigated.

The focus of this study was on the effects of abandonment of mountain meadows on species richness and assemblages of bumblebees, heteropteran bugs and grasshoppers investigating the influence of vegetation cover, flower frequency, plant richness and surrounding landscape on the three insect groups.

Within a Swiss and two Austrian regions three for 15-60 years abandoned and three extensively managed meadows (mown once a year, no fertilizer use) were investigated measuring richness, abundance and species assemblages of bumblebees, heteropteran bugs and grasshoppers. Bumblebees and heteropteran bugs were investigated using sweep net method, grasshoppers were surveyed by applying the time-effective soundscape approach.

Bumblebee species richness and abundance were significantly higher in managed meadows, whereas heteropteran bug and grasshopper richness and abundance showed no differences among both management types. Caelifera and Ensifera differed significantly between management types. Managed and abandoned meadows harboured significantly different species assemblages of heteropteran bugs and grasshoppers, but not of bumblebees. Across management types, bumblebee richness increased with increasing flower frequency and plant richness, richness of heteropteran bugs correlated negatively with flower frequency and plant richness, and positively with surrounding open landscape. Ensifera positively correlated with plant richness.

Abandoned and extensively managed meadows are important habitat types for the conservation of the three insect groups suggesting the maintenance of both habitat types within mountain landscapes.

Results

Bumblebees

Altogether 83 bumblebee individuals (*Bombus* sp.) and 14 species were detected in both managed and abandoned meadows. Fifty-seven individuals belonging to 13 species were identified in managed, and 26 individuals belonging to 9 species were identified in abandoned meadows. One of the total 14 species belonged to the cookoo bumblebees (*Bombus* [*Psithyrus*] sp.). Seven of the 14 species were classified as long-tongued and 7 as short-tongued.

Total species richness of bumblebees was significantly higher in managed meadows compared to abandoned meadows. Similarly, total numbers of individuals were higher in managed meadows. There was no effect of management on long-tongued and short-tongued species and neither on long-tongued individuals. However, higher numbers of short-tongued individuals were found in managed meadows. Total individual numbers and individual numbers of long-tongued species differed significantly between regions. Both flower frequency and plant richness had a significant influence on total bumblebee species richness. Bumblebee species richness increased with increasing flower frequency ($p = 0.05$) and plant species richness ($p = 0.014$). Vegetation cover had no influence on bumblebees. Flowers with open nectar had a significant influence on total individual numbers, long-tongued and

short-tongued species and short-tongued individuals. Total individual numbers (p = 0.047), long- and short-tongued species (p = 0.03 and p = 0.007, respectively) and short-tongued individuals (p = 0.001) were positively influenced by increasing amount of flowers with open nectar. Flowers with hidden nectar had a significant influence on total species richness of bumblebees and long-tongued species richness. Linear regression revealed a positive influence of flowers with hidden nectar on total species richness (p = 0.009) and long-tongued species richness (p = 0.004).
Neither percentage of open landscape nor forest area had an influence on bumblebees. Results of the point-biserial correlation did not indicate an association of single bumblebee species to either managed or abandoned meadows.
The graphical representation of species assemblages in the principal coordinate analysis (PCO) showed no clear separation of species assemblages between managed and abandoned meadows. Both axes (PCO 1 and PCO 2) of the PCO explained 56 % of the total variance. This was confirmed by significance test (PERMANOVA, p = 0.1196). PERMANOVA reveals that there were no differences in bumblebee species assemblages among habitat types and regions. SIMPER-analysis showed, that the average Bray-Curtis similarity in managed meadows was 25.02, whereupon the five species *B. lucorum*, *B. terrestris*, *B. lapidarius*, *B. hortorum* and *B. humilis* explained 88.36 % of the similarity within managed meadows. The average Bray-Curtis similarity in abandoned meadows was 6.37 due to the three species *B. lapidarius*, *B. pascuorum* and *B. humilis*, which explained 91.27 % of the similarity within abandoned meadows. These species can be mentioned as typical of managed or abandoned meadows, respectively. An average dissimilarity of 87.11 was detected between managed and abandoned meadows, whereupon 78.91 % of the dissimilarity was explained by the six species *B. lucorum, B. lapidarius, B. hortorum, B. terrestris, B. mucidus* and *B. humilis.*

Heteropteran bugs
In total, 390 individuals comprising 37 bug species were collected in both managed and abandoned meadows. Twenty-one species were found in managed meadows which belonged to 187 individuals, and 29 species belonging to 203 individuals were found in abandoned meadows. The majority of the collected bugs were phytophagous, only three individuals belonging to three species were zoophagous. Concerning overwintering strategy, 28 bug species overwinter as imago and 9 species overwinter as egg.
Management had a significant influence on species and individuals that overwinter as imago indicating higher numbers of species and individuals in abandoned meadows. No significant management effects could be detected for total species richness and total number of individuals, phytophagous species/individuals and species/individuals overwintering as egg. Total number of individuals as well as numbers of phytophagous individuals and number of individuals overwintering as imago differed among regions. No significant influence of vegetation cover could be detected on bug parameters. Significant influences of flower frequency could be shown for total bug species richness, richness of phytophagous species and on species and number of individuals overwintering as imagos. Linear regression revealed a decrease of total species richness of heteropteran bugs (p = 0.03), richness of phytophagous species (p = 0.03) and species and individuals overwintering as imagos (p = 0.04 and p = 0.02, respectively) with increasing flower frequency. Plant species richness significantly influenced phytophagous species and number of species and individuals overwintering as imagos. Phytophagous species (p = 0.04), and number of species and individuals overwintering as imagos (p = 0.006 and p = 0.003, respectively)

decreased with increasing plant species richness. Testing the effects of surrounding landscape structure there is evidence that open landscape significantly affects total bug species richness, total number of individuals and number of phytophagous individuals. Higher amount of surrounding open landscape increased total species richness (p = 0.009), total number of individuals (p = 0.04), and number of phytophagous individuals (p = 0.04). Forest cover had a significant influence on total number of species and richness of phytophagous species. In contrast to open landscape, forest cover indicates a negative effect (total species number: p = 0.02 and phytophagous species: p = 0.02).
Bug species assemblages differed significantly between managed and abandoned meadows. In the PCO both assemblages were clearly separated which was confirmed by PERMANOVA analysis (PERMANOVA, p = 0.0107, Figure 11). The average Bray-Curtis similarity in the SIMPER-routine in managed meadows was 18.68, whereupon the four species *Leptopterna dolobrata*, *Plagiognathus crysanthemi*, *Carpocoris purpureipennis* and *Hadrodemus m-flavum* explained 90.43 % of the similarity within the managed meadows. In abandoned meadows, a Bray-Curtis similarity of 17.32 was observed made up by *Myrmus miriformis, Stenodema holsata* and *Carpocoris purpureipennis* which explained 76 % of the similarity in abandoned meadows. An average dissimilarity of 88.4 was detected between managed and abandoned sites. Sixty-seven percent of the dissimilarity was explained by 10 species (*Leptopterna dolobrata*, *Myrmus miriformis*, *Stenodema holsata, Stenodema sericans, Plagiognathus crysanthemi, Carpocoris purpureipennis, Spilostethus saxatilis, Hadrodemus m-flavum, Dolychoris baccarum, Stenodema calcarata)*. The point biserial correlation coefficient r_{pb} clearly indicates a positively significant association of *Myrmus miriformis* (r_{pb} association index: 0.54, lower and upper confidence intervals: 0.33 and 0.88, respectively) with abandoned meadows. None of the other species revealed associations with either managed or abandoned meadows.

Grasshoppers

In total, 17 species of grasshoppers were recorded in managed and abandoned meadows. Fifteen species were detected in managed meadows and 14 species in abandoned meadows. Due to the method of assessing grasshopper diversity with soundscapes, no data on individual numbers was available. Six species belonged to the Ensifera and eleven species belonged to the Caelifera.
Caelifera and Ensifera differed significantly between managed and abandoned meadows revealing higher Caelifera species richness in abandoned meadows and higher Ensifera species richness in managed meadows (Figure 10). Plant richness significantly affected Ensifera species. Increasing plant richness increased number of Ensifera species (p = 0.013). There were no significant management effects in total species richness and no difference of grasshopper parameters among regions. Vegetation cover, flower frequency and the amount of open landscape and forest cover did not significantly influence grasshopper species richness.
Grasshopper species assemblages differed significantly between managed and abandoned meadows. In the PCO both assemblages were clearly separated which was confirmed by PERMANOVA analysis (PERMANOVA, p=0.001). Both axes of the PCO (PCO 1 and PCO 2) explained 81.4 % of total variation. The average Bray-Curtis similarity in the SIMPER-routine in managed meadows was 55.8, whereupon five species (*Pseudochorthippus parallelus*, *Roeseliana roeselii*, *Euthystira brachyptera*, *Gomphocerippus rufus*, *Pholidoptera griseoaptera*) explained 81 % of the similarity within the managed meadows. In abandoned meadows a Bray-Curtis

similarity of 61.3 was observed made up by *Stenobothrus lineatus*, *Pseudochorthippus parallelus* and *Chorthippus biguttulus* which explained 76 % of the similarity in abandoned meadows.

An average dissimilarity of 52.3 was detected between managed and abandoned sites whereupon 72.5 % was explained by eight species (*Stenobothrus lineatus*, *Gomphocerippus rufus*, *Pholidoptera griseoaptera*, *Chorthippus biguttulus*, *Tettigonia cantans*, *Metrioptera brachyptera*, *Euthystira brachyptera*, *Roeseliana roeselii*). The point biserial correlation coefficient r_{pb} clearly indicates a positively significant association of *Stenobothrus lineatus* (r_{pb} association index: 0.89, lower and upper confidence intervals: 0.67 and 1, respectively) with abandoned meadows. None of the other species revealed associations with either managed or abandoned meadows.

(b)

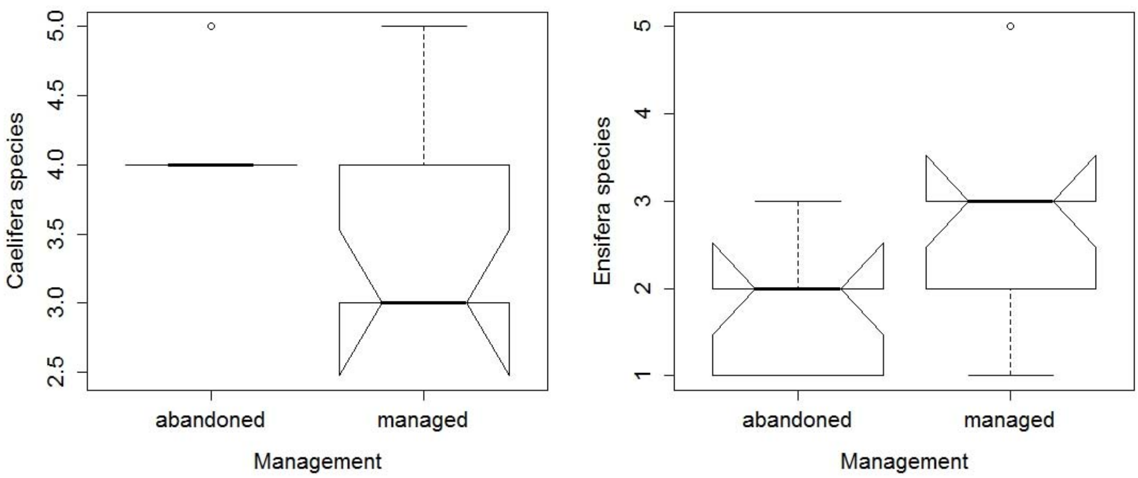

Figure 10 Effects of management (abandoned and managed) on Califera and Ensifera species.

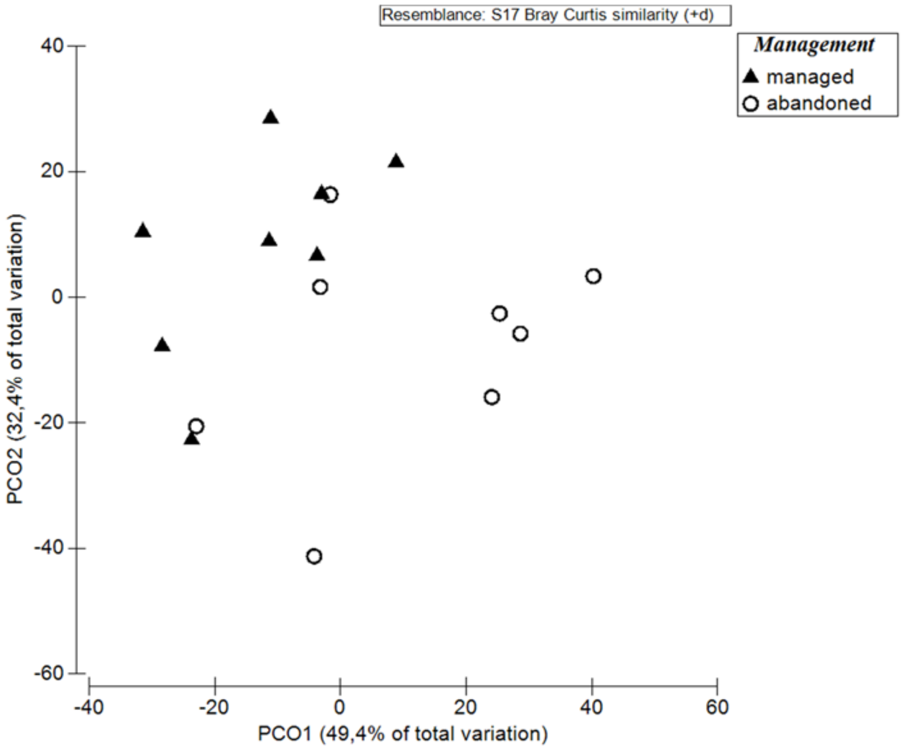

Figure 11 Principal coordinate analysis (PCO) showing distribution of bug species assemblages between managed and abandoned meadows.

3.1.3 Influence of abandonment on syrphid assemblages in mountainous meadows

Abstract: Grasslands are often managed with different intensities in the European Alps. Studies have shown that a medium management can benefit plant and animal biodiversity in these ecosystems. However, in recent decades abandonment of extensively managed meadows is an ongoing global challenge. Syrphids (hoverflies) have been recognized as a threatened group due to environmental drivers, and these managed grasslands provide preferred habitats for them. Yet, at what extent syrphids respond to grassland management strategies is little known. We investigated whether abandonment of managed mountain meadows (mown once a year, no fertilizer use) affects syrphid abundance, richness and species assemblages. Moreover, the influence of plant richness, flower frequency and surrounding landscape on syrphids were assessed. Four managed meadows were compared with four abandoned meadows in a mountainous region in Austria. Adult syrphids were sampled over two consecutive years (June and August 2015-2016) by sweep netting using line transects and observation plots. Syrphid abundance was significantly higher in managed than abandoned meadows and increased with increasing plant richness and flower frequency across management types. Management and sampling time also significantly affected syrphid species assemblages. Syrphid richness and abundance were not influenced by surrounding landscape. We conclude that both abandoned and managed meadows provide important habitat types for syrphids. Therefore, efforts should be made to maintain both managed and abandoned meadows in order to protect syrphid species within mountainous landscapes.

Results
A total of 251 syrphid individuals, comprising 22 genera and 35 species were observed both in managed and abandoned meadows**.** Out of total 35 species, 10 were found only at abandoned meadows, 13 only at managed meadows, with 12 occurring at both. *E. balteaus*, *L. lapponicus*, *M. mellinum* and *S. scripta* were by far the most abundant species.

Numbers of syrphid individuals were significantly higher in managed compared to abandoned meadows (GLMM: P = 0.01**)**. Species richness was not significant between the two management types (GLMM: P = 0.07). Syrphid individuals increased with increasing plant species richness (P = 0.038). Flower frequency was significantly related to syrphid individual numbers (P = 0.050). We observed a single outlier which was statistically determine by creating boxplot. When a single influential outlier was removed, which was due to high flower frequency in one meadow, the former relationship disappeared (P = 0.142). Plant species richness and flower frequency were significantly different between the two management types. Evenness values implied that the species dominance pattern was similar under both types of managements (P = 0.973). Average Shannon-Wiener index for managed meadows (H = 1.13) was slightly higher than for abandoned meadows (H = 0.87); however, this was not significantly different among management types (P = 0.232).
There were significant effects of both management and time on syrphid species assemblages (Table 3). Syrphid species assemblages were significantly different between managed and abandoned meadows (PERMANOVA: P = 0.042) and differed significantly between sampling months (PERMANOVA: P = 0.002). In the average Bray-Curtis similarity in SIMPER-routine, four species *(Sphaerophoria scripta, Melanostoma. mellinum, Syritta. pipiens, and Episyrphus. balteatus)* explained 92.75% of the similarity in managed meadows, while five species *(E. balteatus, S. scripta, Chrysotoxum. bicinctum, M. mellinum, Lapposyrphus. lapponicus)* described 93.56% of the similarity in abandoned ones. An average dissimilarity of 71.33% between both types of meadows was detected by eight species *(S. scripta, M. mellinum, E. balteatus, L. lapponicus, S. pipiens, Myathropa florea, C. bicinctum and Merodon equestris)*.

3.1.4 Efficiency of two methods of sampling used to assess the abundance and species diversity of adult Syrphidae (Diptera) in mountainous meadows in the Austrian and Swiss Alps

Abstract: The outcome of assessments of the biodiversity of a taxonomic group often depend on the sampling method. The choice of an adequate method is especially important for biomonitoring purposes. In this study, the effectiveness of two methods of sampling syrphids (Diptera: Syrphidae) is compared: observation plot method vs. line transect, both sampled by sweep netting. Altogether, 18 meadows were selected in three mountain regions in the Austrian and Swiss Alps. We recorded a significantly higher abundance and richness of syrphids using the observation plot method than the line transect method in 2015. Comparing data for one region recorded in 2015 and 2016, similar results were obtained. Syrphid species assemblages were affected by sampling method in both years. More syrphid species and individuals were recorded using the observation plot method, which makes it more suitable for studies

aiming at comparing differences in the numbers of adult syrphids in different grassland habitats.

Results
Overall, 361 individuals and 41 species belonging to 26 genera were recorded using the two methods over the course of two years. In 2015, a total of 224 individuals belonging to 29 species and 23 genera were recorded in the three regions. 26 species were recorded in the observation plots and 12 species along the line transects. In 2016, 137 individuals belonging to 24 species and 16 genera were recorded at Eisenwurzen. 23 species were recorded in the observation plots and seven species along the line transects. A significantly higher abundance (p = 0.001) and richness of syrphids (p = 0.002) was recorded in observation plots than along the line transects in 2015. *Eupeodes lapponicus* and *Melanostoma mellinum* were the most abundant species in 2015. Comparing data for one region (Eisenwurzen) in 2015 and 2016, revealed similar results. In addition, syrphid abundance (p = 0.003) and richness (p = 0.034) were significantly higher in the observation plots. Again, *M. mellinum* and, in addition, *Sphaerophoria scripta* were the most abundant species in 2016. Significantly different species assemblages were recorded using the two sampling methods. Syrphid species assemblages in 2015 were significantly affected by sampling method, month and region. There was also a significant interaction between month and region. Separation of species assemblages recorded using the two sampling methods was revealed by PCO for the region Eisenwurzen in 2015 and 2016. In addition, there were significant effects of sampling method, month and year, including a significant interaction between month and year, on species assemblages in the region Eisenwurzen in 2015 and 2016. Four species (*M. mellinum*, *S. scripta*, *Episyrphus balteatus* and *E. lapponicus*) accounted for 95.43% of the similarity in the species assemblages recorded for the observation plots and two species (*M. mellinum* and *S. scripta*) accounted for 96.22% of in the similarity in the records for the line transects. The average dissimilarity of 70.58% in the species assemblages recorded using the two methods was due differences in the incidences of five species(*S. scripta*, *M. mellinum*, *E. balteatus*, *L. lapponicus* and *Syritta pipiens*).

3.1.5 Impact of land use change in mountain semi-dry meadows on plants, litter decomposition and earthworms

Abstract: Mountain meadows face to ongoing socio-economic challenges: agricultural intensification when are easily accessible, and abandonment when slopes are too steep/remote and difficult to manage. Both trends are known to directly affect plant and insect diversity, however not much is known about effects on soil processes and soil biota such as litter decomposition and earthworms. To assess this, we studied four managed (mown once a year, no fertilization) and four abandoned (no mowing, no fertilization) semi-dry meadows in a mountain region in Austria. Plant species richness, plant cover, plant traits, biomass, litter decomposition (tea bag index) and earthworm species richness and density were measured. Additionally, soil temperature, moisture and electric conductivity were assessed. Managed meadows contained more plant species than abandoned meadows (118 vs. 93 spp., respectively) and there was a clear separation of plant species assemblages between the two management types. In managed meadows, hemirosette and ruderal

plant species were more abundant, while more erosulate growing plant species occurred in abandoned meadows. Plant necromass in abandoned sites was higher than in managed ones. Additionally, decomposition rate was higher in abandoned sites. There was a trend towards higher earthworm densities in managed meadows, but no difference in earthworm richness. We conclude that meadow management effects on aboveground vegetation have consequences on belowground biota and processes, and that both abandoned and extensively managed meadows are important in order to sustain overall biodiversity and ecosystem functioning in the study region.

Results

Vegetation

In total 149 different plant species were recorded in the meadows. 93 species were found in abandoned and 118 in managed meadows. Species richness, Shannon-index and Evenness were significantly higher in managed compared to abandoned meadows.

The dominant species in abandoned meadows was *Brachypodium pinnatum* which occurred in all sampling plots with a mean cover of 31.8%, followed by *Laserpitium latifolium* (mean cover 7.5%). In contrast, the cover of individual species in managed meadows was more equal. *Bromus erectus*, which was present in half of the plots with a mean cover of 8.9%, was the predominant species in managed meadows, followed by *Astrania major major* and *Festuca rubra rubra* with a mean cover of 7.9% and 6.2%, respectively. Plant cover was similar in abandoned and managed sites (Kruskal-Wallis, $p = 0.248$). PCO revealed a clear and significant separation of species assemblages between abandoned and managed meadows, (PERMANOVA, $p = 0.028$). Total plant biomass was significantly higher in abandoned compared to managed meadows (GLM, $p = 0.045$). Furthermore, the structure of functional groups in the plant assemblage was influenced by management. Abandoned meadows had significantly higher necromass, and grasses were marginally higher in this management type. Herbs and legumes exhibited no differences in management. Within the plant strategy types ruderal plants had a significantly higher proportion in managed meadows. The proportion of competitors and stress-tolerators showed no differences between management types. In abandoned meadows, significantly more erosulate growing and less hemirosette plant species were found. The predominant character states of rosettes in both management types was hemirosette. Proportion of rosette plant species showed no significant difference.

Litter decomposition

Decomposition rate *k* was significantly higher in abandoned meadows compared to managed meadows. For stabilisation factor *S*, no significant difference was found.

Earthworms

In total, seven species were found in all meadows. The endogeic spp. *Aporrectodea rosea* and *Octolasium lacteum* were most abundant across management types, followed by the endogeic *Aporrectodea caliginosa* in abandoned meadows and epigeic *Lumbricus rubellus* in managed meadows. Only one species belonged to the ecological group anecic, with two recorded individuals in managed sites. Ecological groups (anecic and epigeic) did not significantly differ between meadow types. Neither species richness (GLM, $p = 0.866$), nor earthworm assemblages were affected by management (PERMANOVA, $p = 0.642$). Total earthworm density and endogeic earthworm density were marginally higher in managed compared to abandoned meadows.

Soil parameters
Soil temperature, soil moisture, electric conductivity (EC) and pH did not significantly differ between management types (GLM, $p_{soil\ temperature} = 0.858$, $p_{soil\ moisture} = 0.742$, $p_{EC} = 0.276$; Kruskal-Wallis, $p_{pH} = 0.673$).

3.1.6 Long-term abandonment of mountain meadows affects bumblebees, true bugs and grasshoppers: A case study in the Austrian Alps

Abstract: We investigated how abandonment of mountain meadows influences bumblebees, true bugs and grasshoppers in 2015 and 2016. We surveyed abandoned (20-40 years old) and annually mown unfertilized meadows. Bumblebees were observed in 20 m^2 plots, bugs were collected by sweep netting and grasshoppers identified with a soundscape approach. The insect groups were analysed in relation to plant species richness, flower 30 cover, vegetation cover and the surrounding landscape. Bumblebee species richness and richness of long-tongued species were significantly higher in managed meadows. Similarly, we found significantly more phytophagous bug species in managed meadows, whereas grasshoppers showed no difference between meadow types. Bumblebee species richness and abundance, the abundance of phytophagous bugs and total grasshopper species richness were associated with total flower cover. Surrounding forest area negatively affected bugs, while open landscape positively affected bugs, both regarding species richness and abundance, number of phytophagous species and individuals and individuals overwintering as egg. Species assemblages of the three insect groups did not significantly differ between meadow types. Extensive management is an important management scheme to preserve bumblebee and bug richness. However, abandoned meadows, which are not yet re-grown into forest can still act as suitable habitats for the three insect groups.

Results
Bumblebees
We collected 98 bumblebee individuals of 13 species (*Bombus sp.*). Twelve species with 64 individuals were found in managed, and 8 species with 34 individuals in abandoned meadows. We identified three cuckoo bumblebees (*Bombus* [*Psithyrus*] *sp.*). Further, we distinguished between 5 long- and 8 short-tongued species. Managed meadows harboured a significantly higher total bumblebee richness and higher numbers of long-tongued species (GLMM, $p = 0.0132$ and $p = 0.0318$, respectively). Higher total flower cover increased total bumblebee species richness and abundance, and both number of short- and long-tongued species and individuals. Higher plant species with hidden nectar flowers significantly increased total bumblebee species richness as well as number of long-tongued species. No relationship was found between number of bumblebee species and individuals, abundance of short-and long-tongued species and individuals and total plant species richness, surrounding landscape (open landscape and forest cover), vegetation cover and number of plant species with open nectar flowers. The point-biserial correlation did not show a significant association between individual bumblebee species and meadow types.

There was no significant difference between meadow types regarding bumblebee species assemblages (PERMANOVA, p = 0.145). We found an average similarity of 15.30 in annually mown meadows (SIMPER-analysis). 92.17 % of the similarity was described by *B. lapidarius*, *B. hortorum*, *B. humilis* and *B. terrestris*. *Bombus humilis*, *B. pascuorum, B. hypnorum* and *B. terrestris* explained 91.42 % of the similarity of 7.22 in abandoned meadows. Both meadow types revealed a dissimilarity of 91.49. *Bombus humilis*, *B. hortorum*, *B. lapidarius*, *B. pascuorum* and *B. terrestris* described 70.34 % of the dissimilarity.

True bugs

We found 281 bug individuals of 32 species. We found 165 individuals of 27 species in managed, and 116 individuals of 13 species in abandoned meadows. Twenty-nine species were classified as phytophagous and three species as zoophagous. We classified 12 species as overwintering as eggs and 20 species as overwintering as imagos. We did not further include zoophagous bug species in the analysis due to the underrepresentation of this trophic group.

Managed meadows harboured significantly higher phytophagous bug species than abandoned meadows (GLMM, p = 0.0488). Richness and abundance of true bugs, number of phytophagous bug species and individuals and individuals hibernating as eggs decreased with an increasing amount of forest cover in the surrounding landscape. A larger proportion of open landscape in the surrounding landscape positively affected total number of individuals, individuals overwintering as eggs and species and individuals belonging to the phytophagous trophic group. Increasing flower cover increased the number of phytophagous individuals. No individual bug species was associated with either annually mown or abandoned meadows.

True bug species assemblages did not significantly differ between meadow types (PERMANOVA, p = 0.565). The average Bray-Curtis similarity in the SIMPER-analysis in managed meadows was 7.19, with *Leptopterna dolobrata*, *Carpocoris purpureipennis*, *Orthops kalmii*, *Dolychoris baccarum*, *Graphosoma lineatum* and *Halticus apterus* explaining 91.58 % of the similarity. Abandoned meadows revealed a similarity of 9.13. 91.11 % of the similarity was due to the species *Nabis rugosus*, *Leptoperna dolobrata*, *Polymerus microphtalmus* and *Graphosoma lineatum*. We found an average dissimilarity of 92.30 between meadow types, where 62.70 % of the dissimilarity was explained by the species *Leptopterna dolobrata*, *Nabis rugosus*, *Halticus apterus*, *Polymerus microphtalmus* and *Carpocoris purpureipennis*.

Grasshoppers

We detected a total of 15 grasshopper species in both meadow types. We found 12 species in managed and 13 species in abandoned meadows. We found eight Caelifera species and seven Ensifera species.

There was no management effect on total species richness or on richness of Caelifera and Ensifera. Increasing total flower cover increased total grasshopper species richness. Caelifera were significantly negatively affected by higher amounts of forest cover in the surrounding landscape. We found *Stenobothrus lineatus* to be significantly associated with managed meadows.

Grasshopper species assemblages did not differ between meadow types (PERMANOVA, p = 0.257). 94.01 % of the similarity of 61.63 in managed meadows was due to the species *Chorthippus biguttulus*, *Stenobothrus lineatus*, *Pseudochorthippus parallelus*, *Metrioptera brachyptera*, *Roeseliana roeselii* and *Euthystira brachyptera*. 84 % of the similarity of 53.42 in abandoned meadows was explained by the species *Euthystira brachyptera*, *Pholidoptera griseoaptera*, *Gomphocerippus rufus*, *Pseudochorthippus parallelus*, *Roeseliana roeselii*, and *Chorthippus biguttulus*. The average dissimilarity between meadow types was 52.36, with *Stenobothrus lineatus, Metrioptera brachyptera, Pholidoptera griseoaptera, Gomphocerippus rufus, Chorthippus biguttulus, Roeseliana roeselii, Barbitistes serricauda* and *Pholidoptera aptera* explaining 67.13 % of the dissimilarity.

3.1.7 Landscape structure and vegetation parameters

Managed meadows comprised a significantly higher total plant species richness as well as a higher total flower cover compared to abandoned meadows ($p < 0.001$ and $p = 0.019$, respectively). Similarly, managed meadows harboured a significantly higher number of plant species with hidden nectar flowers ($p < 0.001$). Vegetation cover as well as number of plant species with open nectar flowers did not differ between habitat types. There was a negative correlation between forest cover and open landscape ($p < 0.001$).

3.2 Cultural ecosystem services and health benefits

3.2.1 Measured and perceived soundscapes

At each study site, permanent measurements of soundscapes during the stay were undertaken. On average, noise level across all sites was 47 dB(A). Much higher noise levels were measured at the urban site and at the Lutz River in the Großes Walsertal Biosphere Reserve ($p < 0.001$) (Table 3). Noise levels at the meadows sites were rather similar with lowest noise levels measured at the meadows of the Großes Walsertal Biosphere Reserve.

Table 3 Measured average noise levels per study region/sites; BR=Biosphere Reserve

Sites	dB (A)
Urban (Vienna)	62.2
Meadows LSTER Eisenwurzen (C. Ennstal)	43.0
Meadows BR Großes Walsertal BR	41.2
Meadows Val Müstair BR	44.1
Lutz River (Großes Walsertal BR)	66.6

Significant differences between study sites emerged for the perceptions of sound ($p < 0.001$). Participants' perceptions of sound were highest and similar for the urban site visits, the river and for the LTSER-region, while lowest for the meadows of the Großes Walsertal. Different answer patterns were received for the perceptions of the background noise. Again, the meadows of the Großes Walsertal were perceived as the sites with the lowest background sound, followed by the Lutz River. Perceived background sound was highest for the second urban visit.

3.2.2 Perceived cultural ecosystem services

Perceived aesthetics and naturalness

Study participants perceived the river and the meadows as more beautiful and more natural than the urban sites (Figure 12). No differences between meadows types (managed, abandoned) regarding aesthetics emerged, while the unmanaged meadows were perceived as more natural than the managed ones ($p < 0.05$).

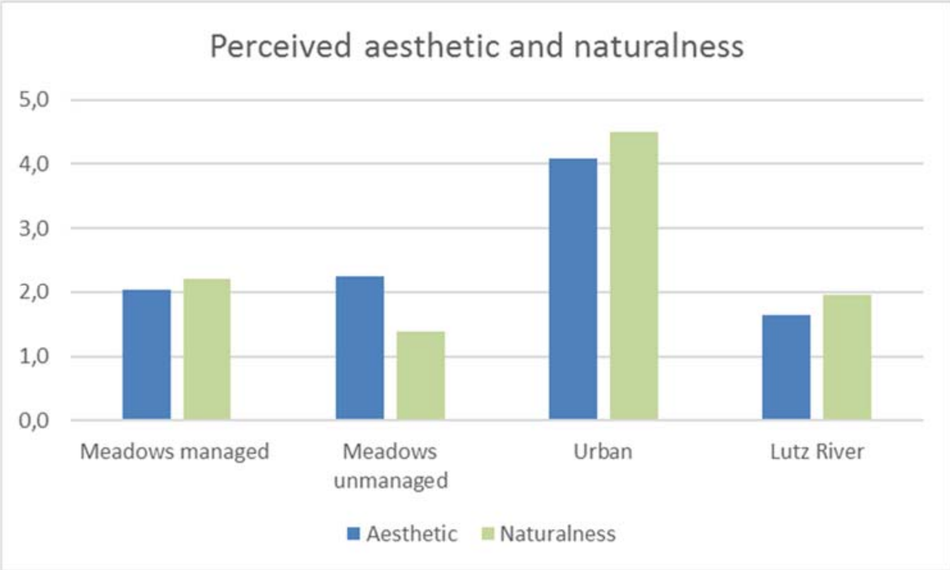

Figure 12. Perceived aesthetics and naturalness (Answer scales: aesthetics 1=very high, -5=very low; naturalness 1=very natural 5=very unnatural).

Perceived restorativeness (PRS)
The river was assessed as the site with the highest restorative qualities, while the urban site was the opposite ($p < 0.001$; Fig. 13). Participants perceived the meadows as quite restorative places. They assigned both meadow types high PRS-qualities in being away, followed by fascination and compatibility. Participants perceived the meadows as not chaotic or disturbing sites. Differences between the meadow types for found for three qualities ($p < 0.05$): fascination, coherence and compatibility. The unmanaged meadows were perceived as more fascinating, but less coherent and compatible compared to the managed meadows.

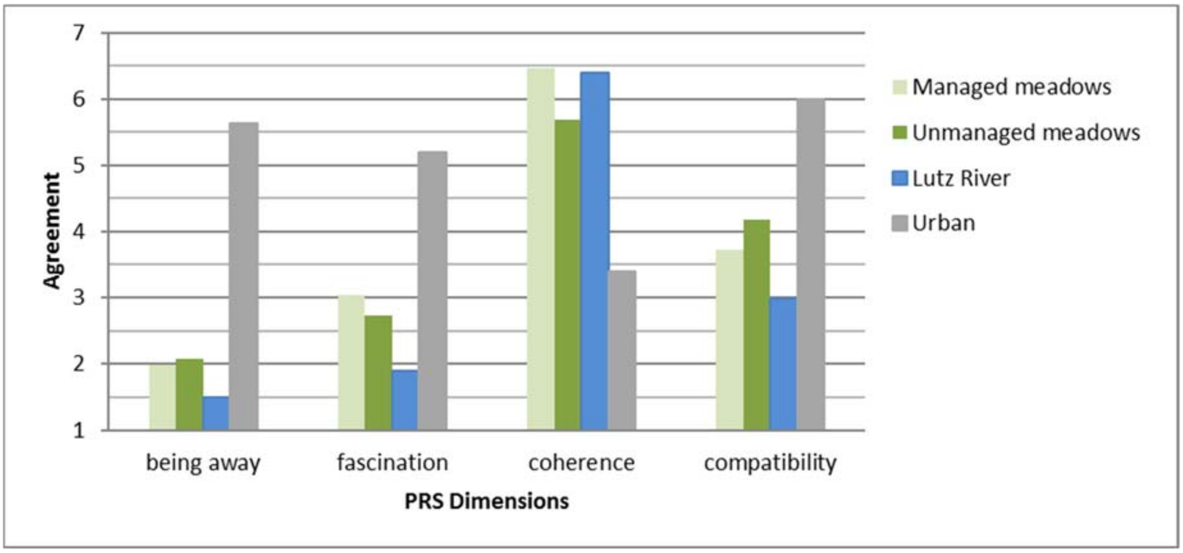

Figure 13. Perceived restorativeness per dimension and meadow type. PRS answer scale 1 = totally agree; 7 = totally disagree.

3.2.3 Results of physiological, psychological, and cognitive measurements
Results of psychological health measurements

Perceived health benefits across study sites
Study participants perceived the urban site as less effective in reducing stress, restoring attention and improving well-being compared to the meadows and in particular to the river (Fig. 14). Even between the meadow types significant differences were found. Participants believed that they can better reduce stress, restore attention and increase their well-being in the managed compared to the abandoned meadows, particular during the afternoon measurements.

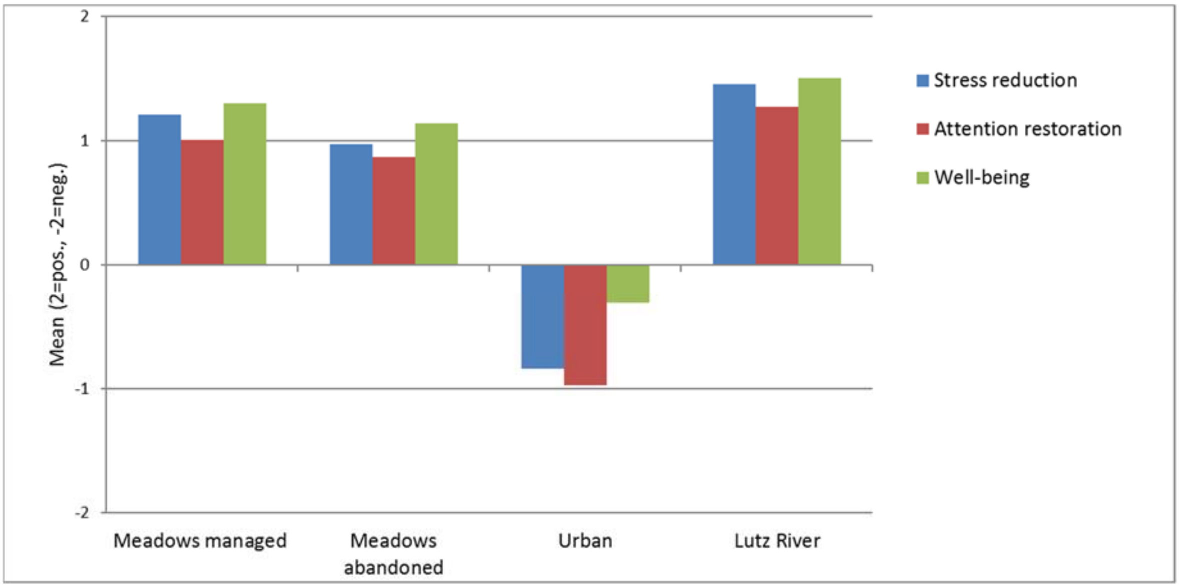

Fig. 14. Perceived stress reduction (Answer scale: 2=very good, -2=not a bit), attention restoration (Answer scale 2=very good, -2=not a bit) and perceived changes in well-being (Answer scale 2=improved, -2=declined) per meadow-management type and compared to urban site and river [answer scales modified to ease interpretation]. Differences between all sites for stress, attention and well-being at $p < 0.001$ level using ANOVA with repeated measures.

Results of Nitsch wellbeing Scales
As we supposed that the nature exposition would change the wellbeing of the study participants, i.e. the viewing of the meadows that took place between T2 and T3, we suppose that the values for the willingness to make an effort, mood, tenseness, fatigue (recoded/inverted), and sleepiness (inverted) will increase after T2.

Firstly, we were interested in differences between settings with managed and unmanaged meadows within each of the three research areas. In Münstertal we found significant differences over time for the willingness to make an effort ($p < 0.001$), tenseness (n.s), fatigue (recoded/inv.; $p < 0.05$), and sleepiness (inv.; $p < 0.001$).

Significant differences in the Nitsch values between managed and unmanaged meadows were found for willingness to make an effort ($p < 0.05$), mood ($p < 0.05$), and sleepiness (inv., $p < 0.05$), the values for the managed meadows being higher than for the unmanaged, suggesting that these are better suited to enhance human well-being.

In the Biosphere Reserve Großes Walsertal we found significant differences over time for the willingness to make an effort ($p < 0.05$), mood ($p < 0.05$), fatigue (recoded/inv.; $p < 0.001$), and sleepiness (inv., $p < 0.001$). We found no significant differences in the Nitsch values between managed and unmanaged meadows. In the LTSER (Long-Term Socio-economic and Ecosystem Research)-Region Eisenwurzen we found significant differences over time for the development of the values for mood only ($p < 0.001$).

We found significant differences in the Nitsch values between managed and unmanaged meadows for the factor tension ($p < 0.05$) and a significant interaction for time x management for the factor mood ($p < 0.05$).

In the ANOVA with repeated measures including the two regions Münstertal and Grosses Walsertal significant differences for willingness to make an effort and for sleepiness were found for time of measurement ($p < 0.001$).

The other factors could be analysed for the three study regions, the analysis revealed significant differences for the factor tension between the management options managed/unmanaged ($p < 0.05$) and for time ($p < 0.05$), For the factor fatigue (inverted) significant results were found for time of measurement ($p < 0.05$). For the factor willingness to make an effort the interaction between region and time of measurement ($p < 0.05$) was significant. For the factor sleepiness interactions between region and management ($p < 0.05$), region and time of measurement ($p < 0.05$) and management and time of measurement ($p < 0.05$) were significant.

Results of psychological resilience

There was a significant increase in psychological resilience ($p < .05$) as the field trip progressed (Figure 15). Differences in psychological resilience appeared manly after the second day compared to the start of the field trip in Vienna. A further significant decrease with time was not observed.

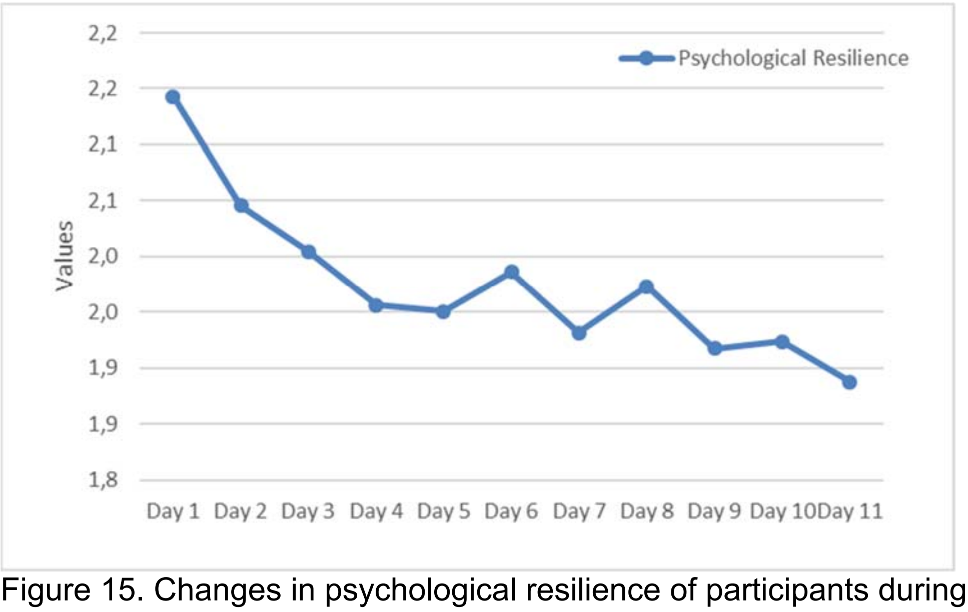

Figure 15. Changes in psychological resilience of participants during the field trip (N = 22; Answer scale 1= totally agree to 7= totally disagree).

Results of physiological measurements

Pulse rates

Differences in pulse rates emerged between the sites ($p < 0.001$) with differences between the urban site and the Lutz River, and between the meadows and the Lutz River (Figure 16). While a constant and similar significantly decrease in pulse rates was observed with time at the urban site and meadows, the stay at the river slightly increased the pulse rate. No differences were observed between managed and unmanaged meadows.

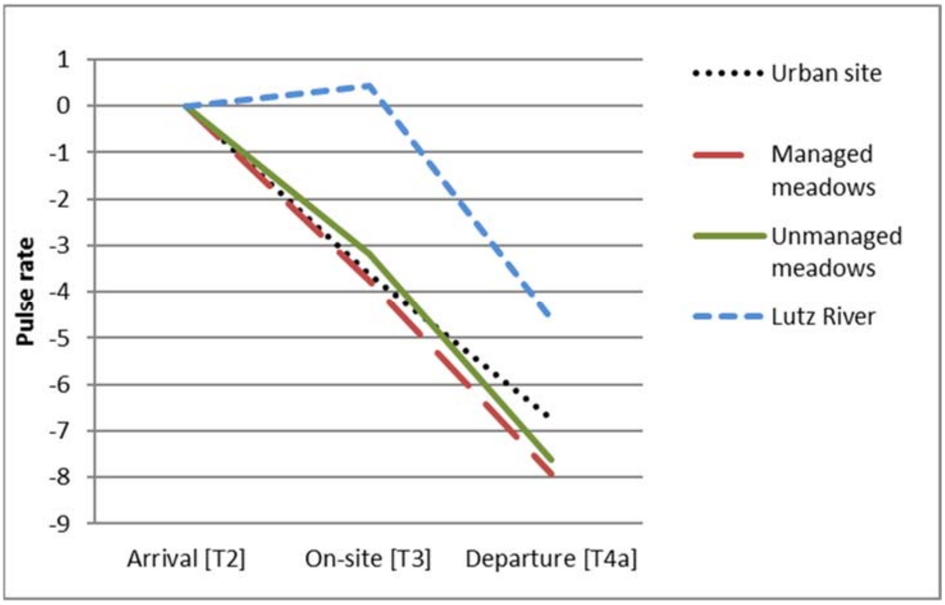

Figure 16 Changes in pulse rates per study site type and measurement time [T]

Blood pressure

Overall, the stay in the study sites (both meadow types, urban, river) significantly increased the systolic blood pressure ($p < 0.001$; Figure 17). The increase was significantly lower for the river compared to the other sites, while no differences in systolic blood pressure between the meadow types were found.

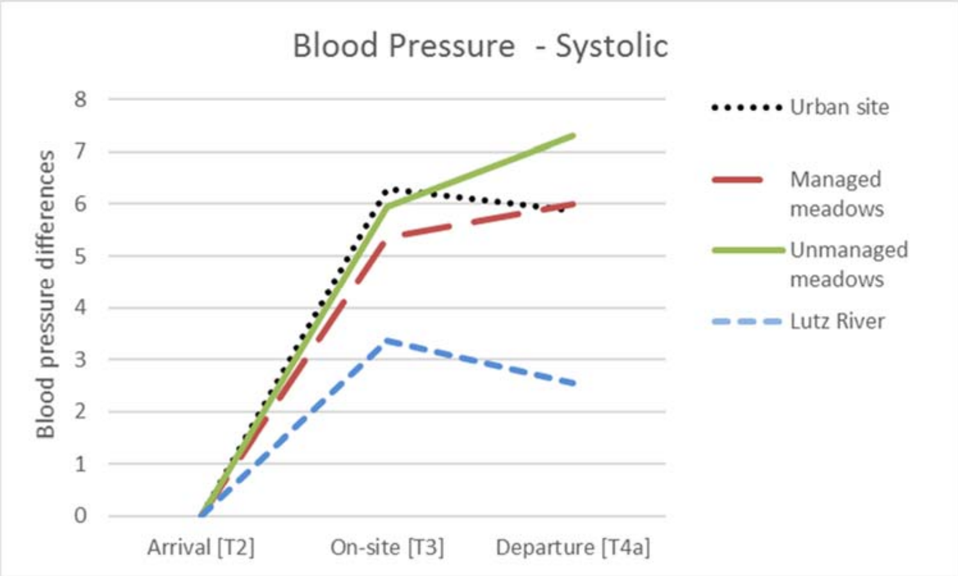

Figure 17. Changes in systolic blood pressure per study sites and measurement time [T]

Similarly, the stay in the study sites (both meadow types, urban, river) significantly increased the diastolic blood pressure ($p < 0.001$; Figure 18). The increase was slightly lower for the river and urban sites compared to the meadows. The stay in the unmanaged meadows had the strongest effect on blood pressure increase. No differences were observed between managed and unmanaged meadows.

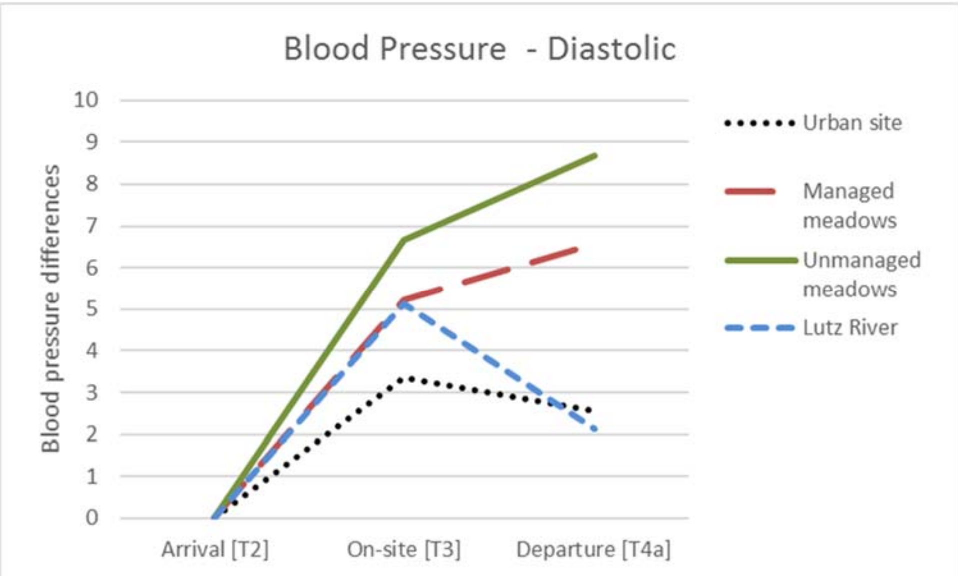

Figure 18. Changes in diastolic blood pressure per study sites and measurement time [T]

Results of cognitive measurements

The 3-DW-Test found a significant difference between the two meadow types (Figure 19). The stay in unmanaged meadows had a significantly more positive influence on the cognitive performance ($p < 0.05$) compared to a stay in managed meadows.

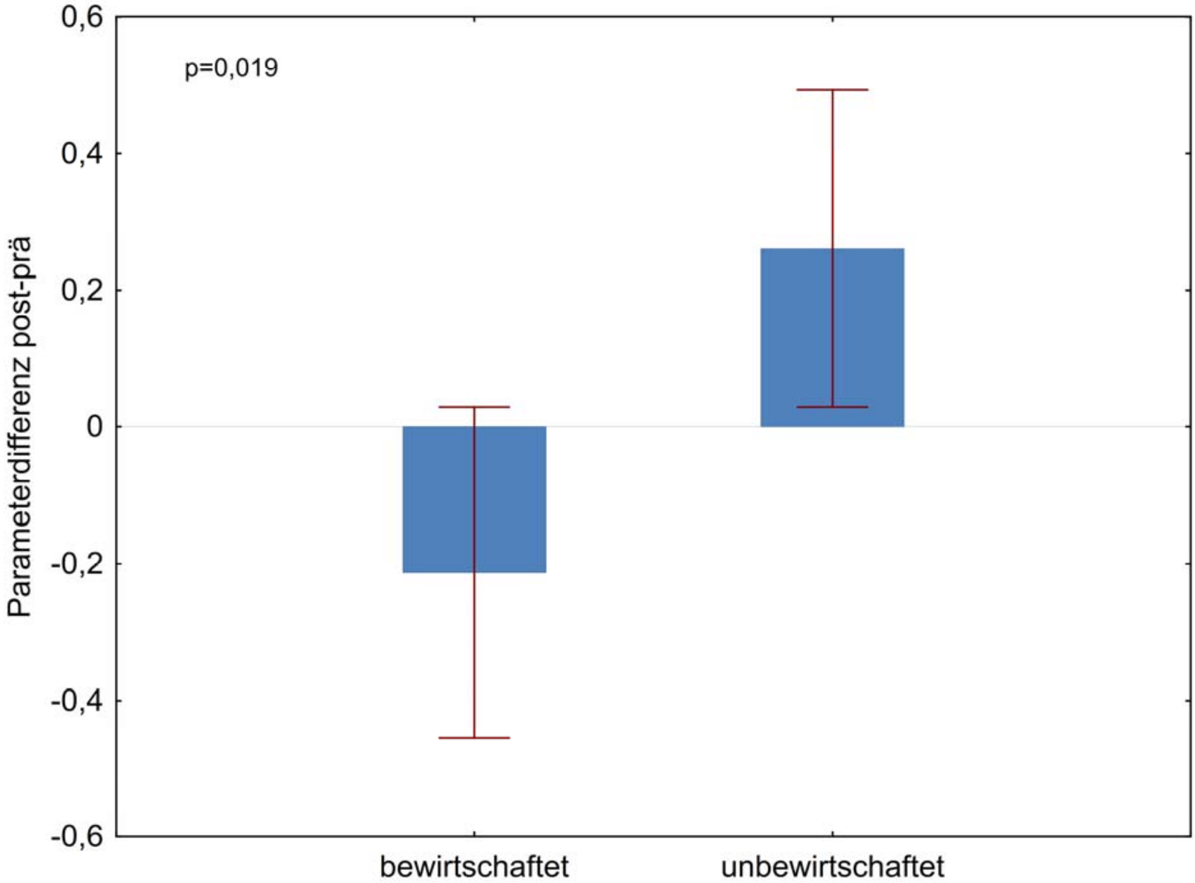

Figure 19. Results of the 3 DW-Test per meadow type (bewirtschaftet=managed; unbewirtschaftet=unmanaged/abandoned)

3.2.4 Detailed analyses of the health benefits of the meadows in the Großes Walsertal

Short-term, psychological health-related benefits of visiting the meadows of the Austrian Großes Walsertal Biosphere Reserve were analysed in detail (Arnberger et al., 2018). Participants were asked about perceptions of health benefits and perceived restorativeness (PRS), scenic beauty, naturalness, and biodiversity.

Study participants perceived the meadows as beautiful, in particular the landscape scenery, natural and biodiverse (Table 4). They reported a positive effect of the stay on stress reduction, attention restoration and well-being. While participants perceived the abandoned meadow as more natural and higher in biodiversity than the managed one, no differences were found for scenic beauty of the meadows and the surrounding landscape, as well as for the perceived effects on well-being, attention restoration and stress relief.

Table 4. Perceived landscape beauty, and health effects per meadow, day and day time (N = 22)

Items	**1rst Day** Abandoned, morning	**1rst Day** Managed, afternoon	**2nd Day** Managed, morning	**2nd Day** Abandoned, afternoon	ANOVA repeated measures
Landscape Scenery	1.14	1.14	1.09	1.23	p = 0.457
Meadow beauty	2.27	1.95	2.00	2.14	p = 0.532
Naturalness	1.23	2.41	2.14	1.05	p = 0.000
Biodiversity	4.23	3.23	3.77	4.59	p = 0.000
Stress reduction	1.50	1.59	1.55	1.82	p = 0.319
Attention restoration	1.50	1.73	1.91	1.91	p = 0.113
Well-being	1.45	1.36	1.55	1.73	p = 0.164

Perceived naturalness: 1 = very natural; 5 = very unnatural; Perceived scenic beauty: 1 = very high; 5 = very low; Perceived biodiversity: 1 = very low; 5 = very high; Perceived stress reduction (Answer scale 1=very good, 5=not a bit), attention restoration (Answer scale 1=very good, 5=not a bit) and perceived changes in well-being (Answer scale 1=improved, 5=declined) per meadow-management type and compared to urban site.

Based on the results of the PRS-scale, participants perceived the meadows as restorative places and assigned both meadow types the four qualities of a restorative environment. However, different results were obtained regarding the four PRS-qualities. No differences were observed for being away and compatibility items, while most items of fascination and coherence differed. Participants perceived the abandoned meadow as more fascinating, where their attention is drawn to many interesting things, and there is much to explore and discover. They would like to get to know the meadow better. At the same time, participants perceived the abandoned meadow as more chaotic and confusing with a greater deal of distraction than the managed one. Differences between the morning and afternoon treatments were marginal. No significant correlations between these fascination and coherence were found for both meadow types, while correlations exit between fascination and escape as well as compatibility at least at the $p < 0.01$ level.

This analysis found differences but also commonalities in perceptions for PRS, health benefits, biodiversity, scenic beauty and naturalness between the meadow types of the Großes Walsertal Biosphere Reserve. Overall, respondents perceived both meadows as beautiful and restorative places, providing several health benefits to them.

3.3 Interactions between biodiversity, regulating and cultural ecosystem services and health benefits

The relationships between ecosystems, biodiversity and human health and well-being have received increased attention in international scientific debates and policy making in recent years. Our study is among the first which simultaneously evaluates inter-relationships between the biodiversity of several organismic groups (grasshoppers, syrphids, bumblebees and true bugs), landscape characteristics, perceived cultural ecosystem services and human health and well-being. Additionally, it investigated to what extent agricultural management intensity influences these relationships.

We found several positive and negative correlations between biodiversity attributes and human health and well-being and cultural ecosystem services. The research found that perceived naturalness has a positive association with flower cover ($p < 0.05$) and plant richness ($p <. 0.05$). High flower cover and plant richness in managed meadows increased the perception of naturalness which highlights their importance as landscape characteristic.

While we found no differences in blood pressure between management regimes (see chapter 3.2.3), a strong and negative correlation between systolic blood pressure (SBP) and openness of the landscape and a positive correlation with forest cover were found ($p < 0.001$). SBP is lower in a more open landscape.

Negative relationships were found between grasshopper diversity and health perceptions as well as perceptions of the landscape. Participants disliked the presence of grasshoppers for stress reduction ($p < 0.05$) and attention restoration ($p < 0.01$). Grasshopper diversity was negatively correlated with landscape beauty and the suitability of the area for recreation ($p < 0.05$). The higher the grasshopper diversity, the more participants perceived noise ($p = 0.05$). We assume that grasshopper sounds were quite unpleasant to those persons who are unimpressed by the world of insects. Adult grasshoppers not only jump, but fly, and that means these insects become more visible to the casual observer, and the presence of many different grasshoppers jumping around and on participants while they were sitting in the meadows may have caused a chaotic and disturbing impression.

We conclude that several biodiversity attributes correlate with perceptions of cultural ecosystem services and perceived health benefits within the studied management regimes. Agricultural management appears to play only a minor role in this context.

3.4 Stakeholder workshop

In November 2018, a stakeholder workshop was organised in Raumberg-Gumpenstein in the LTSER region Eisenwurzen to develop recommendations for the management of mountain meadows and the health benefits. Owners of the study sites, regional representatives, researchers, people responsible for regional tourism, and NGOs were invited. Due to illness several stakeholders were not able to participate.

Study results were presented by several members of the project team (Arnberger, Bohner, Frank, Walcher). From a botanical and zoological viewpoint, the research team recommend to sustain a mosaic of both managed and abandoned meadows. This is important as there are species particularly favoured by one or the other kind of grassland management. This study could demonstrate this by species assemblages being significantly different between managed and abandoned meadows.

For most of the stakeholders, the topic “relationships between ecosystems, biodiversity and human health and well-being” was rather new but they found it very interesting. A lot of discussion emerged among stakeholders about the identified relationships between biodiversity attributes and human health, in particular the relationship between grasshopper diversity and perceived health benefits. Stakeholders found this project very useful, and suggested a pile of management recommendations, in particular for meadow management, and future research directions. An important question addressed by workshop participants was whether the two management types tested respond differently when they are applied in homogeneously structured lowland agroecosystems compared to heterogeneously structured alpine grassland regions. An interesting but open question that could not be answered by our “Healthy Alps” project.

4. Discussion and recommendations

Although restoration research has shown that natural environments achieve higher outcomes concerning the improvement of the psychological and physiological state of humans than built environments (e.g., Ulrich et al. 1991; Hartig & Staats 2006; Van den Berg et al. 2003; 2010; Tyrväinen et al. 2014; Wallner et al., 2018), little is known about the health benefits of natural and semi-natural mountain landscape types compared to blue (rivers, lakes) and grey (urban built-up areas) spaces. In addition, only few studies tested the relationships between human health and well-being and natural environments with varying levels of land use intensities and plant and animal biodiversity.

We observed that bumblebee species richness and abundance were significantly higher in extensively managed meadows, whereas bug and grasshopper richness and abundance showed no differences between both management types. On the other hand, managed and abandoned meadows harboured significantly different species assemblages of bugs and grasshoppers, but not of bumblebees. This shows that insects respond differently to the two management regimes. Therefore, we recommend to sustain a mosaic of both extensively managed and abandoned meadows. Abandoned and extensively managed meadows are important habitat types for the conservation of the three insect groups, thus suggesting the maintenance of both habitat types within mountain landscapes.

Healthy Alps found that both meadows types are perceived as very restorative places which are providing many health benefits. However, differences and communalities regarding health benefits and cultural ecosystem services between the meadow types were found. The abandoned meadows were perceived as more fascinating, but less coherent and compatible compared to the managed meadows. Participants believed that they can better reduce stress, restore attention and increase their well-being in the managed compared to the abandoned meadows (except for the Großes Walsertal). Specifically, participants reported more positive psychological health effects as a result of their stays at the most remote meadows of the Großes Walsertal and the Lutz River on attention restoration, stress reduction and wellbeing compared to the urban site. The analyses further showed that the values of the Nitsch scale increased after the stay in the meadows. Differences between managed and abandoned meadows could be found only for the factor tension, suggesting that on unmanaged meadows the values on the factor tension were higher.

The study found that pulse rates decreased during the stays at all the meadows and the urban site while no decrease was observed at the river. Blood pressure increased at all sites during the stay, with no study-site differences for systolic, but for diastolic, blood pressure. While only marginal differences in the physiological measurements between managed and abandoned meadows were found, cognitive performance increased in the abandoned meadows.

This study suggests that perceived and measured health benefits were rather independent of the degree of naturalness of meadows. While differences measured on the physiological level between urban built and natural sites were marginal, psychological measures showed higher health benefits of the natural environments compared to the built one. Thus, extensively managed and abandoned meadows seem to have a potential for health offers. Nevertheless, managers and researchers should be aware that not each result of the various methods applied in this study for measuring human health and well-being pointed into the same direction. Healthy Alps also found that several biodiversity attributes, health benefits and cultural ecosystem services are well correlated within two studied management regimes. Nevertheless, this explorative study cannot provide clear evidence for the causal relationship between human health and biodiversity and other ecosystem services.

European mountain biosphere reserves typically include cultural and natural landscapes, among these are extensively managed and abandoned meadows. If future studies can provide additional empirical evidence on health benefits of both mountain meadow types, then such benefits can be used for health-related offers for tourists. In addition, their potential health effects should be considered in protected area management, for example, of biosphere reserves, in political decision making, and in the design of agro-environmental, public health and nature conservation policies and measures.

This was, to our knowledge, the first study systematically investigating perceived health effects of mountain meadows with different levels of naturalness. Additional studies comparing meadows with other alpine land-use types such as forests and pastures are necessary to gain a deeper understanding of health effects of alpine landscapes. Additional studies may also assess physical health parameters such as cortisol measurements (Lee et al. 2009), heart rate variability (Frohmann et al. 2010) or brain activities (Johansson et al. 2014).

5. <u>Dissemination</u>

Published SCI papers

Arnberger, A.; Eder, R.; Allex, B.; Hutter, HP.; Wallner, P.; Bauer, N.; Zaller, JG.; Frank, T. (2018). Perceived health benefits of managed and unmanaged meadows in a mountain biosphere reserve - an experimental study in the Austrian Alps. ECO MONT. 10(1): 5-14.

Arnberger, A.; Eder, R.; Allex, B.; Ebenberger, M.; Hutter, H.-P.; Wallner, P.; Bauer, N.; Zaller, J.G.; Frank, T. (2018). Health-Related Effects of Short Stays at Mountain Meadows, a River and an Urban Site—Results from a Field Experiment. INT. J. ENVIRON. RES. PUBLIC HEALTH, 15, 2647.

Hussain, R.I.; Walcher, R.; Brandl, D.; Jernej, I.; Arnberger, A.; Zaller, J.G.; Frank, T. (2018). Influence of abandonment on syrphid assemblages in mountainous meadows. J APPL ENTOMOL. 142(4): 450-456.

Hussain, R.I.; Walcher, R.; Brandl, D.; Arnberger, A.; Zaller, J.G.; Frank, T. (2018). Efficiency of two methods of sampling used to assess the abundance and species diversity of adult Syrphidae (Diptera) in mountainous meadows in the Austrian and Swiss Alps. EUR J ENTOMOL. 115: 150-156.

Walcher, R.; Karrer, J.; Sachslehner, L.; Bohner, A.; Pachinger, B.; Brandl, D.; Zaller, J.G.; Arnberger, A.; Frank, T. (2017). Diversity of bumblebees, heteropteran bugs and grasshoppers maintained by both: abandonment and extensive management of mountain meadows in three regions across the Austrian and Swiss Alps. LANDSCAPE ECOL. 32(10): 1937-1951.

Scientific papers in revision

Bohner, A.; Karrer, J.; Walcher, R.; Brandl, D.; Michel, K.; Arnberger, A.; Frank, T.; Zaller, J.G. Ecological responses of mountain meadows to long-term abandonment in three regions in the Eastern Alps.

Scientific papers submitted

Hussain, R.I.; Walcher, R.; Eder, R.; Allex, B.; Wallner, P.; Hutter, H.P.; Bauer, N.; Arnberger, A.; Zaller, J.G.; Frank, T. Linkages between biodiversity attributes, perceived health benefits and cultural ecosystem services among grasslands management in the Austrian and Swiss Alps.

Jernej, I.; Bohner, A.; Walcher, R.; Hussain, R.I.; Arnberger, A.; Zaller, J.G.; Frank, T. Impact of land use change in mountain semi-dry meadows on plants, litter decomposition and earthworms.

Walcher, R.; Hussain, R.I.; Sachslehner, L.; Bohner, A.; Jernej, I.; Zaller, J.G.; Arnberger, A.; Frank, T. Long-term abandonment of mountain meadows affects bumblebees, true bugs and grasshoppers: A case study in the Austrian Alps.

Scientific papers in preparation
Walcher, R.; Hussain, R.I.; Karrer, J.; Bohner, A.; Brandl, D.; Zaller, J.G.; Arnberger, A.; Frank, T. Effects of management cessation on hoverflies across Austrian and Swiss mountain meadows.

Walcher, R.; Sachslehner, L.; Hussain, R.I.; Zaller, J.G.; Arnberger, A.; Frank, T. Assessing grasshopper (Orthoptera; suborders Ensifera and Caelifera) communities – a comparison of a visual-acoustic and a novel, purely acoustic, soundscape method.

(Additional manuscripts are in preparation).

Popular scientific journals
Arnberger, A.; Eder, R.; Böhm, S.; Ebenberger, M. (2015). Healthy Alps: Erfassung der Erholungswirkung einer bewirtschafteten Bergwiese in der Steiermark. Medi.um, 4, 4-4.

Frank, T. (2018). Verlust der Artenvielfalt, Pestizide und menschliches Wohlbefinden. Gyn-Aktiv, 6, 42-42.

Hutter, H.P., Weitensfelder, L., Wanek, G., Wallner, G., Eder, R., Allex, B., Bauer, N., Zaller, J.G., Frank, T., Arnberger, A. (2018): Healthy Alps: Effekte alpiner Wiesen auf die kognitive Leistungsfähigkeit. Medi.um, 02-03/2018, 14-14.

Congress contributions
Arnberger, A., Eder, R., Allex, B., Hutter, H.-P., Bauer, N., Hofmann, M., Zaller, J.G., Frank, T. (2017). Restorative effects of managed and unmanaged Alpine meadows. In: Austrian Research and Training Centre for Forests, Natural Hazards and Landscape & Institute of Landscape Development, Recreation and Conservation Planning, University of Natural Resources and Life Sciences, Vienna (Eds.). Proceedings of the 3rd International Conference on Landscape and Human Health: Forests, Parks and Green Care, p. 44; ISBN: 978-3-902762-79-5.

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