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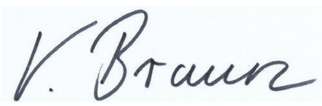
The Covid-19 pandemic is a human tragedy which has changed life for everybody. In our last editorial, Matej Gabrovec wrote about the impact of Covid-19 on the protected area near his home, where many local people were enjoying nature thanks to lockdown. During the summer months, restrictions on the mobility of people in Central Europe were eased, but many states have now reinstated the restrictions due to rising numbers of Covid-19 infections. These restrictions had and still have far-reaching consequences not only on our daily lives and the economy, but also on biodiversity, climate change and human wellbeing. Some conservationists have already written about the impact the pandemic is having on protected areas. Corlett et al. (2020) state that the first concern must be human health and the containment of the pandemic, but that we also need to be thinking ahead to the resumption of conservation practice and education. Hockings et al. (2020) argue that protected areas will have an important role in a resilient planetary recovery from Covid-19, advancing human and economic health and wellbeing. Concerns about Covid-19 are also present in this issue of the journal, where Martha E. Apple describes the impact of coronavirus restrictions on alpine field work in the state of Montana in the US.

Other articles in this issue deal with various concerns relating to mountain protected areas. Discussions of biodiversity, conservation conflicts, and various aspects of tourism take readers to protected areas in Malaysia, Turkey, Kosovo, Poland, Slovakia, the USA and Chile. The study by Azlan Abas & Laily Din explores lichen diversity, composition and distribution along elevational gradients in the tropical mountain forest of Gunung Nuang, Malaysia. Some species are threatened by the loss of forest and by human activities and need to be protected and managed to ensure their survival. Schabetsberger et al. present a preliminary limnological characterization of two neighbouring alpine lakes, Leqinat and Drelaj, in the Bjeshkët e Nemuna National Park (Kosovo). The lakes differ in their hydrology and species assemblages in the open water. Fish introduction poses a threat to the lakes and could alter the community of prey organisms very significantly. García et al. introduce the reader to the mountain ecosystems of the Southern Central Andes where tensions between traditional herding practices and conservation policies are evident. The herding practices have existed since pre-Hispanic times and have contributed to the production of particular ecosystems, yet official conservation policies create conflicts and affect the herders' territorial rights. The study by Drage et al. takes us to the String and Leigh Lakes area in the Grand Teton National Park, in the Rocky Mountains in the US. The area is a favoured alpine destination for numerous day-trippers and an important starting point for backcountry and overnight recreational users. The results show that overnight recreational users gain more positive experiences within the Recommended Wilderness, away from high-density, trailhead-proximate areas. A case study from the Tatra National Parks in Poland and Slovakia by Hibner et al. reveals skiers' expectations as a challenge for managers of protected areas. In looking at skiers' opinions and complaints regarding the resorts, the authors found that there was a high level of acceptance of further development by the respondents to their survey, who didn't perceive the skiing infrastructure as a factor that decreased the landscape value. The implementation of further restrictions in the functioning of the ski resort, although a reasonable management strategy concerning environmental factors, is unlikely owing to political and economic pressure. Finally, Turgut et al. introduce a case study in Hatila Valley National Park, Turkey in which indicators for natural characteristics and landscape values were used to identify mountain forest roads as potential hiking routes.

Time will tell whether Covid-19 will be reflected in future articles in *eco.mont*, but after the virus has cut so deeply into our lives, we can assume that this will be the case. The ubiquitous impact of the pandemic on all aspects of human society offers has given rise to unforeseen research opportunities. The long-term impact of the pandemic on socio-ecological systems cannot be predicted, but systems studied before the pandemic will be closely monitored during and after it. Studies presented in the current issue of *eco.mont* may well lead to new insights and knowledge about human-nature interaction viewed through the lens of the pandemic.



Valerie Braun

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Diversity, composition and distribution of lichens along elevational gradients in the tropical mountain forest of Gunung Nuang, Selangor, Malaysia.

Azlan Abas & Laily Din

Keywords: biodiversity, epiphytic lichen, Malaysia, montane forest, tropical lichen

Abstract

This study aims to explore how lichen diversity, composition and distribution vary with altitude, and environmental factors (temperature and relative humidity). The study was conducted in the forest of Gunung Nuang, Selangor at five sites (at different altitudes) which were chosen as sampling stations. Forty-four lichen species were identified. Their diversity, composition and distribution correlated significantly with the forest's altitude and environmental factors, increasing at higher altitudes. While Graphidaceae and Physciaceae species were present at all altitudes, the dominant species changed according to altitude: some species of Parmeliaceae were found only at higher altitudes (601–1 493 m), while C. *xanthina* and a few species from Physciaceae were present only at lower altitudes (0–600m). These findings will provide additional information about the lichens of the tropical montane forest of Malaysia, enhancing knowledge on how to manage and sustain lichens in this type of forest.

Profile

Protected area

Gunung Nuang

Mountain range

Titiwangsa Main Range of Peninsular Malaysia

Introduction

Lichen diversity and species composition are varied, depending on environmental conditions and type of ecosystem (Nimis et al. 2002). Lichens can be found growing from low-tide level to mountain summits, and from arctic and desert to tropical climate areas (Nash 2008; Abas et al. 2018). Lichens are unique dual-organisms (comprising fungus as mycobiont, and blue-green algae or cyanobacteria as photobiont) which can show immediate responses to changes in environmental conditions (Abas et al. 2020). Some species are able to grow under harsh environmental conditions, while even slight changes in their environment cause others to perish. Lichens have three different growth forms: crustose, which grow attached to the substratum; foliose, which are leaf-like and loosely attached to the substratum; and fruticose, which are bush-like, and either hang, or grow upright on the substratum (Gaurav & Upreti 2016). As well as their ecological roles, lichens with their metabolites have numerous biological properties, including antimicrobial, antiprotozoal, antiviral, anti-proliferative, anti-inflammatory, analgesic, antipyretic, anti-termite, antioxidant, cytotoxic, enzyme inhibitory, insecticidal, wound healing, and antitumor properties (Yilmaz et al. 2004; Kosanić et al. 2013; Rajan et al. 2016).

Malaysia, a tropical country, is known for its diverse and unique species of flora and fauna, but the study of lichen in Malaysia is far from complete (Abas & Wang 2017). Most tropical lichens grow abundantly only at higher altitudes, such as in the montane forest, on hill summits, and in mountain ranges (Chongbang et al. 2018). The first lichen samples in Malaysia were recorded by Beccari (1904), who carried out a study on lichen in Sarawak. Galloway et al. (1994) prepared a bibliography of Malaysian lichenology comprfFising 90 entries, and an additional list comprising a further 192 entries (Galloway et al. 1997). Seven genera of lichens collected from Bario, Sarawak were identified by Din et al. (1998). Zakaria et al. (2010) reported on the morphology and chemical constituents of *Cladia aggregata* collected from Gunung Jerai, Kedah. The chemical components of a few specific samples of *Heterodermia flabellata* and *Heterodermia leucomela* from Gunung Jerai, Kedah and the Cameron Highlands, Pahang were described by Din et al. (2010). Lichens of North Eastern Langkawi and Gunung Machincang, Kedah were investigated by Zulkifly and Merican (2005), and lichen diversity and species composition (36 species were found) at Gunung Machincang were studied by Zulkifly et al. (2011). Urban lichen diversity and distribution in Kuala Lumpur have been analysed by Abas & Awang (2017), and in Kota Kinabalu by Abas et al. (2020). Abas et al. (2019a) have reported 12 lichen species in Teluk Nipah, Pulau Pangkor, Perak as well.

Studies carried out in tropical forests have shown that environmental factors (e.g. temperature and humidity) and the forests' structure will vary significantly with altitude (Boonpeng et al. 2017). Other research has shown that lichen diversity, composition and distribution correlate significantly with, and are influenced by, environmental factors and the forest structure (Sulaiman et al. 2018; Abas et al. 2019b). Altitude has a strong connection with, and significant effects on, lichen diversity, composition and distribution. The results of the present study are consistent with the findings of Zulkifly et al. (2011), Upadhyay et al. (2018), and Abas et al. (2019a, b), who all concluded that lichen diversity, composition and distri-

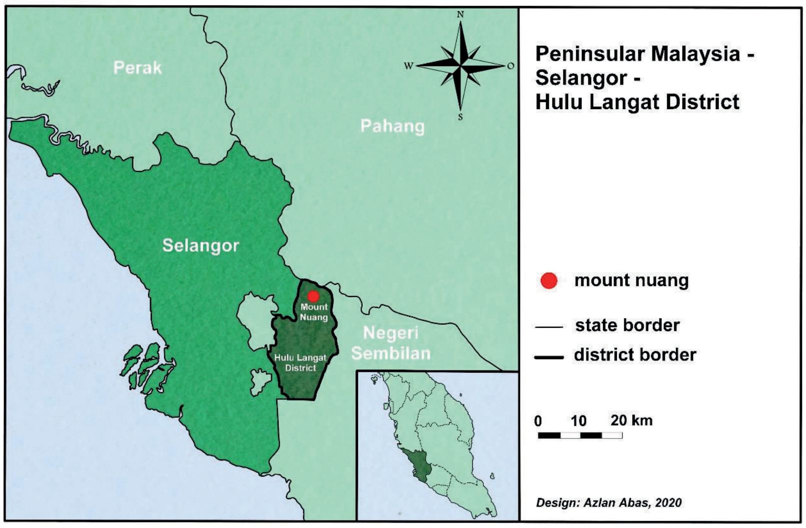

Figure 1 – Map of Gunung Nuang, Selangor

bution increase significantly, the higher the forest's altitude.

In Malaysia, there has been limited study of the specific lichens of tropical montane forest, and few studies are similar to our own. In this respect, Zulkifly et al. (2011) on Gunung Machincang, Langkawi, and Shahpuan et al. (2019) on foliicolous lichen in the Borneo Rainforest, Sabah, stand out. However, Shahpuan et al.'s study of composition and distribution is only very basic. Abas et al. (2019a, b) and Abas & Awang. (2017) focused solely on lichen diversity in the lowland area, and more specifically on how lichen diversity was affected by air pollution and urbanization.

Information on lichen diversity, composition and distribution is still lacking for montane forests, especially in Malaysia. In addition, the uncontrolled development of land and recreational activity at Gunung Nuang have affected the diversity of the fauna. Hence, this study aims to identify and analyse lichen diversity, composition and distribution in Gunung Nuang, Selangor. It also aims to investigate the spatial distribution of lichens with regard to different elevations of Gunung Nuang. It could also raise awareness of how environmental changes at Gunung Nuang have affected the diversity of the mountain's flora and fauna.

Study area

Gunung Nuang is located in Hulu Langat District, Selangor. Rising to 1 493 m (4 898 feet), Gunung Nuang is the highest mountain in the state of Selangor, while part of its peak lies in the Titiwangsa Main Range of Peninsular Malaysia. The peak also borders on Pahang state and is close to the Pahang-Selangor-Negeri-Sembilan border tripoint. Gunung Nuang is covered by an extensive montane forest, making it an attractive tourist destination for hiking and mountain climbing. There are three hiking routes to the peak, all of them built by the Malaysian Department of Wildlife and National Parks. Two of them start in Selangor – one at Kuala Pangsun in Hulu Langat, the other at Kampung Kemensah in Gombak. The third route originates in Bukit Tinggi. The Genting Highlands in Pahang are visible (especially at night) from the peak of Gunung Nuang, which is accessible from the Kuala Pangsun route. The climb involves a two-hour hike on a very steep track, then an optional stop at Camp Lolo, followed by a four-hour trek to the start of the climb proper and a six-hour push to the summit. Gunung Nuang is vulnerable to global climate change. In 1990, Gunung Nuang's lowest recorded temperature was 14°C, but in 2015 it had increased to 18°C. This temperature increase is due also to the development, since 1995, of the nearby Semenyih Dam, and the numerous recreational activities conducted in the region since 1997, with the opening of its famous trail (Forest Department Peninsular Malaysia 2019).

The study was conducted at five sites along the hiking trail of Gunung Nuang, Selangor, between the Kuala Pangsun entrance and Gunung Nuang's peak (Figure 1). According to Zulkifly et al. (2011), the ecological stands of tropical forests vary every 200–400 m. In order to observe the change in lichen diversity, distribution and composition along elevational

Table 1 – Environmental factors for each sampling site. Source: Malaysia Meteorological Department (2019).

Site	Coordinates	Altitude [m]	Relative Humidity [%]	Temperature [°C]
1	3.216894 N, 101.883468 E	0–299	80.7	32.5
2	3.235284 N, 101.901734 E	300–599	81.1	31.8
3	3.246242 N, 101.905081 E	600–899	82.5	27.1
4	3.256777 N, 101.905365 E	900–1 199	87.9	23.2
5	3.263782 N, 101.903943 E	1 200–1 493	90.3	21.3

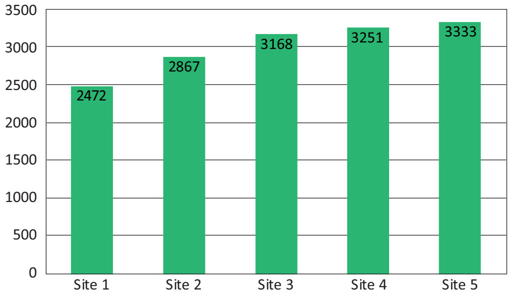

Figure 2 – The Shannon-Weiner Index.

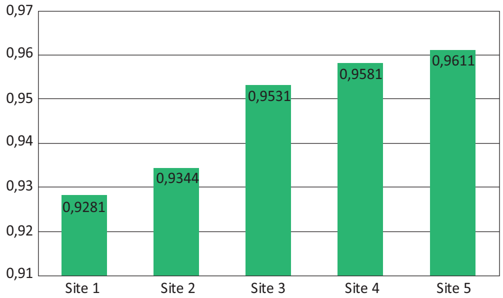

Figure 3 – Simpson's Diversity Index.

gradients, therefore, this study used mostly 300 m intervals in selecting the study sites: Site 1 (0–300 m a.s.l.), Site 2 (300–599 m a.s.l.), Site 3 (600–999 m a.s.l.), Site 4 (1 000–1 299 m a.s.l), and Site 5 (1 300–1 493 m a.s.l.). The study area has a warm tropical climate, with annual average minimum and maximum temperatures of 19ºC and 33ºC respectively; monthly rainfall can be as low as zero in January and as high as 342 mm in December, when there is heavy monsoon rain, which starts in November (Malaysian Meteorological Service 2018). The study sites included protected tropical rainforest reserves; diverse species and a variety of forest structures are distributed throughout the region. In addition, Gunung Nuang is also a protected area (Category VI: Protected Area with sustainable use of natural resources) under the management of Selangor State Foresty Department.

Method

Sampling procedures and data analysis

The sampling of lichens was carried out at five sites along the trail that leads to the summit of Gunung Nuang. The environmental conditions of the study sites, such as temperature, humidity and altitude, were recorded (see Table 1). The sampling plot at each site was determined using a stratified random sampling method for an area of 20 m x 20 m, or 400 m^2, the size being based on a preliminary site investigation, as recommended by Khaien et al. (2018). Only epiphytic lichens were collected; the coordinates of the lichens were noted.

The lichen samples were taken to the Algae Lab at the National University of Malaysia (UKM) for identification by observing their morphological traits under stereoscopic and optical microscopes. The external characteristics of the lichens, such as the lobes, thallus, pycnidia, rhizines, ciliates and apothecia, were analysed thoroughly (Nimis et al. 2002). A spot test was used to determine the presence of acid (the lichen's secondary metabolites) in the medulla and cortex (Sipman 2009). All the data acquired from both techniques (morphological observation and spot test) were recorded and incorporated into the Lichen Herbarium of UKM, Malaysia.

Lichen species richness and composition were calculated and presented as percentages of the total number of samples, using a cluster bar chart. Next, an independent t-test was used to examine the difference in species composition between lower- and higher-frequency species (Sevgi et al. 2019). Species diversity was analysed using the two most common diversity indices – the Shannon-Weiner Index and Simpson's Diversity Index. The Shannon-Weiner Index is more useful in identifying rare species; Simpson's Diversity Index is more useful and effective for more abundant species (Simpson 1949; Barnes et al. 1998). The Similarity Index was used to investigate which lichens were endemic to certain sites (according to altitudinal difference). Correspondence Analysis (CA) was used to illustrate the variation in the species distribution and abundance along the elevational gradient in Gunung Nuang, Selangor (Benzecri 1973). All the statistical analyses were performed using the R program version 4.0, and SPSS statistical software version 23.0.

Results

Lichen species diversity

A total of 44 lichen species belonging to 11 families were collected from Gunung Nuang, Selangor. The highest number of species collected was at site 5 (35 species), followed by Site 4 (32), Site 3 (31), Site 2 (25), and lastly Site 1 (21).

The diversity of lichen species was determined using the Shannon-Weiner Index (Figure 2) and Simpson's Diversity Index (Figure 3). The diversity varied significantly among sampling sites (ANOVA, $p < 0.05$), with Site 5 having the greatest diversity, showing that lichen species diversity tends to increase with increased altitude.

Lichen species composition and distribution

The lichen species composition and distribution varied within and among sampling sites. Bar charts were produced to analyse lichen distribution and composition for each of the sampling sites (Figure 4: Site 1; Figure 5: Site 2; Figure 6: Site 3; Figure 7: Site 4; Figure 8: Site 5). Lichen species from Graphidaceae, Physiaceae, Pyrenulaceae and Chryptotaceae were found at all sampling sites, but the particular species found varied from site to site. Some species were found at only one site – for example, *Chrysothrix xanthina* at Site 1, and *Parmotrema mellissñ* and *Parmelia sulcata* at Site 5.

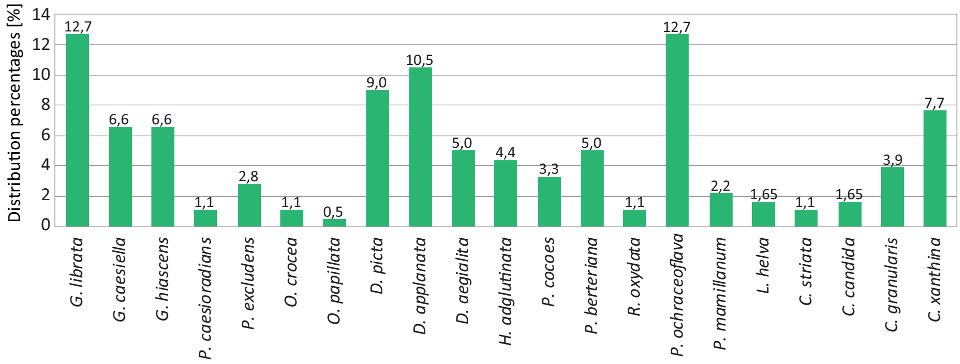

Figure 4 – Distribution of lichen species for Site 1 (0–300m).

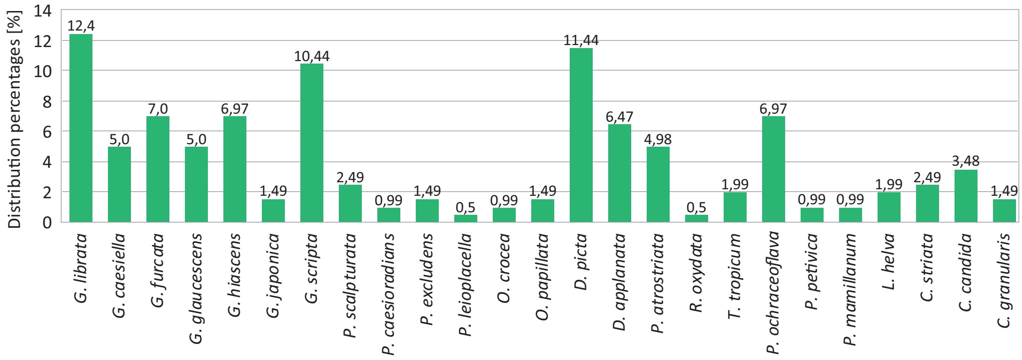

Figure 5 – Distribution of lichen species for Site 2 (301–600m).

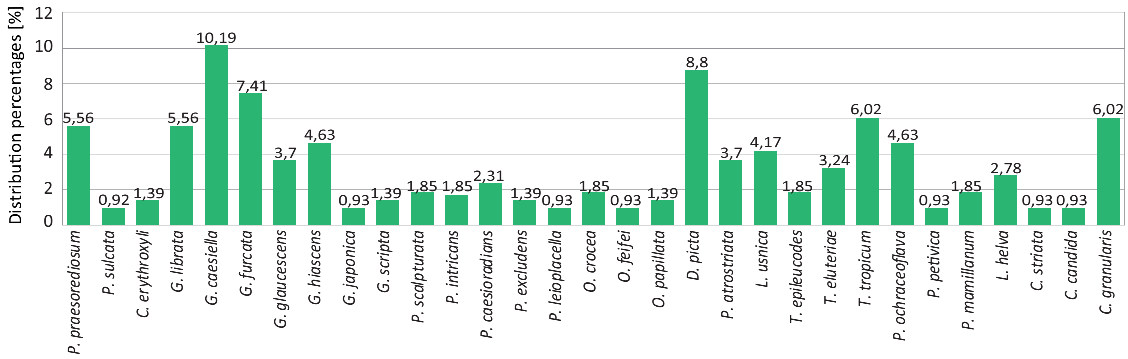

Figure 6 – Distribution of lichen species for Site 3 (601–900m).

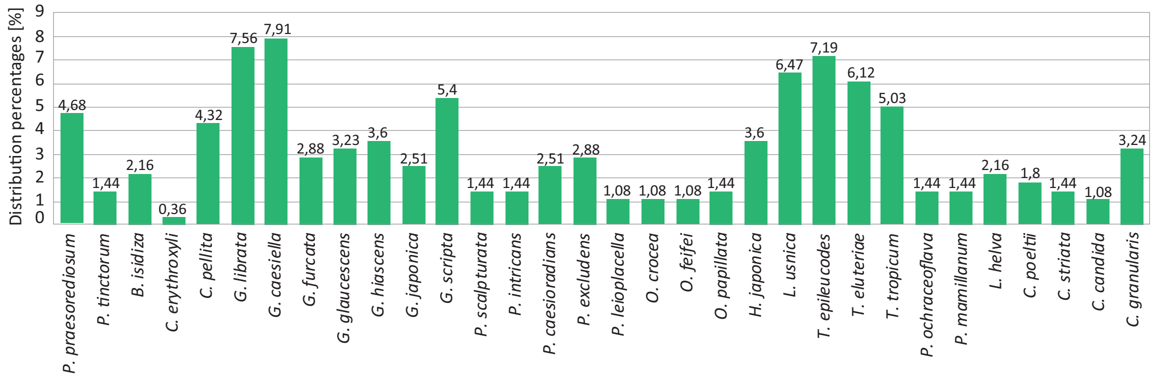

Figure 7 – Distribution of lichen species for Site 4 (901–1 200m).

As shown in Figure 4, there are two dominant species at Site 1, namely *Graphis librata* and *Pyrenula ochraceoflava* (both 12.7% of samples). These are followed by *Dirinaria applanata* (10.5%), *Dirinaria picta* (9.0%), *Chrysothrix xanthina* (7.7%), *Graphis casiella* (6.6%), *Graphis hiascens* (6.6%), *Dirinaria aegialita* (5.0%), and *Pyxine berteriana* (5.0%). Other species – *Phaegraphis caesioradians* (1.1%), *Rinodina oxydata* (1.1%), *Ocellularia papillata* (0.5%) – had percentages significantly below 5%. The majority of the samples from Site 1 were from the

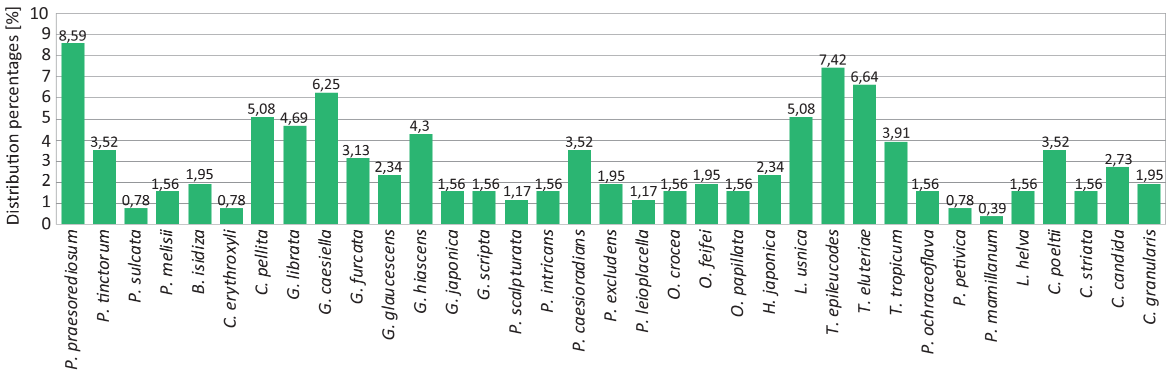

Figure 8 – Distribution of lichen species for Site 5 (1 201–1 493 m).

Table 2 – The Similarity Index data for each sampling site

	Site 1	Site 2	Site 3	Site 4	Site 5
Site 1		0.570681	0.433249	0.331155	0.28833
Site 2	0.570681		0.623501	0.480167	0.424508
Site 3	0.433249	0.623501		0.663968	0.631356
Site 4	0.331155	0.480167	0.663968		0.816479
Site 5	0.28833	0.424508	0.631356	0.816479	

crustose group, and only *Chrysothrix xanthina* was from the leprose group. Graphidaceae and Physciacea are the dominant lichen families for Site 1, both families being represented there by at least five species.

At Site 2, as Figure 5 shows, the most dominant species was again *Graphis librata*, with 12.4%. This was followed by *Dirinari picta* (11.44%), *Graphis scripta* (10.44%), *Graphis furcata* (7.0%), *Graphis hiascens* (6.97%), *Pyrenula ochraceoflava* (6.97%), *Dirinaria applanata* (6.47%), *Graphis caesiella* (5.0%), and *Graphis glaucescens* (5.0%). The lowest figures for Site 2 were for *Phaeographis leioplacella* (0.5%) and *Pyrenula petivica* (0.99%). The majority of the species collected at the site were from the crustose lichen group. Graphidaceae and Physciaceae are again the most dominant families here, represented by at least 5 species each.

Figure 6 shows the composition distribution of lichen species for Site 3. The most dominant species was *Graphis caesiella*, with 10.19%, followed by *Dirinaria picta* (8.8%), *Graphis furcata* (7.41%), *Trypethelium tropicum* (6.02%), *Cryptothesia granularis* (6.02%), and *Graphis librata* and *Pramotrema praesorediosum* (both 5.56%). *Coccocarpia erythroxyli* and *Cryptothesia striata* were among the lichen species that scored less than 5%. The majority of the lichens found here belong to the crustose group, but foliose lichens such as *Coccocarpia erythroxyli* and *Pramotrema praesorediosum* were also collected at this site. The most dominant family was Graphidaceae (12 species found); 2 species of Parmeliaceae and 1 of Coccocarpiaceae were also found at Site 3.

Site 4 recorded 32 lichen species (see Figure 7). The most dominant species here was *Graphis caesiella* (7.81%), followed by *Graphis librata* (7.58%), *Trypethelium epileucodes* (7.19%), *Lepraria usnica* (6.47%), *Graphis scripta* (6.12%), and *Trypethelium tropicum* (5.4%). *Coccocarpia erythroxyli* and *Parmotrema tinctorum* both accounted for less than 5% of samples. Crustose lichens dominated, but the foliose group was also represented by several species. Graphidaceae was the dominant lichen family at Site 4; other species belonged to the Collemataceae family.

Figure 8 shows the lichen species composition and distribution for Site 5. The most dominant species was *Parmotrema praesorediosum* (8.59%), followed by *Trypethelium epileucodes* (7.42%), *Trypethelium eluteriae* (6.64%), *Graphis caesiella* (6.25%), *Coccocarpia pellita* and *Lepraria usnica* (5.08%). *Bulbothrix isidiza* and *Parmotrema mellissii* each accounted for less than 5% of samples. Both crustose and foliose lichen groups were found abundantly. Graphidaceae was the dominant lichen family, but Parmeliaceae were also well represented.

The Similarity Index for the sampling sites

The Similarity Index (Table 2) showed how the sites differed according to the presence or absence and abundance of species. The similarity between Sites 4 and 5 was higher than for Sites 3 and 4, or for Sites 3 and 5. Sites 1 and 5 have the lowest similarity (less than 30%).

The sampling sites can be classified into two main groups, based on their ecological distances. A dendrogram (Figure 9) shows that the ecological distances between Sites 3 and 5, and between Sites 1 and 2 were the closest. Thus altitudes of 601–1 493 m can be considered as one group, with altitudes of 0–600 m falling into a separate group.

Effects of altitude on lichen species diversity, composition and distribution

Lichen diversity, composition and distribution varied according to altitude, and environmental conditions such as humidity and temperature. The differences between lichen diversity and abundance correlated significantly with the location's altitude, temperature and humidity. Altitude and environmental factors had a stronger effect on species distribution from 0 to 1 493 m. Correspondence analysis (CA) showed that there was a very clear correlation between species diversity and distribution on the one hand, and sam-

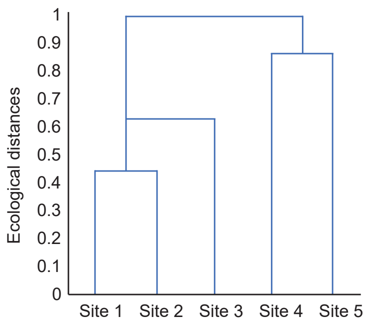

Figure 9 – Dendrogram showing the similarity of species abundance for all sites.

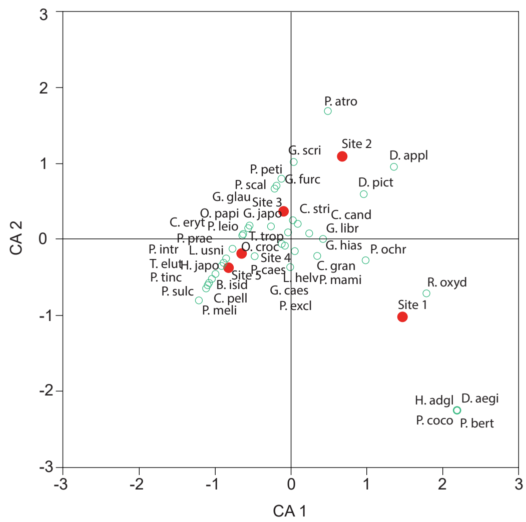

Figure 10 – CA showing the relationship between species distribution and elevation for each sampling site.

pling site altitude on the other (Figure 10). The first and second axes of CA show more than 60% of the total fitted variation. The weighted average scores for lichen diversity at different altitudes vary greatly, with the abundance and distribution of lichens spreading into different quarters of the ordination graph. Where a sampling point in the graph is located close to a particular species, that species is expected to be highly abundant and frequent at the sampling point. For example, *Chrysothrix xanthina, Pyxine cocoes, Pyxine berteriana, Hyperphyscia adglutinata* and *Dirinaria aegialita* are located close to Site 1, which means that these species are abundant only at Site 1; a higher altitude than that of Site 1 was not an appropriate condition and habitat for this species. It should be noted that a small vector angle between species corresponds to a strongly positive association, and a 180° vector angle between species corresponds to a negative correlation.

Discussion

Lichen species that belong to the Graphidaceae and Physciaceae families were present at all forest altitudes (Sites 1–5), but the specific species that emerged were different. For example, among the Graphidaceae *Phaeographis intricans* and *Graphis japonica* were present only at 601–1 493 m (Sites 3–5), while *Heterodermia japonica*, of the Physciaceae family, was found only at 901–1 493 m (Sites 4 and 5). On the other hand, *Dirinaria aegialita, Pyxine cocoes*, *Pyxine berteriana* and *Hyperphyscia adglutinata* (all Physciaceae) were present at 0–300 m (Site 1) only. Similarly, *Chrysothrix xanthina* (a leprose lichen) was found only at 0–300 m. These differences can be explained by the differing environmental factors between altitudes. For example, altitudes of 0–300 m are lowland areas, which are vulnerable to air pollution and human activities. Anthropogenic activities lead to increased nitrogen and sulphur in the atmosphere, and only acidophile and nitrophile types of lichens can survive in high concentrations of these elements. Parmeliaceae, Coccocarpiaceae and Collemataceae species were present only at high altitudes (601–1 493 m; Sites 3–5). These three families are foliose-type lichens, which only grow at low temperatures in areas of high humidity. A study by Sipman (2009) concluded that foliose-type lichens can grow abundantly at higher altitudes in regions with tropical climates. In addition, most of the Parmeliaceae, such as *Parmotrema tinctorum*, *Parmotrema mellissii* and *Coccocarpia pellita*, are highly sensitive to air pollution, which is why these species are found commonly only in pristine and remote forests.

Species distribution correlated strongly with climatic conditions, especially temperature and relative humidity. Furthermore, the abundance of species has been proved to vary according to altitudinal zone. Our study found that *Chrysothrix xanthina, Pyxine cocoes, Pyxine berteriana, Dirinaria aegialita, Rinodina oxydata* and *Hyperphyscia adglutinata* grew exclusively at altitudes of 0–300 m, with average coverage of 33%. *Dirinaria picta, Dirinaria applanata* and *Physcia atrostriata* grew in abundance at 301–600 m, where they were 55% more abundant than at lower altitudes. Graphis japonica and Cryptothesia striata were found exclusively at 601–900 m, with average coverage of 44% for both species. Several Parmeliaceae, Coccocarpiacea and Collemataceae species, such as *Parmotrema tinctorum, Parmotrema praesorediosum, Parmotrema mellissii, Bulbothrix isidiza, Parmelia sulcata, Coccocarpia pellita, Coccocarpia erythroxyli* and *Collema poeltii*, were found thriving at 901 m and above, with average coverage of 53%.

Our study found that some lichen species, such as *Cryptothesia granularis, Ocellularia crocea, Graphis librata* and *Graphis caesiella*, were present at almost all altitudes. This is in agreement with the findings of Zulkifly et al. (2011), who found that some Graphidaceae and Cryptothesiacea species were common in montane forest at all altitudes. This may be because of the ability of this lichen family to adapt, making it less vulnerable to its surroundings even if there are changes in the quality of the environment (Abas et al. 2018).

Geographically, tropical forests are located in equatorial regions (Khamis & Nizam 2013). This gives the forests a unique structure which makes them suitable habitats for thousands of endemic bryophyte and lichen species (Sevgi et al. 2019). The number of lichen species found in Gunung Nuang, Selangor (44 species) was significantly higher than that found for the montane forest at Gunung Machincang, Langkawi (33 species) (Zulkifly et al. 2011). Somewhat fewer lichen species again were found in Araucaria forest of Southern Brazil (27 species) (Kaffer et al. 2009). The varying numbers of lichen species present in different areas may be due to physical geographical boundaries and climatic variation.

Conclusion

In this study, we found that lichen species diversity, composition and distribution in Gunung Nuang, Selangor increase with the montane forest's altitude. The dominant lichen species also varied according to altitude. Although the diversity does not change significantly between 0 and 600 m (Sites 1 and 2), at altitudes of 601–1 493 m (Sites 3–5) it did do so, with the presence here of a few endangered lichen species. Given the link between altitudinal gradient and environmental factors (lower temperature and higher humidity at higher altitudes) which are essential for lichen growth and forest productivity, our study's findings are consistent with earlier studies that show a positive correlation between lichen species and forest altitude. The study also verified that some lichen species present in Gunung Nuang, Selangor, such as *Parmotrema mellissii, Collema poeltti* and *Coccocarpia pellita*, are threatened by the loss of forest and by human activities. These species need to be protected and managed to ensure their survival in this tropical montane forest.

Our findings add to knowledge of Malaysia's lichens, and have implications for phytogeography and ecology, especially montane forest ecology, giving insight into how elevation gradient and variation of environmental factors can determine the diversity, composition and distribution of lichens. The results of our study will thus be of use in determining appropriate management techniques in tropical regions more widely.

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First limnological characterization of Lakes Leqinat and Drelaj in Bjeshkët e Nemuna National Park, Kosovo

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Keywords: Balkan Peninsula, conservation, diversity, Ichthyosaura alpestris, *plankton*

Abstract

The Balkan Peninsula is a biodiversity hotspot and hosts numerous mountain lakes, which offer a refuge for a multitude of species. However, previous pristine habitats have been deeply affected by anthropogenic change, such as non-native fish introductions, which calls for multi-species considerations in the last remaining unaltered habitats. We carried out abiotic measurements and biodiversity assessments in two neighbouring alpine lakes, Lakes Leqinat and Drelaj in the Bjeshkët e Nemuna National Park in Kosovo, in August 2018. Lake Leqinat is a permanent, stratified water body and exhibits weak oxygen depletion below 3 m. Phytoplankton was dominated by chrysophycean, cryptophycean and chlorophycean algae. Zooplankton consisted of five rotifer species and *Daphnia longispina*. A mark-recapture experiment yielded a population of alpine newts (*Ichthyosaura alpestris*) of nearly 4 000 adult individuals. In contrast, cold water from the surrounding karst seeps into Lake Drelaj, which is a well-oxygenated temporary lake. Hence phytoplankton and zooplankton biomasses were considerably lower than in Lake Leqinat. Phytoplankton was dominated by cryptophycean, chlorophycean, and bacillariophycean algae. Zooplankton consisted of the diaptomid copepod *Mixodiaptomus tatricus*, the cladoceran *Daphnia rosea*, and the anostracan *Chirocephalus diaphanus*. Conservation efforts should ensure that Lake Leqinat remains unstocked as introduced fish would probably destroy the natural community.

Profile

Protected area

Bjeshkët e Nemuna National Park

Mountain range

Bjeshkët e Nemuna / Prokletije

Country

Kosovo

Introduction

The Balkan Peninsula is as an important biodiversity hotspot (Griffiths et al. 2004). Mountain lakes harbour unique invertebrate communities often containing large zooplankton species like diaptomid copepods or anostracans (Belmonte et al. 2018; Mancinelli et al. 2019). Under natural, fish-free conditions, amphibians are the native top predators of these aquatic ecosystems (Lejeune et al. 2018; Schabetsberger & Jersabek 1995; Schabetsberger et al. 2006). Among them, newts show an impressive pattern of intraspecific diversity, with several locally described subspecies and phenotypes, especially in Montenegro (see e.g. Radovanović 1951, 1961; Džukić et al. 1990). In neighbouring Kosovo, Bjeshkët e Nemuna National Park was established in 2012 in the Albanian Alps (the Prokletije, or *Accursed Mountains*). It encompasses 630 km^2 of mountainous terrain with dense deciduous and coniferous forests and alpine landscapes. So far, only two limnological studies have been conducted in the park, providing information on algae, zooplankton and macrozoobenthos within the Gjeravica Lakes (Živić et al. 1997; Urošević 1997).

The biggest threat to organisms in closed, permanent alpine lakes is stocking with alien fish species. Introduced fish can drive sensitive prey species to extinction (Knapp et al. 2001; Schindler & Parker 2002; Denoël et al. 2005, 2009; Tiberti et al. 2013; Ventura et al. 2017 and references therein). Large (>1 mm) and often pigmented alpine zooplankton organisms can coexist with natural amphibian predators (Schabetsberger & Jersabek 1995), but they disappear after stocking as a result of size-selective predation by alien fish (Brancelj 1999; Schabetsberger et al. 2009). Most native amphibian species also disappear after fish introduction, as their larvae and sometimes even the adults are particularly vulnerable (Pilliod & Peterson 2001; Knapp et al. 2001, 2005; Denoël et al. 2005, 2009; Miró et al. 2018). Although terrestrial landscapes often remain wild or traditionally managed, large declines of newts have been reported due to fish stocking, the primary local driver of their extirpation in the Balkans. This region is a hotspot for paedomorphic populations. Larval structures, such as gills and gill slits, are retained in adult animals. Many paedomorphic populations have become extinct in the Balkans, including all larger populations from Montenegro (Denoël et al. 2005, 2019). The loss of this intraspecific heterochrony represents a massive loss to diversity and there is an urgent need for better conservation of the remaining populations. Lakes in national parks containing newts are becoming rare and are therefore important targets for monitoring.

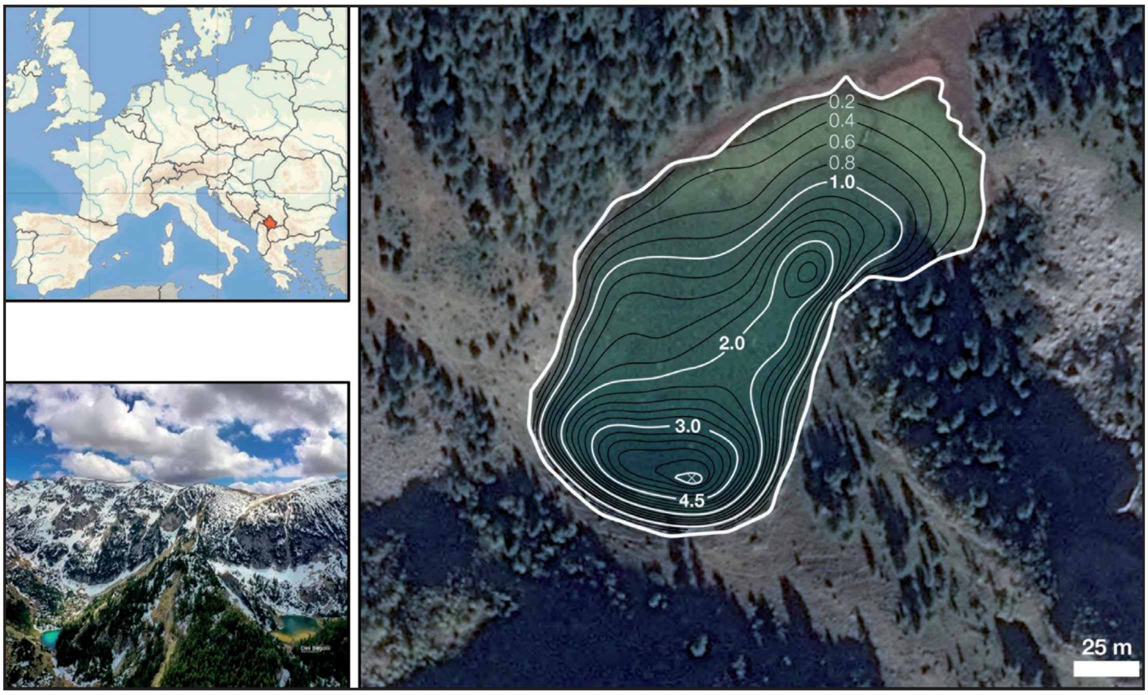

Figure 1 – Bathymetric map of Lake Leqinat © Google Earth Pro, CNES, Airbus. Insert on top left shows the geographical position of Kosovo in Europe (red) © David Liuzzo (Wikimedia Commons, lizenzed under CreativeCommons-Lizenz by-sa-2.0-de, http://creativecommons.org/licenses/by-sa/2.0/de/legalcode) and an aerial photograph of Lakes Leqinat (right) and Drelaj (left) looking South into the Albanian Alps. © Dini Begolli.

The aim of this preliminary, descriptive study was to support conservation efforts by characterizing the abiotic conditions and the biodiversity of phyto- and zooplankton as well as selected benthic organisms (see Darwall et al. 2018) of Lakes Leqinat and Drelaj in the Bjeshkët e Nemuna National Park. Given the important regulatory role of alpine newts (*Ichthyosaura alpestris*, Laurenti 1761), which are the top predators, and their decline in the region, their population size within Lake Leqinat was assessed. Based on the results, the probability of the survival of alien fish is discussed.

Materials and Methods

Study sites

The two study lakes in western Kosovo are pristine, fishless, high-elevation water bodies just below the timberline that had never been investigated before and could serve as refuges for endemic species. Lake Leqinat is permanent (42° 40.110' N, 20° 5.455' E; 1 860 m a.s.l.; Figure 1), whereas Lake Drelaj (42° 40.041' N, 20° 5.956' E; 1 801 m a.s.l., Figures 2A and 2B), 0.7 km east of Leqinat, is temporary and dries out in summer

Figure 2 – Lake Drelaj: A on 5 August 2018; B on 27 September 2018. © Linda Grapci-Kotori

or autumn. Both lakes are free of fish and inhabited by alpine newts.

Sampling

Lake Leqinat

Lake Leqinat was sampled from 1 to 4 August 2018. It was sounded along 6 transect lines (108 soundings in total) across the lake to generate a bathymetric map. Surface area and volume were estimated using Fields R package version 10.0 (Nychka et al. 2017). Profiles of temperature, pH, conductivity and oxygen were measured at 1-m intervals at the deepest point of the lake (4.5 m). Water samples were taken with a 1.5-l Schindler trap. Temperature (±0.1°C) was measured using a thermometer mounted inside the trap. Dissolved oxygen, oxygen saturation, pH and conductivity were measured with a HACH HQ30d portable multi-meter. Integrated plankton samples were collected by towing a 30-µm plankton net vertically from the bottom to the surface. Quantitative phytoplankton and zooplankton samples were collected with the Schindler trap at depths of 1, 2 and 3 m. For phytoplankton, samples of 100 ml of unfiltered water were preserved with Lugol's solution (Schwoerbel 1993) and kept in brown glass bottles. Zooplankton samples were filtered through a 30-µm mesh sieve and preserved in 4% formaldehyde. Macrophytes were collected in the littoral area. Samples for diatoms were taken from stones, sand and mud with a spoon or a pipette. Stones were scraped using a toothbrush and the surface biofilm was removed by gentle washing. Parts of submerged macrophytes and mosses were collected by hand and put into plastic vials. All samples were preserved using 4% formaldehyde. Rotifers and nematodes were sampled by snorkeling and towing a small plankton net (20 cm diameter, 30-µm mesh size) through the dense benthic algal mats. Adult trichopterans were caught with entomological nets in the vicinity of the lake. A capture-mark-recapture experiment (Chapman estimator, Krebs 1989) was conducted to estimate the total population size of alpine newts (*Ichthyosaura alpestris*) from Lake Leqinat. The newts were caught by sight with dip nets around the shoreline and by snorkeling in deeper parts of the lake. They were anaesthetized in MS222 (~50 mg l^{-1}) and marked by clipping one toe for release and recapture. This method does not affect newt survival (Arntzen et al. 1999) and toes regenerate fast (Gutleb 1991). Snout-vent length (i.e. from the tip of the snout to the end of the cloaca) and total length (i.e. from the tip of the snout to the end of the tail) of 30 males and females each were measured using ruler calipers. Adulthood and sex were determined on the basis of the shape of the cloaca (Denoël 2017).

Lake Drelaj

Lake Drelaj was sampled on 5 August 2018. The surface area was calculated from Google Earth Pro. Temperature, pH, conductivity and oxygen levels were

Table 1 – Phytoplankton species in Lakes Leqinat and Drelaj.

Lake Leqinat
Cyanobacteria
Aphanocapsa incerta (Lemmermann) G. Cronberg & Komárek
Aphanocapsa sp.
Gloeobacter violaceus Rippka, J.B. Waterbury & Cohen-Bazire
Microcystis sp.
Planktothrix sp.
Radiocystis geminata Skuja
Chlorophyceae
Botryococcus braunii Kützing
Desmodesmus brasiliensis (Bohlin) E. Hegewald
Didymocystis sp.
Elakatothrix genevensis (Reverdin) Hindák
Neglectella solitaria (Wittrock) Stenclová & Kastovsky
Oocystis sp.
Planktosphaeria gelatinosa G.M. Smith
Scenedesmus sp.
Tetraëdron minimum (A. Braun) Hansgirg
Conjugatophyceae
Cosmarium cf. *baileyi* Wolle
Cosmarium cf. *laeve* Rabenhorst
Cosmarium spp.
Gonatozygon brebissonii De Bary
Staurastrum sp.
Staurodesmus sp.
Zygnema sp.
Chrysophyceae
Mallomonas sp.
Pseudopedinella sp.
Uroglena sp.
Dinophyta
Ceratium hirudinella (O.F. Müller) Dujardin
Glenodinium sp.
Gymnodinium sp.
Cryptophyceae
Cryptomonas cf. *erosa* Ehrenberg
Cryptomonas marssonii Skuja
Bacillariophyceae
Achnanthes sp.
Cymbella sp.
Melosira varians C. Agardh
Nitzschia acicularis (Kützing) W. Smith
Stauroneis sp.

Lake Drelaj
Chlorophyceae
Pseudopediastrum boryanum (Turpin) E. Hegewald
Scenedesmus sp.
Conjugatophyceae
Gonatozygon brebissonii De Bary
Cryptophyceae
Cryptomonas erosa Ehrenberg + sp.
Cryptomonas cf. *marssonii* Skuja
Bacillariophyceae
Amphora ovalis (Kützing) Kützing
Cyclotella sp.
Cymbella spp.
Cymbopleura inaequalis (Ehrenberg) Krammer
Navicula sp.
Nitzschia sp.
Surirella librile (Ehrenberg) Ehrenberg

measured at the surface and above the sediment (3 m depth). One phyto- and one zooplankton sample were taken at 3 m depth. The same methods as described above for Lake Leqinat were applied for phyto-, zooplankton, diatoms and trichopterans. Both lakes were visited again for visual inspection on 26–27 September 2019 with students from Salzburg and Prishtina Universities.

Analyses

Algae were counted under an inverted microscope (Telaval 3, Jena; magnification 40–1000x), applying the method of Utermöhl (1958). Biovolumes were calculated by fitting geometric forms to cell dimensions (Deisinger 1984). The organic content of the samples for diatoms was removed by acid digestion, with the addition of 2 ml of a supersaturated solution of K_2MnO_4 and 4 ml of HCl to a small (ca. 2 ml) subsample. The acid was then removed through a series of water washes. Permanent slides of the cleaned material were mounted with Naphrax®. Slide observations were performed using a Nikon E–80i light microscope, and photomicrographs were taken with a Nikon Coolpix 600 digital camera (40–1000x). Trichopterans were identified under a dissecting microscope (Ibrahimi et al. 2019).

Zooplankton samples were stained with Rose Bengal. Subsamples were counted under the inverted microscope (magnification 40–100x). Biovolumes and biomasses were calculated by approximating natural shapes with geometric formulae for rotifers (Ruttner-Kolisko 1977), and from length–weight regressions for crustaceans (Downing & Rigler 1984). Periphytic nematode samples were mounted on slides in glycerin after a slow, two-step dehydration process (Decraemer et al. 2019).

Results

Lake Leqinat

Lake Leqinat reaches a maximum depth of just 4.5 m, in the southern part of the basin (Figure 1). It has an area of 16 900 m^2 and a volume of 23 000 m^3. Depth profiles of abiotic parameters showed a weakly stratified, oxygen-rich upper layer down to 3 m depth. High pH-values (>9) indicate biogenic decalcification processes. Water of lower oxygen content and higher conductivity was found in the deepest layer (Figure 3).

The phytoplankton community (Table 1) was dominated by the chrysophycean genus *Uroglena* sp., reaching highest densities at around 2 m depth and accounting for 80.5% of the total biovolume (Figure 4A). The cryptophycean species *Cryptomonas marssonii* (9.5%) also reached its highest densities within this intermediate depth layer, while the dominant chlorophycean *Oocystis solitaria* was almost homogeneously distributed throughout the water column, contributing 5.0 to 43.3% of the total biovolume. A total of 391 benthic and periphytic diatom species were recorded in both lakes (no separate counts available; see Appendix A, Supplementary Data). A dense mat of *Chara contraria* A. Braun ex Kützing covered large areas of Lake Leqinat down to the deepest part. In shallow regions, *Potamogeton alpinus* Balb. was present. At the shoreline, *Carex vesicaria* L. dominated.

Zooplankton diversity was low, with only five euplanktonic rotifers and a single cladoceran species

Table 2 – Rotifers, nematodes and crustaceans in Lakes Leqinat and Drelaj. Euplanktonic species are marked with an asterisk.

Lake Leqinat
Rotifera
Anuraeopsis fissa (Gosse)*
Ascomorpha saltans indica Koste*
Cephalodella apocolea Myers
Cephalodella edax Hollowday*
Cephalodella forticula (Ehrenberg)
Cephalodella sp.
Cephalodella ventripes (Dixon-Nuttall)
Collotheca sp.
Colurella obtusa (Gosse)
Eothinia elongata (Ehrenberg)
Euchlanis dilatata Ehrenberg
Lecane closterocerca (Schmarda)
Lecane flexilis (Gosse)
Lecane luna (Müller)
Lecane lunaris (Ehrenberg)
Lepadella patella (Müller)
Monommata sp.
Mytilina mucronata (Müller)
Pleurotrocha petromyzon Ehrenberg
Polyarthra luminosa Kutikova*
Polyarthra sp.*
Proales fallaciosa Wulfert
Trichocerca bidens (Lucks)
Trichocerca rattus (Müller)
Trichocerca cf. *relicta* Donner
Nematoda
Eumonhystera cf. *barbata* Andrassy
Eumonhystera cf. *pseudopulbosa* (Daday) Andrassy
Mesodorylaimus spec. 1
Tridontulus spec. 1
Plectus spec. 1
Plectus spec. 2
Rhabdolaimus cf. *terrestris* DeMan
Cladocera
Daphnia longispina (Müller)
Copepoda
Cylopidae Gen. sp.

Lake Drelaj
Rotifera
Bdelloidea Gen spp.
Cladocera
Daphnia rosea Sars
Copepoda
Mixodiaptomus tatricus (Wierzejski)
Anostraca
Chirocephalus diaphanus Prévost

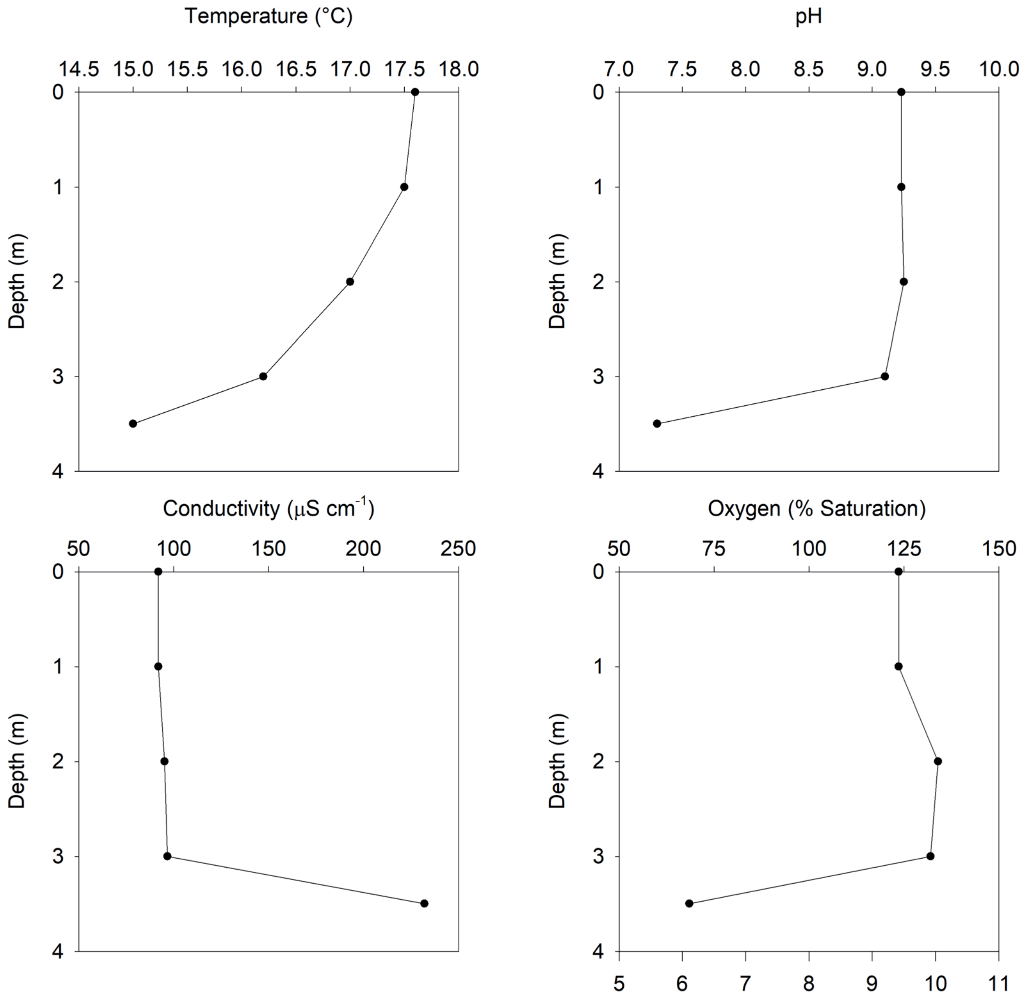

Figure 3 – Profiles of temperature, pH, conductivity and oxygen saturation in Lake Leqinat on 2 August 2018.

recorded in the samples; copepods were encountered only as immature developmental stages of Cyclopoida. Densities of *Daphnia longispina* increased with depth. The zooplankton community was dominated by the rotifers *Anuraeopsis fissa* (20.3% of the biomass) and *Polyarthra luminosa* (42.4%), with peak densities at 1 m depth (Figure 5A). A more diverse rotifer fauna was recorded in the benthic *Chara* mats (Table 2). In the sediment and periphytic samples, 7 nematode taxa were observed (Table 2). Six adult trichopteran species were found at Lake Leqinat (*Limnephilus centralis*, *L. flavospinosus*, *L. flavicornis*, *L. stigma*, *Agrypnia varia*, *Oligotricha striata*).

The alpine newt was the only amphibian recorded. Only the metamorphic phenotype was found among the adults. A total of 108 females and 131 males were marked and released. After one day, 136 females and 145 males were recaptured. The capture-mark-recapture experiment yielded a total population size of 1 492 female (683–2 302; 95% confidence interval) and 2 408 male (925–3 891) alpine newts in Lake Leqinat. The total population was estimated to be 3 980 adults (2 262–5 699). Snout-vent length and total length were 49.15 mm (41.9–58.8; median, minimum-maximum) and 85.1 mm (77.1–94.1) for females, and 42.2 mm (38.1–45.4) and 73.2 mm (67.1–78.2) for males.

Lake Drelaj

Lake Drelaj (Figure 2) is 3 m deep but had dried out between September and October. Its maximum surface area is around 3 100 m². Cold water from the surrounding karst seeps into the well-oxygenated lake, which in August fed a brook (~ 5 l s^{-1}) that emerged from the rocks about 30 m below the lake. On 5 August 2018, at the water surface and at 3 m depth, the temperatures were 9.3 and 5.5°C, Oxygen 9.48 mg l^{-1} (105% saturation) and 9.27 mg l^{-1} (98%), pH 8.29 and 8.17, and conductivity 192 µS cm^{-1}. The diatom *Cyclotella delicatula* dominated the open water community (84.5% of the biomass; Figure 4B). Overall phytoplankton biomass in the cold, clear lake was approximately one tenth of that in Lake Leqinat (Figures 4A and 4B). The zooplankton community consisted of three crustacean species: *Daphnia rosea*, *Mixodiaptomus tatricus* and *Chirocephalus diaphanus*. No rotifer species were recorded, other than a few tychoplanktonic bdelloid species. Zooplankton biomass was 6 times less than in Lake Leqinat (Figures 5A and 5B).

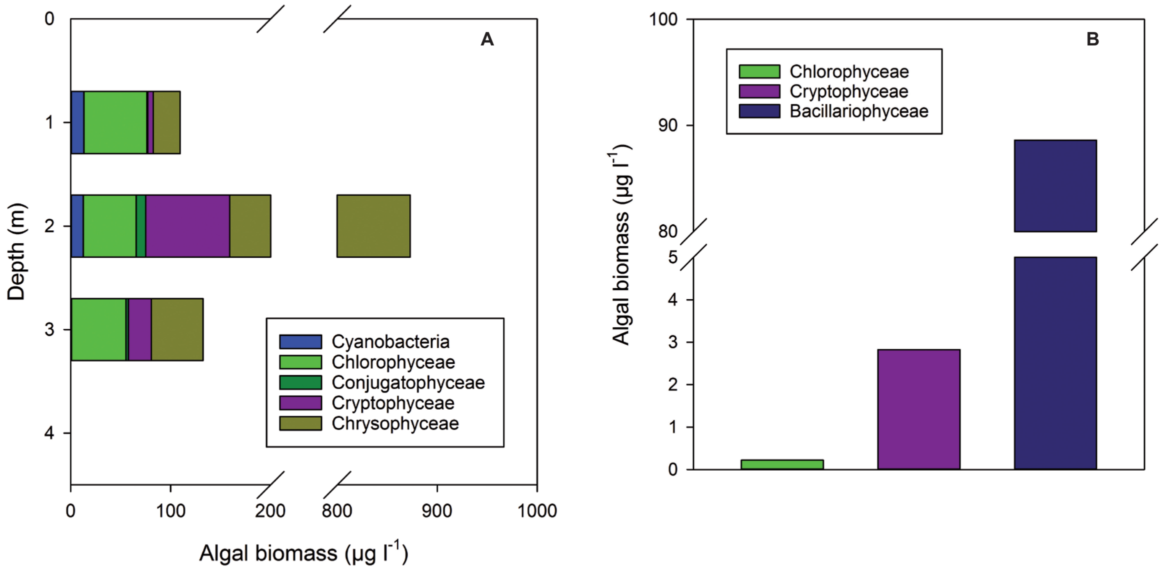

Figure 4 – Phytoplankton. A: Depth profiles of phytoplankton biovolume in Lake Leqinat on 2 August 2018. B: Biovolume of planktonic algae at 3 m depth in Lake Drelaj on 5 August 2018.

The anostracan species *C. diaphanus* reached very high densities in the puddles that remained in September, where adult metamorphosed and larval alpine newts were also found. Two adult trichopteran species (*Allogamus uncatus, Limnephilus bipunctatus*) were recorded in the close vicinity of the lake.

Discussion

Abiotic conditions, phyto- and zooplankton communities

The two alpine lakes differ markedly in their hydrology. Whereas Lake Leqinat is permanent, Lake Drelaj can dry out in summer / autumn. The latter has a visible outflow and comparatively faster water renewal, indicated by colder water temperatures, higher conductivity and lower pH. Lake Leqinat exhibited signs of biogenic decalcification in the upper water column and weak oxygen depletion / ion enrichment in the deepest part of the lake, probably due to summer stagnation, while Lake Drelaj was well oxygenated throughout the water column. Hence phytoplankton and zooplankton biomasses were considerably lower in Lake Drelaj than in Lake Leqinat. Accordingly, species assemblages in the open water also differed markedly. In Lake Leqinat, chrysophycean and chlorophycean species dominated. Zooplankton diversity was low, with only five euplanktonic rotifers, and *Daphnia longispina* as the sole microcrustacean encountered. Although biomasses were low, species compositions of both phyto- (*Oocystis solitaria*, *Uroglena* sp.) and zooplankton (*Anuraeopis fissa*) reflect a meso- to eutrophic character of the lake and are reminiscent of lowland ponds rather than of alpine lakes. In Lake Drelaj, an impoverished phytoplankton community with few small-sized (nanoplanktonic) species was observed together with three crustacean species in low abundances, presumably as a consequence of the lake's hydrological regime. Euplanktonic rotifers were entirely missing.

No diaptomid copepod was found in Leqinat, which may be due to the high feeding pressure of the large alpine newt population (see Dodson 1970; Wissinger et al. 1999). On the other hand, Drelaj contains a considerably smaller newt population (see below) associated with *Mixodiaptomus tatricus*, a species typical of temporary high-altitude water bodies in the Alps and the Balkans (Jersabek et al. 2001; Mancinelli et al. 2019). We are aware that *Daphnia rosea* may be a morphotype and belongs to the *D. longispina* complex (Petrusek et al. 2008; Błędzki & Rybak 2016), but we acknowledge morphological differences and distinct ecological divergences between the two taxa, as known from numerous studies in the Austrian Alps (Gaviria-Melo et al. 2005), by assigning the taxon from Drelaj to *D. rosea*. *Chirocephalus diaphanus* is one of the most widespread and tolerant anostracan species in Europe (Brtek & Thiéry 1995; Demeter & Mori 2004). Its presence confirms regular drying of the lake, as the diapausing eggs usually need such drying up for successful development (Brendonck 1996; Zarattini et al. 2002).

Benthic communities

Diatom assemblage is very rich, indicating the high ecological status of the lakes. The large number of species results from the presence of different microhabitats such as macrophytes, stones and pebbles, and fine and coarse sediment, but it probably also reflects low human impact on the lakes. Several rare and endangered diatom species of the flora of Central and Eastern Europe (Lange-Bertalot & Steindorf 1996) have been recorded. The recently discovered *Neidiopsis borealis* (Vidakovic et al. 2019) was also found. Appre-

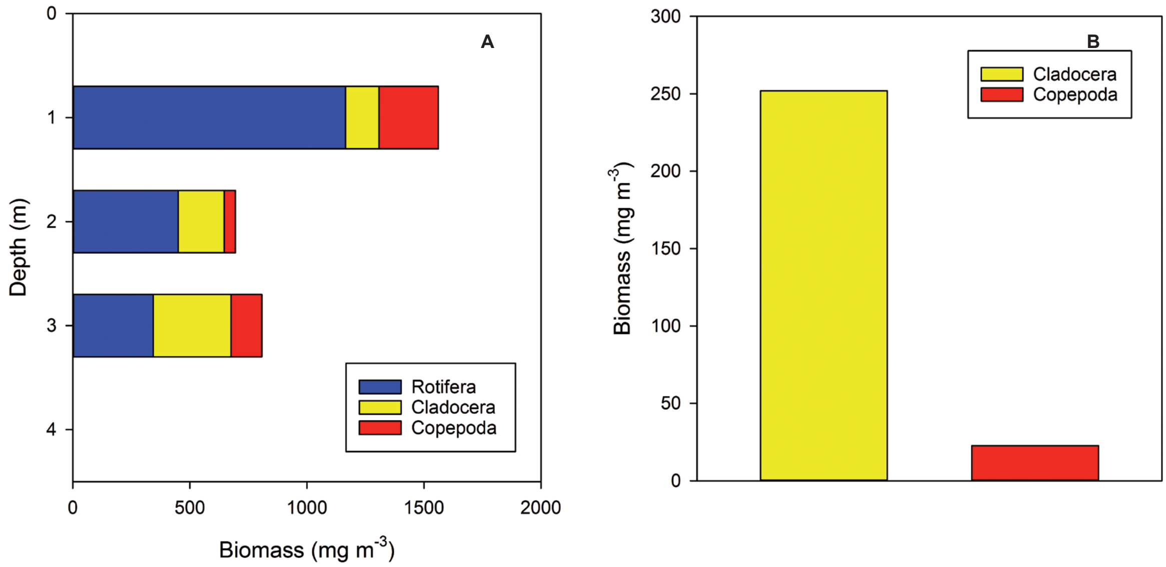

Figure 5 – Zooplankton. A: Depth profiles of zooplankton biomass in Lake Leqinat on 2 August 2018. B: Zooplankton biomass at 3 m depth in Lake Drelaj on 5 August 2018.

ciable macrophyte vegetation was detected only in the permanent Lake Leqinat. However, the three species registered (*Chara contraria*, *Potamogeton alpinus* and *Carex vesicaria*) typically co-occur in oligo- to mesotrophic alpine lakes. *Carex vesicaria* also grows around eutrophic lakes. Nematode taxa represent common sediment and periphytic taxa. The most abundant, *Monhystera* and *Plectida*, are deposit feeders essential for ecological functioning at the base of any freshwater food web. *Tridontus* species are still rarely recorded, because they are often misidentified as *Eumonhystera dispar*. Three of the trichopteran species are new records for Kosovo and are currently known only from Lake Leqinat: *Limnephilus flavospinosus*, *Limnephilus flavicornis* and *Oligotricha striata*, the last one being known in the Balkan Peninsula from only a few localities (Ibrahimi et al. 2019).

A large alpine newt population inhabits Lake Leqinat. Approximately 4000 metamorphosed adults were found, corresponding to a density of 0.24 individuals per square metre within the lake. Higher densities have been reported for similar-sized lakes in northern Greece (Denoël & Schabetsberger 2003; > 30000 individuals), but these included a large proportion of paedomorphic individuals. Hridsko Jezero from the Montenegrin part of the mountain range also used to host a population of paedomorphs (Denoël et al. 2001), but now only metamorphosed individuals occur (Denoël et al. 2019). In Leqinat, the sex ratio was slightly biased towards males (0.62). In other populations of alpine newts from the Balkans, sex ratios were found to be either male- or female-biased (Kalezić et al. 1989; Denoël 2003). This may be explained by different sex-specific payoffs across varied environmental conditions. We were unable to conduct a mark-recapture experiment in Drelaj, but the densities were lower, probably due to the particularly unfavourable cold breeding conditions (5°C at the bottom in summertime). Both locations appear to be new records for the occurrence of the alpine newt (Džukić et al. 2015).

Conservation aspects

Although the lakes so far are pristine, some threats do exist. While in temporary Lake Drelaj, fish introduction poses no threat to the alpine newts, alien fish could potentially survive in Lake Leqinat. Since we have no information about the winter oxygen conditions under ice, we cannot speculate about the survival of salmonids, but it is very likely that minnows (*Phoxinus* sp.) or other species that tolerate low oxygen levels would live through the winter, destroy the alpine newt population, and strongly alter the community of prey organisms (Schabetsberger et al. 2006; Miró et al. 2018). Indeed, many major populations of alpine newts that inhabited mountain lakes in the Balkans, even within National Parks, have now vanished because of fish introductions. Such introductions were particularly detrimental in Montenegro, including in Hridsko Jezero, where fortunately fish have recently disappeared (Denoël et al. 2019). Although we are not aware of any immediate stocking campaigns, hydropower development in the Rugova Valley is an issue and may be associated with stocking campaigns in the region (personal observation). Additionally, a large area of woodland near Lake Leqinat has been burnt deliberately. This calls for an enforcement of the protection of the lakes by rangers, and a visitor centre or at least thematic display panels near the lakes to raise awareness of conservation issues.

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The protection of the mountain ecosystems of the Southern Central Andes: tensions between Aymara herding practices and conservation policies

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Keywords: herding, Aymaras, traditional ecological knowledge, protected areas

Abstract

In the Atacama Desert highlands, Aymara communities have practised herding since pre-Hispanic times. Currently, large areas of the mountains' ecosystems are under official protection. This situation has created tensions between Aymara herding practices and official conservation policies. In this article, we document herding practices and how they have contributed to the production of these ecosystems. We also explore several conservation policies in the area and how they clash with Aymara herding. To do this, we make use of ethnography and state conservation plans. We suggest that these policies reproduce colonial dynamics, creating conflicting aims and affecting Aymara territorial rights. We conclude that traditional Aymara ecological knowledge and practices should guide the conservation of these mountain ecosystems.

Profile

Protected area

National System of Protected Wild Areas

Mountain range

Andes, Chile

Introduction

Prevailing ideas about nature present human action as synonymous with environmental degradation (Dove & Carpenter 2006). Nevertheless, there is widespread scientific recognition of the value of traditional ecological knowledge and practices for the production and safeguarding of nature (Posey 1985; Berkes 1999). Official conservation practices, however, tend to render local actors invisible, and – paradoxically – adversely affecting the very ecosystems they aim to preserve (Fairhead & Leach 1996). This tension is in urgent need of exploration within the mountain ecosystems of the Southern Central Andes (Eisenberg 2013; Jofré 2014; Yepez 2020), as it is highly relevant to questions of biodiversity, the livelihoods of those who inhabit these areas, and the global climate system (Yager et al. 2019). In particular, the Puna (ca. 3 000–5 200 m a.s.l.), located in the border area between Bolivia, Peru, Argentina and Chile, is one of the regions with highest endemic levels of flora and fauna worldwide (Hribljan et al. 2015). For over three millennia – since at least 2500 BCE – herding societies have inhabited the Puna, building upon knowledge and techniques of camelid breeding, specifically llamas (*Lama glama*) and alpacas (*Vicugna pacos*), and managing their lands through diverse cultural practices such as the irrigation of Andean wetlands (known as *vegas* and *bofedales*) and transhumance (Flores Ochoa 1977; Lane & Grant 2016; Erickson 2000; Capriles & Tripcevich 2016). Given its ecological importance, a significant part of Aymara territory in the Chilean regions of Arica-Parinacota and Tarapacá (18º–20º S) is under both State conservation protection through the National System of Protected Wild Areas (*Sistema Nacional de Áreas Silvestres Protegidas del Estado* (SNASPE)), and international protection by UNESCO and the RAMSAR convention (Figure 1; Table 1). All of these areas are managed by the National Forestry Corporation (*Corporación Nacional Forestal*, hereinafter referred to by its acronym, CONAF).

Despite their good intentions, several conservation policies implemented within the Puna Reserves have been the primary drivers of conflict, affecting Aymara herders' practice of their cultural traditions and their territorial rights. Aymara indigenous lands account for around 98% of the Lauca Biosphere Reserve's surface area (José Barraza, personal communication, 2020; Eisenberg 2013); however, like all other designated protected areas, these lands are managed by the State through CONAF. In this context, Aymara agency has been minimized and Aymaran practices looked down upon, with dialogue between policy makers and traditional owners rare. Moreover, this situation has created contradictions that threaten the sustainability of the ecosystems subjected to these policies.

In addition – and also in contradiction – to ensuring conservation in the Lauca Reserve, the State has granted mining concessions and developed water infrastructures affecting ecosystems and Aymara water security (Eisenberg 2013). This is coupled with problems related to urban migration and the subsequent depopulation of indigenous territories, leaving the latter susceptible to the radical Chilean neoliberal economic model (Eisenberg 2013). Currently, a total of 156 754 people in Chile self-identify as Aymara (INE 2018); at least two-thirds live in urban areas, and the rural population is older on average, reflecting the migration of younger generations (Eisenberg 2013; González et al. 2014). Despite the fact that the Aymara maintain ties with their communities of origin (González 1997; Eisenberg 2013; González et al. 2014), their herding practices are decreasing, and many cultural management practices have diminished or disappeared. This has resulted in the high-altitude Andean wetlands becoming more vulnerable (Yager et al. 2019), and live-

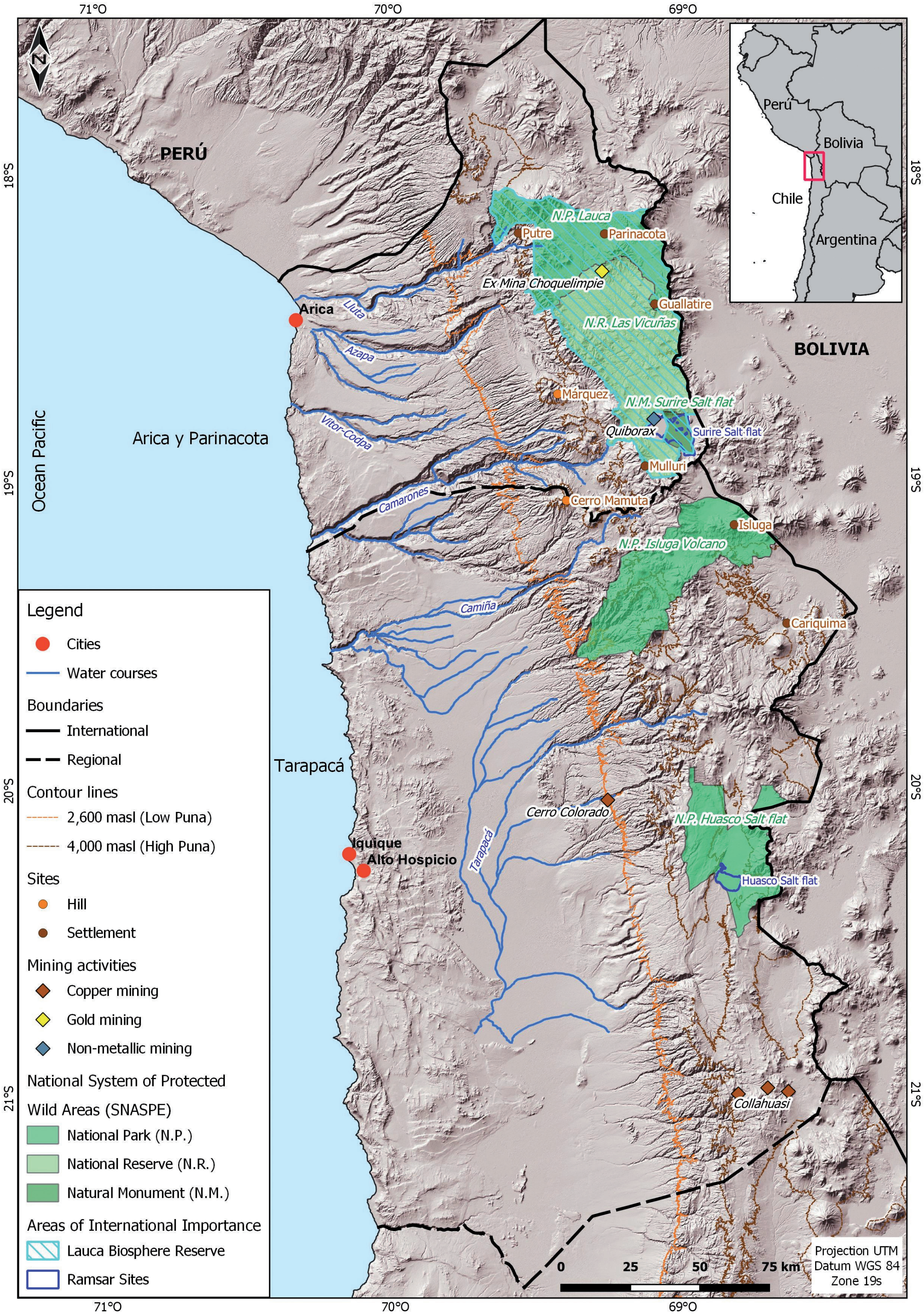

Figure 1 – Study area of Arica-Parinacota and Tarapacá regions.

stock rotation and transhumance circuits becoming more restricted (van Kessel 1992; García 2018).

The aim of this article is to draw attention to the frequently overlooked sociocultural landscape of the *Puna*, which is as relevant as its ecological traits for effectively securing the preservation of this ecosystem. Through the use of ethnography and participatory methodologies, we document the Aymara's traditional herding practice of the *costeo* – a form of transhumance – and their care and nurturing practices

Table 1 – Protected areas in the Aymara-Chilean territory.

SNASPE	Area (ha)	Lauca Biosphere Reserve (UNESCO)	Ramsar Site	Region
Lauca National Park	137833	X		Arica-Parinacota
Las Vicuñas National Reserve	209131	X		Arica-Parinacota
Salar de Surire Natural Monument	11298	X	X	Arica-Parinacota
Volcán Isluga National Park	174744			Tarapacá
Salar del Huasco National Park	9950		X	Tarapacá

of *bofedales*. On the other hand, archaeological surveys of the territory have provided evidence of the temporal depth of settlements and structures associated with these practices. The tensions between Aymara landscape-production practices and the conservation instruments (according to national and international policies) applied in this area are highlighted and discussed, with the aim of contributing to the study of Andean mountain ecosystems in general and of wetlands in particular. The results constitute an invitation to denaturalize Andean landscapes, to stress the role of herders in creating them, and ultimately to recognize traditional ecological knowledge as integral to ecosystem sustainability and territorial justice.

Methodology

Data was collected through various fieldwork activities conducted during 2011 and 2014–2017. We developed a multi-method approach focused on ethnographic, ethnobotanical and archaeological work within the Aymara community of Mulluri (Figure 1). Through interviews, participant observation and participatory mapping workshops, we aimed to understand local management practices, perceptions and productions of the landscape. We also conducted surveys about traditional livestock management and its relationship with official conservation policies. Aymara community members currently living in the city of Arica also participated. Archaeological surveys were carried out alongside the herding circuits, providing chronological and material data which was complemented by oral histories. We also undertook archival research of preservation plans in official repositories related to the SNASPE of the study area. Further information was collected by the authors during preliminary fieldwork in 2009, and short follow-up field campaigns in the research area during 2018 and 2019.

Denaturalizing the cultural landscapes: Aymara costeo and bofedal management in the Dry Puna

The Andean Puna is a large mountainous area shared by Peru, Bolivia, Argentina and Chile, comprising different ecozones, with both longitudinal and latitudinal climate variations. From north to south are the Humid Puna (Titicaca Basin), Dry Puna (Desaguadero, Lauca & Tarapacá), and Salt Puna (Atacama) (Núñez & Santoro 1988). Following the altitudinal gradient of the Andes from west to east, the differences are more marked: the Low Puna and High Puna are below and above 4000 m a.s.l. respectively. Each has its own vegetational floors – *Pre-Puneño* or desert floor (2600–3300 m a.s.l.), *Puneño* or *Tolar* (3300–4000 m a.s.l.), *Altoandino* or *Pajonal* (4000–4300 m a.s.l.) and Subnival (ca. 4400–4800 m a.s.l.) (Villagrán et al. 1999). The Puna is under the influence of both the South Pacific High (a subtropical anticyclone) and the rain shadow effect of the Andes, which blocks moist air from the Amazon basin. Both factors produce very dry and stable conditions, with annual precipitation being concentrated over the summer months (December to March) (Garreaud 2009).

Aymara cultural practices associated with livestock and landscape production are seasonal, organized around the cycles dictated by the rainy period and its related pasture growth cycle, which in turn mobilizes the transhumance circuits (Villagrán & Castro 1997; García et al. 2018). Aymara herders identify three seasons within the annual cycle: *jallu pacha*, rain time; *thaya pacha,* cold season or pasture time; and *lupi pacha*, dry season (Bouysse-Cassagne & Harris 1987; van Kessel 1992).

Herders and their herds move along different circuits exercising a high level of mobility, interacting with different ecosystems (humid and rain-fed) along the altitudinal gradient, thus providing year-round grazing for livestock throughout the seasons and generating a dispersed settlement pattern. Research has focused on different modalities of transhumance according to the region: in the Humid Puna, mobility is restricted, and herders ascend to the High Puna during the rainy season, where they have small settlements of shelters locally known as *chozas*, *cabañas* or *musiña* (Flores Ochoa 1977; Palacios 1988; Quispe & Blanco 2018). In the Salt Puna, during the summer rains, agropastoral communities also ascend with their herds to the High Puna, where they have small, temporary settlements known as *estancias* (Berenguer 2004; Villagrán & Castro 1997; Göbel 2002).

By contrast, Dry Puna herders have developed a transhumance system, the *costeo*, with a high degree of mobility. The term comes from the word *costa* (coast) and refers to the Low Puna, where the herders spend the winter. *Costeo* involves a movement from east to west of decreasing altitude, from the *estancias* or main settlements located in the High Puna (Pajonal floor) to the headwaters at the piedmont ravines (e.g., Camarones, Camiña, Aroma and Tarapacá) located both in the *Tolar* and *Pre-Puneño* floors (Villagrán et al. 1999). The *Tolar* floor, at the core of the Aymara coast, presents the greatest coverage and diversity of species, due to the convergence of moderate altitude and abundant rainfall – both determinants for vegetation growth (Villagrán et al. 1999). In this lower ecozone, herders' *paskanas* (shelters) are used seasonally by each family unit (Provoste 1976; Gundermann 1988; van Kessel 1992; García 2018). Our archaeological work in Mulluri (García 2018) suggests that some of these have been used continuously since pre-Hispanic times (Figure 2).

Costeo takes place during the cold, dry season (March to September). Its importance to herding lies in the fact that rain-fed pasture continues to grow in the Andean piedmont despite the lack of rain, whereas in the High Puna grazing land is covered by ice and snow (Provoste 1976; Villagrán et al. 1999) – hence the name of the season, *tiempo de pasto* (pasture time), at the end of which, and once the peatlands are no longer frozen, herders return to the High Puna (García 2018).

The perceptions and imaginaries associated with the Aymara *costa* refer to a *temperate* or even *hot* landscape, because "*no hela* [hiela] ni *neva* [nieva]" (it neither freezes nor snows) (male adult, Mulluri 2016) as it does in the *cordillera*. These perceptions differ significantly from the scientific construction of the same physical landscape. Climatology defines this *costa* as a *marginal high desert climate (BWH)* where a cold, dry climate with an absence of surface watercourses predominates, making agriculture impracticable. Herders, on the other hand, associate this landscape with pasture time – considered the best time of year, as it is the time when springs refill, grass grows, and livestock fatten up to survive the dry season beginning in September (García 2018).

Figure 2 – Paskana *in Alto Esquiña, Mulluri territory. Above: dry season, September 2014. © P. Méndez-Quirós. Below: Pasture time, March 2017. © José Viza*

Ethnobotanical research, including our recent work at Mulluri, highlights the diversity of *costa* plants known to herders as forage, which cover almost 50% of the puna floor or *tolar* (Villagrán et al. 1999; García et al. 2018). With the seasonal rotation or *costeo*, livestock fertilizes the soil with manure and consumes or *harvests* the grasses that have grown thanks to the manure from the previous year. This draws attention to the role of the animals themselves, who, as a herder told us, "*return to their* guano" each year, thus establishing the seasonal herding patterns and circuits. These patterns simultaneously give the *bofedales* a chance to *descansar* (rest); during this season, *bofedales* are irrigated by the herders (July), preparing them for the ice to melt and the arrival of the herds in September (García 2018; Yager et al. 2019).

The *bofedales* are a type of high-altitude peatland (between 3 200 and 5 000 m a.s.l.), dominated by cushion-like plants (e. g. *Oxychloe andina*, *Distichia muscoides*) which form layers of peat (Squeo et al. 2006; Ruthsatz 2012). Herders maintain the *bofedales* throughout the calendar year, enhancing their adaptation to adverse climatic conditions. Their techniques are diverse, consisting of cleaning, irrigation, manuring and rest periods, which keep the *bofedales* healthy, reduce erosion, prevent frost, and increase the grazing surface and capacity (Verzijl & Quispe 2013; Eisenberg 2013; Yager et al. 2019). Intervention occurs to varying degrees, from simple stone dykes and ditches to complex channels, tanks and pipeline networks. Controlled fires are also used to burn colonizer grasses, fertilize the soil, and increase the vigour of new shoots (Figure 3). Mulluri herders say *"you have to green the* champeal, *green the pasture*" (García 2018) in reference to *bofedal* care and its cultural production, also acknowledging the role of animals that graze excess grasses and fertilize the *bofedales* with their droppings (Yager et al. 2019).

Such practices question the idea that these rain-fed grasslands and *bofedales* are simple natural pastures, presenting them instead as socio-natural ecosystems (Prieto 2015); these ecosystems sustain herding practices, but their existence also requires the above management practices (Prieto & Yager 2018; Yager et al. 2019). In view of their network of channels and ir-

Figure 3 – Landscape management and care practices in Mulluri. Above: bofedal *channelling. Below: controlled fires to fertilize grasslands and increase vigour of new shoots. © authors*

rigation outlets, *bofedales* can be compared to cultivated land, but they also demonstrate different management practices: the social management of water, canal cleaning and irrigation, while livestock *weeds*, *fertilizes*, *sows* and *harvests*. This is coupled with a notable number of plants that provide grazing (62%) and food for humans (20%) in the *bofedales* (Villagrán et al. 1999; Villagrán & Castro 2004).

National and international conservation policies in Aymara territory

In 1965, the Lauca Forestry Reserve (271 300 ha) was created with an emphasis on conserving the vicuña (*Vicugna vicugna*), a wild South American camelid. In 1970, the reserve became the Lauca National Tourism Park, doubling its surface area (520 000 ha) and emphasizing tourist activities. In 1983, three important events occurred under the Pinochet dictatorship. First, the park was split into three units: Lauca National Park (137 883 ha), Las Vicuñas National Reserve (209 131 ha), and Surire Natural Monument (11 298 ha), reversing public ownership of over 161 000 ha (D.S. 29 of the Ministry of Agriculture). Protected areas were also declared to be sites of *scientific interest* for mine exploration (CONAF 2008). Second, the new Mining Code created exploration and extraction concessions in protected areas. Finally, the UNESCO Lauca Biosphere Reserve was also created in 1983 and included the three aforementioned protected areas. The focus of these reserves today is to link research and development associated with the loss of biodiversity, climate change and sustainable development – thus promoting a greater participation of science in policies on the rational use of biodiversity (Borsdorf et al. 2013).

In contradiction to the conservation purpose of the reserves, the State has granted mining concessions to various companies (e. g., Quibórax, formerly Choquelimpie mine) with a significant impact on Puna ecosystems and local communities. Additionally, the diversion of the Lauca River in 1962 toward the Azapa Valley for hydroelectricity and irrigation has affected Aymara water security and ecosystems, and has created geopolitical tensions with Bolivia (Eisenberg 2013). These policies, coupled with urban migration and the subsequent depopulation of indigenous territories, reflect the imaginary vision of this territory as *terra nullius,* allowing for its control by the state and private capital (Eisenberg 2013; Prieto 2015).

CONAF management plans and Aymara participation

Until the early 21st century, the local demographic component and ecosystem management practices were not mentioned or considered in CONAF management plans. Only recently has CONAF for the first time considered a participatory management approach involving the local indigenous community (CONAF 2008). The document associated with the Lauca National Park recognizes the high degree of knowledge that Aymara people have developed over time *of the diverse characteristics of ecological profiles, with their heterogeneity of climates, altitudes, flora and fauna and use of resources from all these areas* (CONAF 2008: 34). It also recognizes that the traditional use and management of Puna resources protected the area from over-exploitation – a balance that was broken with the emergence of individual private property, along with a subdivision of community lands, competition for resources, and income from state-owned property, to name a few (CONAF 2008: 36).

Despite this recognition, CONAF management plans (1998, 2008, n/d) do not confer an active role upon herders in the management of park ecosystems. The documents indicate that the management experts are those who plan and put proposals to the local population or gather the latter's knowledge and then re-express it using technical language. In this way, the herders' role is first relegated and then further reduced to a secondary level. Although there are periodical events to involve local communities, Jofré (2014) states that local residents criticize these for not being consultative or participatory but rather merely informative. Our analysis of CONAF's management plans confirms Jofré's statement: they are predefined and reductive, based on business models and giving no room for discussion with community members.

As part of engaging with the local population in the reserve and involving them in development, the Lauca National Park management plan has proposed the creation of a Cultural Promotion Program. Among its objectives are exchanges of knowledge and experience, a revalorization of living heritage, and an interest in disseminating and *enriching the particular local vision of the interaction between humans and nature* (CONAF 2008: 74). It also proposes a Comprehensive Training Program, which includes training in environmental education and biodiversity conservation, and instructing local people in data recording and monitoring.

At the same time, development programs focus on tourism as a business opportunity, stimulating competition over cooperation, and are thus in conflict with management plans that respect indigenous people and their practices. CONAF has promoted new values in which economic concerns dominate cultural ones, imposing new ways of life related to market forces and economic rationale (Rivera Andía 2019). Jofré (2014) indicates that there is a negative perception of the programs among the local residents of Guallatire, as the tourism plan would only benefit a few people, increasing inequality within the community. Jofré also describes the confrontational climate and absence of dialogue between the indigenous community and government institutions. Similarly, Eisenberg (2013: 140) notes that *the funds that maintain wildlife management programs do not permit any direct benefits to the Aymara people. The park's management plan was a unilateral imposition in which the local Aymara population had little or no input.*CONAF, like mining companies, restricts and has a negative impact on the Aymaras' everyday life (Eisenberg 2013).

Analysis of the CONAF documents shows that the priorities, issues and main concerns expressed by community members at the meetings (e.g., the competition between wild and domestic camelids for *bofedal* fodder) are ignored. There are also profound differences at an ontological level, where relations between humans and non-humans are defined, redefined and negotiated (see Blaser 2009). On the one hand, locals regard the land as a *mother* (*Pachamama*), and their interactions with animals and plants pursue a principle of reciprocity. On the other hand, CONAF promots a hegemonic binary division between nature and culture, the physical and the metaphysical, the material and the spiritual. In the Aymara world, these distinctions do not exist, for everything is interwoven (de la Cadena 2015). For example, the management plan for Las Vicuñas National Reserve aims to promote the participation of Aymara communities in the productive management of the vicuña, attempting to make their management compatible with a scarce resource. This perspective reduces the vicuña to a *resource*, in circumstances where the Aymara worldview places it in a heterarchical relationship with humans – and even as mediator in the relationship between humans and sacred mountain entities (van Kessel 1998; Cereceda 2010; de la Cadena 2015). It also fails to acknowledge the close emotional bonds of herders with their herds, which they raise as their own (Flores Ochoa 1977). Finally, there is also a lack of understanding of Aymaran ritual technologies (Lansing 1991). These are important both in terms of practical livestock management (e.g., *k´illpa, wayño*, *machaje*, etc.) and in terms of the beliefs that they embody. Indeed, these ritual technologies are considered fundamental to livestock raising, and the animals' health, fertility and reproduction (van Kessel 1998; Dransart 2002; Eisenberg 2013).

CONAF presents *bofedales* as priority areas in management plans. However, no mention is made of the role of herders in the production of these landscapes. Indeed, there is no mention of the herders at all, and the ecosystems are defined as *natural grasslands* (CONAF 2008: 44), which is coherent with the SNASPE, at the core of which is the concept of *Wild*. In addition to naturalizing the *bofedales*, CONAF provides *lessons* on the best practices for herders. It emphasizes that livestock activities should be sustainable and should consider the capacities of the *bofedales*, avoiding their over-exploitation by livestock at the expense of wildlife. The canalization of the *bofedales* is part of the Aymara cultural practice to ensure a dependable water supply for both cold and dry seasons (Eisenberg 2013; Yager et al. 2019). Due to the ecological problems produced by the diversion of the Lauca River, Eisenberg notes that *if water diversion and appropriation continue, the bofedales will inevitably dry up, leading to the disappearance of llama and alpaca herds and the highland people who depend on them* (Eisenberg 2013: 140).

Of the rain-fed grasslands or pastures that grow on hills and pampas, CONAF states that 'these only provide complementary feed (to livestock) due to their low nutritional value' (CONAF 2008: 44). On the contrary, as we have already indicated, these grasslands play a fundamental role in Andean herding, forming a structural part of traditional livestock management, and are not merely supplementary grazing (Gundermann 1988. Based on our work in Mulluri, we would affirm that during pasture time (March-August) livestock feeding is completely dependent on this food source, as it allows the animals to reach their optimal weight to survive the dry season, thereby guaranteeing the economic and social welfare of the community.

Also of relevance are the hunting restrictions, and measures concerning the collection of Chilean flamingo (*Phoenicopterus chilensis*) and Darwin's rhea (*Rhea pennata*) eggs, the collection of native plants, and the use of fire, which apply to both visitors to the Reserve and local communities, as reported by local residents in Guallatire and Isluga (Dransart 2002; Eisenberg 2013; Jofré 2014). These resources are fundamental to the Aymara's daily diet, construction of dwellings, fuel and medicine, among other uses (cf. Villagrán et al. 1999; Villagrán & Castro 2004; García et al. 2018). Furthermore, controlling predators and the use of fire are essential to increase grazing capacity. Finally, the local residents of Guallatire report that the authorities who visit the Reserve consider the empty homes to be 'abandoned'. In reality, they are empty because of the high mobility of the herders, the simultaneous maintenance of several dwellings, and the long hours spent in the field each day (Jofré 2014; van Kessel 1992; Garcia 2018). Finally, we have noted how CONAF and technical studies aim to limit burn practices and consider that these have a negative impact on ecosystems (see also Dransart 2002).

Towards greater territorial justice

Aymara herding practices are rooted in traditional ecological knowledge developed through the cumulative experiences of generations, from the first attempts to domesticate camelids and the development of Andean herding lifeways since circa 2500 BCE. (Capriles & Tripcevich 2016). These practices have been perfected, and transmitted both orally and through site-specific tasks over generations (Flores Ochoa 1977; Lane & Grant 2016). Among other activities, herders practise *costeo* and care for *bofedales*. These are based on – and interwoven with – the cycles of nature, not only enhancing the fertility of the herds, but also producing richer ecosystems. Thus, the Puna is the result of collaborative engagement between human and non-human agents, within a specific historical context and distinct ontology (de la Cadena 2015; Rivera Andía 2019). In other words, herders have created their environment through a relationship of co-production, rather than settling in – or for – a pre-provided landscape (Prieto & Yager 2018).

Hegemonic ideas about nature present human action as a destructive force (Dove & Carpenter 2006), where humans represent a threat to the conservation of nature. In Chile, the entanglement between centralized decision-making processes, the institutional denial of multiple socio-ecological realities, the lack of recognition of indigenous peoples, and the developmentalist conservation and management policies that overlook traditional knowledge have all reproduced dynamics of internal colonialism (Blaser 2009). Similarly, CONAF conservation policies and management plans have disregarded indigenous herding practices, their cultural value, and their material effects on the conservation of Puna ecosystems. These dynamics weaken the autonomy of the local population in managing, caring for – and producing – their own territories (Jofré 2014).

Those who still inhabit these areas and continue herding deal with the experience of living inside protected areas. Here, a colonial legacy intersects with economic and geopolitical interests in fixing boundaries and determining who can gain access to resources, and how they can use them. This scheme is sustained by prioritizing expert knowledge over traditional ecological knowledge, suppressing and erasing other possible worlds (Blaser 2009).

Rather than imposing conservation policies that reify, ignore or minimize indigenous agency, we suggest that traditional ecological knowledge should be considered as part of a larger project for territorial and environmental justice, since it invites us to understand cultural practices as a productive driver of nature (Posey 1985; Fairhead & Leach 1996). This would necessitate Aymara self-governance over their claimed territories. The active role of Aymara communities in the production of their territory would result in a collective benefit, ensuring the conservation of ecosystems indispensable to the sustainability of mountain environments (Yager et al. 2019; Yepez 2020). Within the current context, however, consultations and participatory opportunities have a token value only and do not lead to any binding decisions. Both nature management and conservation instruments – as well as scientific research agendas – must open up spaces for traditional knowledge in pursuit of a productive dialogue for the co-creation of knowledge that recognizes mutual opportunities and limitations. This should translate into new conservation strategies, policies and knowledge construction which recognize the political role of indigenous communities in managing – and caring for – territory.

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Mapping spatial dimensions of Wilderness recreation outcomes: a study of overnight users

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Keywords: outdoor recreation, outcomes-focused management, PPGIS, spatial dimensions

Abstract

Grand Teton National Park (GRTE) is a popular mountain recreation destination which, like many National Park Service (NPS) units, has experienced a significant increase in visitation in recent years, with total visits increasing by 27% between 2014 and 2017 (NPS 2020). Particularly popular within GRTE is the String and Leigh Lakes (SLL) area, which is a favoured alpine destination for numerous day-use recreation activities and also an important starting point for backcountry and overnight recreational users within GRTE's Recommended Wilderness. To better understand the visitor experience of overnight backcountry recreationists in the SLL area, data were collected using novel public participatory geographic information systems (PPGIS) during the summer of 2018.

PPGIS data were used to identify the locations in which overnight recreationists experienced positive and negative recreation outcomes. Results indicate that they experience more positive outcomes within the Recommended Wilderness, away from high-density, trailhead-proximate areas outside the Recommended Wilderness. Findings also indicate that overnight users experience crowding and conflict more outside of the Recommended Wilderness than elsewhere on their backcountry trip. While this may seem intuitive, these are some of the first empirical results spatially contextualizing backcountry visitor outcomes in a popular national park. The findings thus provide managers with a visitor experience baseline that can be monitored and adaptively managed in the future.

Profile

Protected area

Grand Teton National Park

Mountain range

Teton Range, Rocky Mountains

Country

U.S.

Introduction

Over the last century, recreation management in parks and protected areas (PPAs) in the United States has changed significantly as managers have attempted to adjust to the growing diversity of conflicting visitor expectations, recreation goals and social values (Lee & Driver 1992; Newsome et al. 2008; Vaske et al. 2007). As visitor trends and management issues within PPAs change, national park administrators must adopt innovative monitoring and management strategies to attend to the expectations of visitors and the need to protect natural resources (White et al. 2016). Various data are needed to inform management strategies, allowing for a better understanding of the changing political, social and natural landscapes of PPAs (Graefe et al. 1984). As research techniques advance with technology, spatial methods are becoming especially relevant in PPA studies seeking to understand the social conditions of parks, including incorporating public participation in the mapping of social values (Beeco & Brown 2013). As new methods are developed and become feasible for field research, the spatial dimensions of various recreational activities are becoming more exact, more available, and thus more useful to managers in understanding visitor recreation outcomes correctly (Riungu et al. 2018). Despite a growing body of literature and an improved understanding of how best to manage for the social values and benefits derived from recreation, very few studies have explored the spatial dimensions of backcountry overnight recreationist outcomes (i. e. of overnight stays in particularly remote areas). Building on public participatory geographic information systems (PPGIS) methodology, this study therefore offers spatial representations of overnight backcountry visitors' outcomes in Recommended Wilderness (which by National Park Service policy is managed in the same way as federally designated Wilderness), and specifically in the String and Leigh Lakes (SLL) area as a case study.

Research purpose

Using PPGIS and building on Outcomes-Focused Management as a PPA managerial framework, this research seeks to answer the question: how are the positive and negative outcomes experienced through overnight backcountry recreation, within or outside the Recommended Wilderness boundary, distributed across the String and Leigh Lakes area?

Literature review

Outcomes-focused management

For decades, researchers and protected area managers have been grappling to find the most effective ways of meeting visitors' needs while managing for the potential social and environmental impacts of park visitation (Eagles 2001). A clear understanding of the outcomes achieved by visitors to national parks helps managers to deliver on National Park Service mandates and achieve effective Wilderness management. Several social science methods used to understand visitor experiences have been proposed since the 1970s, with visitors' goals, preferences and benefits emerging as important components of management frameworks (Lee & Driver 1992). One management framework that was quickly adopted by protected areas management agencies in the United States was Benefits Based Management (BBM), an approach to recreation management proposed by Lee and Driver (1992). Unlike previous recreation management approaches, BBM did not focus on recreation activities and settings as the starting point for management, but sought to identify the benefits derived from recreation activities, and the specific activities and settings which could potentially procure these benefits (Lee & Driver 1992; McCool et al. 2007).

More recently, Driver (2008) proposed Outcomes-Focused Management (OFM) as a new research and management model that expands on its precursor, BBM, to address some of its shortcomings. One of the most distinguishing characteristics of OFM is its ability to focus on both positive and negative outcomes of recreation experiences (Driver 2008). OFM maintains that visitors have preferences for certain experiences because they believe that engaging in a specific experience leads to the attainment of a goal or outcome (Driver 2008). To fully understand visitor experiences in PPAs, visitor preferences and the positive outcomes they seek, along with the negative outcomes that may be experienced during recreation, are crucial information for managers. Because overnight visitors may be more sensitive to negative outcomes including crowding (Pierce & Manning 2015), managers may benefit from a better understanding of where overnight recreationists experience positive and negative outcomes. Despite the benefits to be derived from understanding visitor outcomes, spatial data explicitly linking visitor experience outcomes to specific locations, resources or features is lacking; yet these data are extremely important both to advance OFM and for adaptive management of PPAs through applied science.

Spatial dimensions of outdoor recreation and participatory mapping

When it comes to parks and recreation management, spatial data are important for understanding the distribution of PPA visitors, impacts on natural resources, and where recreation experiences may be negatively impacted (D'Antonio & Monz 2016). Likewise, because so much of PPA management is done in a spatial context, a spatial understanding of visitor perspectives on recreation and the use of PPAs is important to ensure the holistic management of social and natural resources (Beeco & Brown 2013). Spatial representations of outdoor recreational activities collected through a variety of mapping methods have been shown to help managers measure the social, environmental, cultural and managerial impacts of visitors to protected areas by demonstrating the locations people visit, their travel routes, and the amount of time spent at particular locations (Hallo et al. 2012).

In recent years, the importance of understanding the spatial dimensions of visitor conditions in PPAs has become increasingly clear. One method with noteworthy potential to be applied to social science research is PPGIS, through which spatial data are provided directly by study participants who identify locations on a digital or physical map (Riungu et al. 2018). This approach allows visitors to highlight place attributes based on their own understanding of a park, thereby revealing their unique perceptions, place knowledge and experiences (Brown et al. 2015). In an attempt to add to the understanding of the spatial dimensions of recreation experiences, public participatory mapping is used in recreation social sciences research (Beeco & Brown 2013; Van Riper et al. 2012). Using public participatory mapping, spatial dimensions can be overlaid with conventional social variables, such as visitors' values, benefits, goals and outcomes. In this way, PPGIS has the potential to bridge the gap between the way that PPA visitors feel about space and place, and the science-based management of natural and recreational resources.

While PPGIS has been used in recreation planning and management in recent years to better understand visitor distribution, recreational activities, conservation priorities and place values (Brown, Raymond & Corcoran 2015), there have been only a few applications of PPGIS to visitor outcomes. Recently, Wolf, Brown and Wohlfart (2017) used PPGIS and GPS methods to identify perceived crowding and visitor conflicts between mountain bikers and horseback riders in Australia. They found the application of PPGIS to crowding research to be effective in identifying trails used by different visitor groups, and to show promise for predicting areas of conflict. The researchers postulated that innovative methods such as PPGIS will be essential in the future to identify and manage conflicts along multi-use trails (Wolf et al. 2017). Beeco et al. (2014) also used spatial methods, including GIS and GPS data, to map visitors' preferences and to create recreation suitability models for competing recreation activity groups. Using GPS tracking of visitors to compare and contrast visitor use patterns and preferences, they concluded that combining spatial data with conventional social science methods was

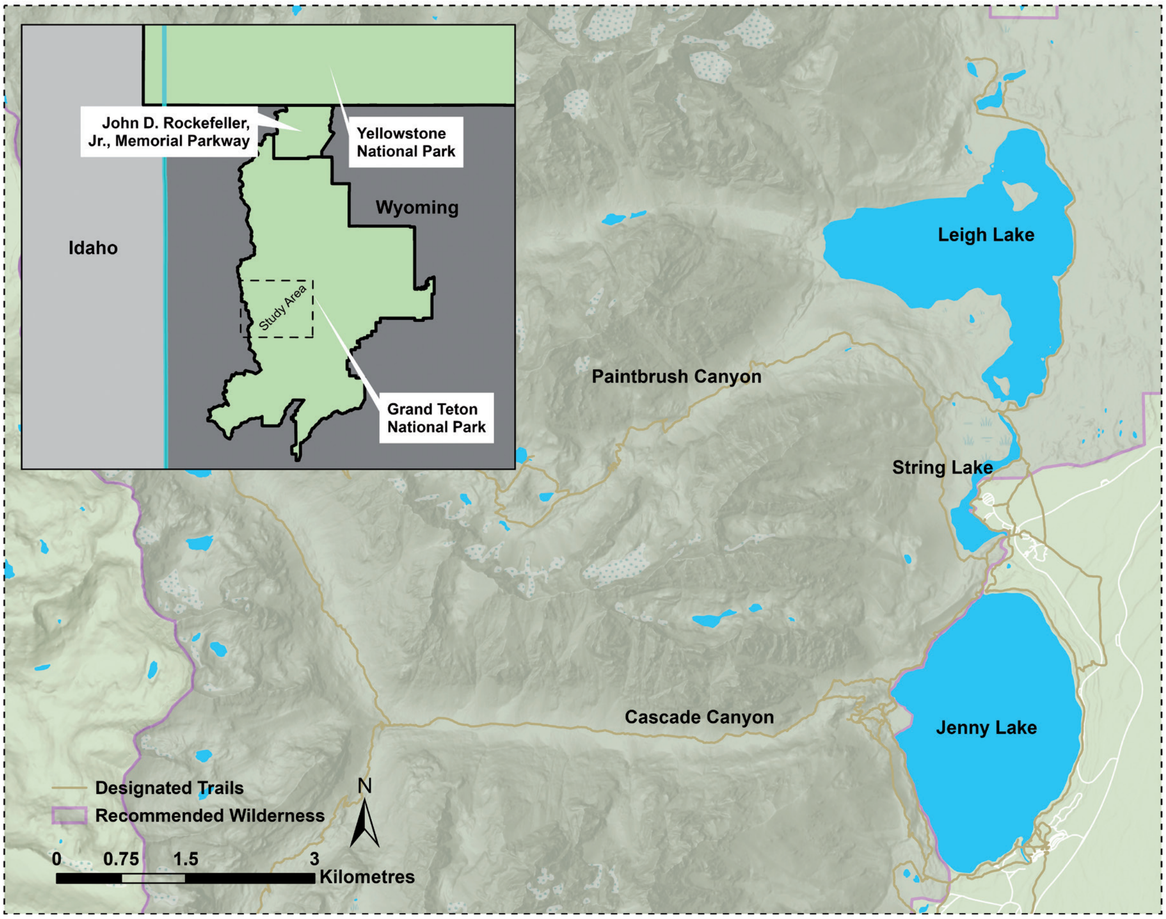

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Figure 1 – The study area within Grand Teton National Park, Wyoming.

useful for informing visitor management. Similarly, Pietilä (2017) used spatial methods to measure positive visitor outcomes in Oulanka National Park in Finland. In this study, Pietilä used an online PPGIS survey to assess how visitor experiences differ across park settings, contributing important insights into the benefits of PPGIS for understanding visitor outcomes. Additionally, Beeco and Brown (2013) conducted an in-depth review of the application of spatial data to social sciences and management in PPAs. They noted the novelty of the integration of spatial and social science methods, calling for the increased incorporation of spatially relevant data in the field of PPA social science research. They also noted that while literature has been emerging on the importance and value of spatial data for recreation managers, few studies have offered a spatial visualization of visitor outcomes. To date, no previous research has applied PPGIS to analyse both positive and negative outcomes through an OFM design, leaving an important gap in the research. Furthermore, there is a lack of this type of research within the Wilderness-focused literature. This study therefore uses PPGIS to assess outcomes achieved by overnight backcountry users within and outside the Recommended Wilderness boundaries in GRTE's SLL area, thus contributing a better understanding of the spatial dimensions of OFM in a backcountry setting. In doing so, this paper answers the question: How does the spatial distribution of overnight users' positive outcomes compare to the distribution of their negative outcomes?

Methods

Study site

Established in 1929, Grand Teton National Park (GRTE) is a popular US national park that is renowned for its exceptional mountain scenery and abundance of wildlife. At 310 000 acres, GRTE protects pristine wildlife habitat, countless ecosystem and recreational services, and the major peaks of the 40-mile long Teton Range. Like many other US National Park Service (NPS) units, GRTE has experienced large increases in visitation in recent years (NPS 2020). Particularly popular within GRTE is the SLL area, which has experienced an increase in visitation in recent years, with approximately 4 000 people entering the SLL parking area every day during the summer of 2017 (NPS 2017). Most of the SLL area lies within Federally Recommended Wilderness and is therefore managed in the same way as congressionally designated Wilderness, outlined in the 1964 Wilderness Act. The area of-

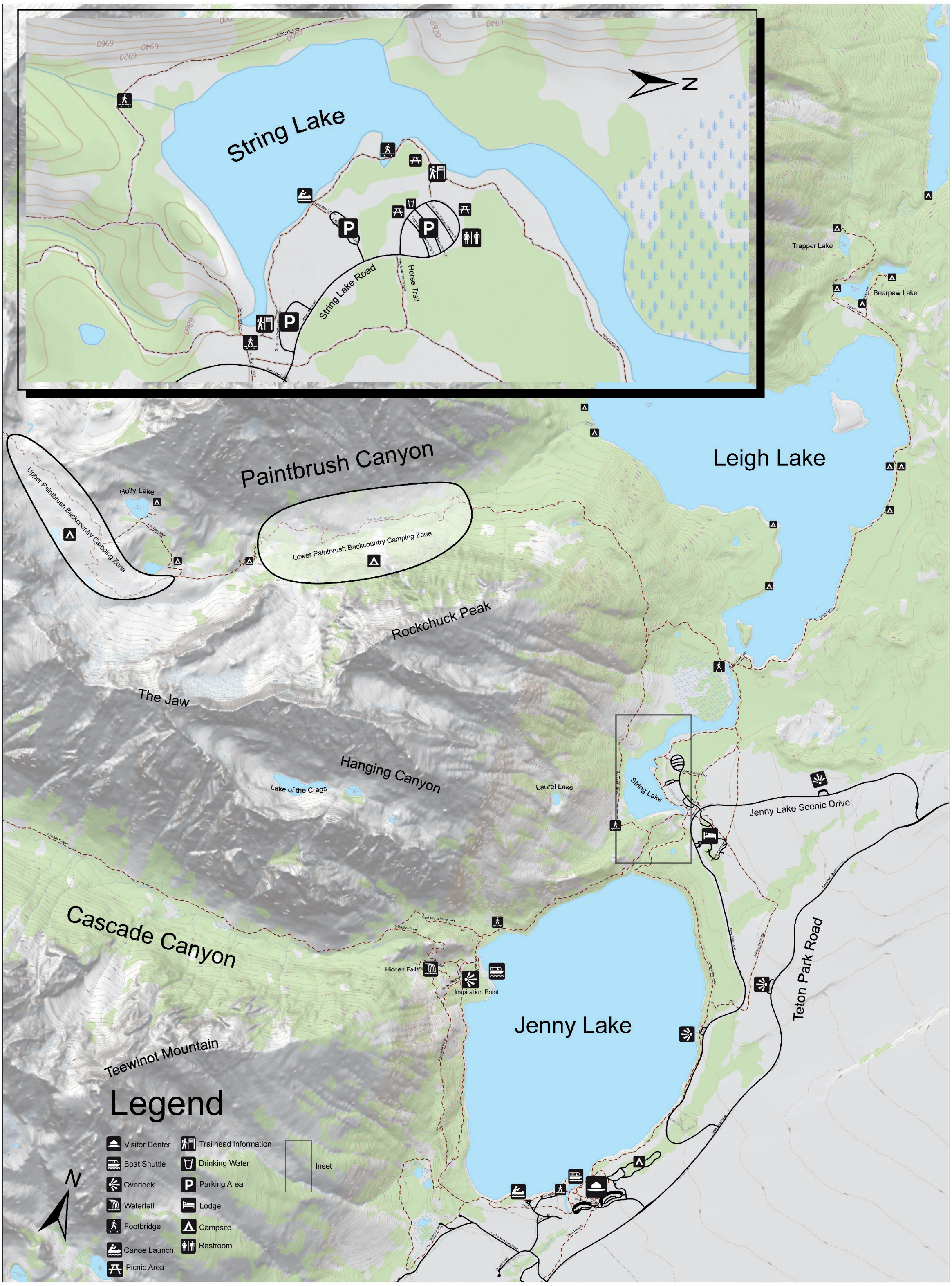

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Figure 2 – Map presented to public participatory geographic information system (PPGIS) respondents for the mapping of outcomes.

fers spectacular views of the Teton Range, making it a favoured mountain destination for numerous day-use recreational activities, including paddling, swimming, hiking and picnicking (D'Antonio et al. 2019). The SLL area includes two trailheads leading to numerous hiking trails, designated picnic areas, and a boat launch site for non-motorized watercraft such as canoes, kayaks and stand-up paddleboards. The trailheads in the SLL area are also starting points for backcountry and overnight recreational users, providing access to some of the most popular backcountry destinations in the park, including Paintbrush Canyon, Cascade Canyon and Holly Lake (Rice et al. 2019). There are several established backcountry camping zones in Paintbrush Canyon and Cascade Canyon, and campsites on the shores of Holly, Bearpaw, Trapper and Leigh Lakes, within the Recommended Wilderness boundary.

Data collection and analysis

PPGIS data collection

Public participatory mapping data were collected from overnight visitors who, for the purpose of this study, included any person who stayed one or more nights in the GRTE backcountry of the SLL area. A combination of convenience sampling and stratified random sampling was used to maximize the sample size (Singh & Mangat 1996). All data collection took place between 28 June and 12 August 2018, which is a peak-use period for the SLL. Data were collected throughout the day, with sampling shifts taking place from 8:00 am to 4:00 pm, and from 11:00 am to 7:00 pm. From 8:00 am to 7:00 pm, recreationists who demonstrated signs of overnight use of the park (e.g. camping gear, large backpacks, heavily loaded canoes) and / or were confirmed (by an initial screening question) to be exiting a SLL trailhead from an overnight trip in the SLL backcountry, were recruited for the study. One survey was administered per group of visitors through a randomized process in which the adult with the next upcoming birthday was asked to take the survey. The data collection consisted of a short survey collecting demographic data completed on an iPad equipped with Qualtrics survey software, and a short PPGIS activity. For the PPGIS component, participants were given a detailed map of the area (Figure 2) containing place names and topographic features, and asked if during their trip they experienced any of six positive outcomes (*improved connection with nature*, *improved state of mind*, *improved self-confidence*, *enhanced sense of adventure*, *enhanced family togetherness* and *improved social bonding*) or three negative outcomes (*crowding*, *conflict with other visitors* and *damage of natural resources*). If participants did experience any of these outcomes, they were asked to identify on the map the specific location where they perceived the outcome to the greatest extent. Trained research technicians transferred the mapping data collected from visitors on paper into ESRI ArcCollector on an iPad.

PPGIS data analysis

The distributions of the positive and negative outcomes experienced by overnight users were overlaid and converted to point density-based heat maps using ArcGIS Pro. Several maps were created using these data, including individual point density heat maps (Brown & Weber 2011) of each positive and negative outcome, and maps of all positive outcomes combined and all negative outcomes combined. These maps were analysed visually and compared to each other to better understand the spatial relationships between the positive and negative outcomes of overnight users (Steinberg & Steinberg 2015). Finally, in an effort to further understand these spatial relationships and to advance the application of PPGIS methodologies to visitor outcomes (e.g., Pietilä 2017), we used percentages of positive and negative outcomes experienced through overnight backcountry recreation within or outside the Recommended Wilderness boundary, distributed across the String and Leigh Lakes area.

Table 1 – Frequency of reportings of positive and negative outcomes.

Outcome	Number of reportings	Portion of total reportings
Improved connection with nature	53	17%
Improved state of mind	46	15%
Crowding	43	14%
Enhanced sense of adventure	41	13%
Improved self-confidence	40	13%
Improved social bonding	32	10%
Enhanced family togetherness	24	8%
Conflict	19	6%
Damage of natural resources	12	4%

Results

The PPGIS sample size for backcountry overnight respondents was 58, with an overall response rate of 95.1%. Of the 58 survey respondents, 50 identified themselves as backpackers and 8 as canoe / kayak campers. Positive outcomes for backcountry users were reported most densely in the Bear Paw and Trapper Lakes area, and in the vicinity of Holly Lake in Paintbrush Canyon (see Figure 2). All of these destinations within the SLL area have backcountry campsites, and are located several miles from the SLL trailheads and within the Recommended Wilderness boundary. Figure 3 further demonstrates that all of the six positive outcomes were experienced in Paintbrush Canyon, with improved social bonding and improved connection with nature being especially prevalent. In contrast, relatively few positive outcomes occurred along the eastern shoreline of String Lake (a popular area within the park, adjacent to trailheads), which is considered a front country (i.e. readily accessible) area, near Hidden Falls / Inspiration Point, or in Cascade Canyon, which are located within the Recommended Wilderness boundary. Improved connection with nature – the most frequently reported outcome (17%, Table 1) – resulted in a distinct distribution, with a high density of reports in Cascade Canyon and in the vicinity of Lake of the Crags.

Figure 4 shows where negative outcomes were experienced by overnight users. Conflict with other users and crowding were most often reported in the vicinity of String Lake and in the lower reaches of Paintbrush Canyon and Cascade Canyon, adjacent to or outside the Recommended Wilderness boundary. Meanwhile,

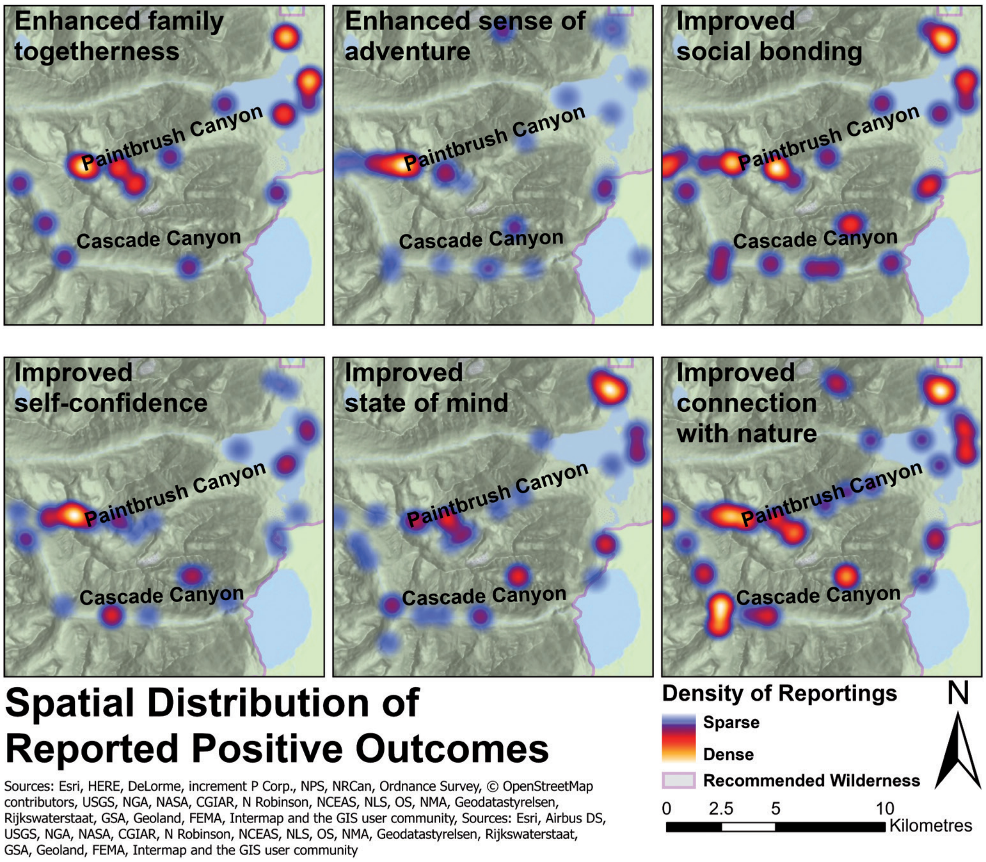

Figure 3 – Spatial distribution of the 6 positive outcomes reported by overnight users in the String and Leigh Lakes (SLL) area.

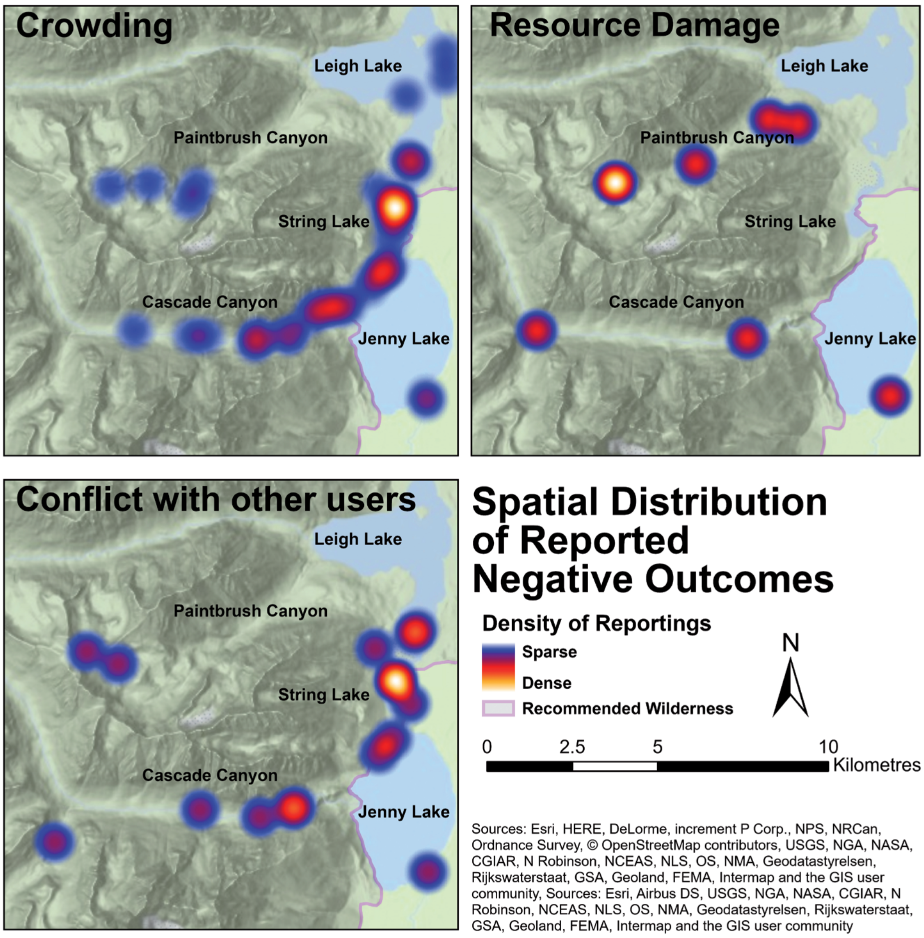

Figure 4 – Spatial distribution of negative outcomes reported by overnight users.

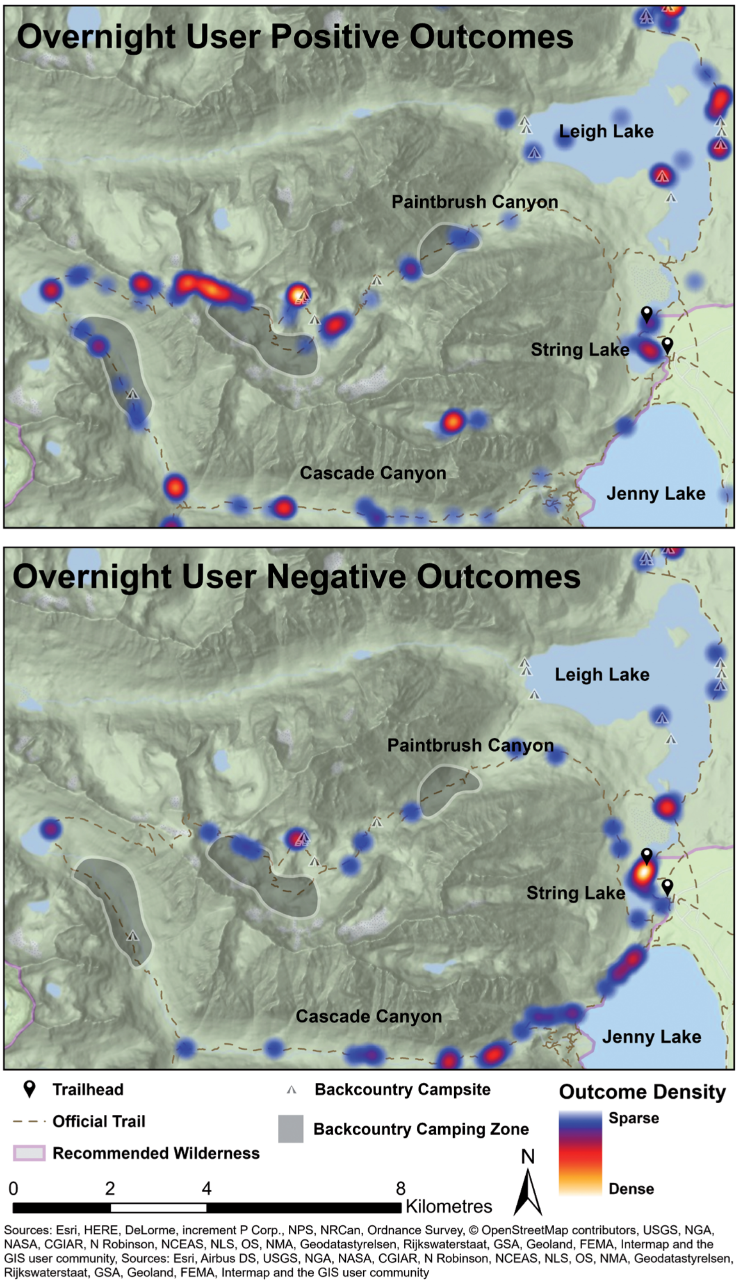

Figure 5 – Spatial distributions of positive and negative outcomes reported by overnight users.

resource damage was most commonly reported in Paintbrush Canyon and Cascade Canyon, both within the Recommended Wilderness boundary.

Figure 5 illustrates the combined positive and combined negative outcomes across the study area. Overall, the majority of positive outcomes were reported near campsites or camping zones, and within the Recommended Wilderness boundary. However, Lower Cascade Canyon, the northwest shoreline of Jenny Lake, and the eastern shoreline of String Lake generated the highest densities of negative outcomes for overnight users. These areas are outside the Recommended Wilderness boundary or adjacent to the boundary. To extend the previous outcome-focused management and PPGIS methodologies, Table 2 highlights the percentage differences between positive and negative outcomes experienced within or outside the Recommended Wilderness boundary. Results indicate that more positive than negative outcomes were experienced within the Recommended Wilderness boundary (95% and 82% respectively).

Discussion and conclusion

When critically analysing the PPGIS maps of outcomes experienced in the SLL area, it becomes clear that there is a difference between the spatial distributions of overnight users' positive and negative outcomes. This is further highlighted through percentage differences (Figures 3–5 and Table 2). Figures 3–5 demonstrate that overnight users experience negative outcomes in places where they are likely to encoun-

Table 2 – Distribution of outcomes within and outside the Recommended Wilderness

	Within Recommended Wilderness	Outside Recommended Wilderness
Positive outcomes	95%	5%
Negative outcomes	82%	18%

ter other visitors (i.e., in areas close to trailheads outside the Recommended Wilderness boundary), while experiencing positive outcomes further away from trailheads and within the Recommended Wilderness boundary. Positive outcomes were densest in the Bear Paw and Trapper Lakes area, and in the vicinity of Holly Lake in Paintbrush Canyon. Interestingly, some negative outcomes were also reported in these areas. Tables 1 and 2 explicitly highlight these differences, and the occasionally overlapping positive and negative outcomes.

These findings emphasize the difficult dual mandate faced by the National Park Service, to enable quality recreational experiences while protecting the resources that provide those experiences. Damage to natural resources, although reported infrequently compared to the other outcome variables, occurred in some of the same locations where visitors reported positive outcomes. This suggests that some level of natural resource impact may even enhance overnight users' positive experiences (e.g. visitor-created social trails), but begs us to question at what point those impacts caused by recreationists will be so severe that it negates the positive outcomes gained in these locations (Taff et al. 2019). With these results in mind, managers may be able to increase monitoring efforts and management strategies that facilitate the positive outcomes within the SLL area, while potentially mitigating some of the negative outcomes.

This study provides managers with baseline data within and outside the Recommended Wilderness boundary to inform their monitoring of potentially changing social and ecological conditions in the SLL area. Some trends suggest that day-visitors are going further into the backcountry (Papenfuse et al. 2000). If this were to occur in the SLL area, it could interfere with the positive outcomes which overnight visitors gain within the Recommended Wilderness boundary. Continuing to evaluate overnight and day visitors' experiences, both within and outside the Recommended Wilderness boundary, will be particularly important if use of the area continues to increase. These results should enable park management to consider other areas within GRTE that may offer similar outcomes, and to begin monitoring them. For example, if visitation to the SLL area continues to increase, managers can expect other areas within GRTE that potentially offer similar outcomes to see increased use, due to visitors' desires to obtain the same or similar recreational outcomes (Hall & Shelby 2000). By developing monitoring plans for these areas early, managers can proactively implement different measures to address potential impacts on the ecological and social environments.

Because individuals who experience more encounters with others than expected are more likely to feel crowded (Manning 2011), managers have an opportunity to shape visitor expectations and ultimately satisfaction through clear communication strategies. Using theory-based and science-informed messaging, managers may help alleviate perceptions of crowding and increase the perceived quality of the recreation experience (Taff et al. 2014). Furthermore, clear communication efforts can help build realistic visitor expectations, and encourage onsite visitor behaviours that align with the management objectives for the SLL area, both within and outside the Recommended Wilderness boundary.

Finally, this study offers important methodological insight into the spatial dimensions of outdoor recreation, particularly within the context of Wilderness management. Understanding the spatial dimensions of visitors' experiences has been shown to be important in managing visitor preferences in recreation (Beeco & Brown 2013). By collecting spatial data, managers are better able to fully contextualize the locations of positive and negative outcomes obtained by recreationists. This holds great potential to aid managers in assessing both positive and negative outcomes experienced by visitors to parks and protected areas, especially crowding and displacement (Manning 2011). In this study, PPGIS successfully helped identify the locations of visitor outcomes in the SLL area of GRTE. The potential of integrating more spatial methods with social sciences and management strategies continues to grow as technology that allows for ease of field data collection develops. Future research should consider the application of PPGIS to other backcountry recreation outcomes and contexts of recreation management, considering how further GPS methods may be paired with social sciences data to spatially represent visitor experiences.

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Skiers' expectations as a challenge for managers of protected areas – a case study from the Tatra National Parks in Poland and Slovakia

Joanna Hibner, Jarosław Balon, Miłosz Jodłowski & Szymon Ciapała

Keywords: protected areas, ski resorts, Tatra Mountains

Abstract

Mountain areas are particularly attractive for the development of winter activities such as skiing, owing to both morphological and climatic conditions. However, mountain areas are at the same time vulnerable. For this reason, they are often under protection. This study focuses on two important and heavily used ski resorts in the Tatra National Parks, Kasprowy Wierch (Poland) and Skalnaté Pleso (Slovakia), looking at skiers' opinions and complaints regarding the resorts. In addition, a comparison between the resorts was conducted. In order to verify the relationship between socio-demographic variables and the skiers' opinions, two types of statistical tests were used: Spearman's rank correlation coefficient and Chi-square. The results show that the Kasprowy Wierch ski resort received a larger number of negative comments than Skalnate Pleso. However, Skalnate Pleso drew more negative opinions regarding the impact of the cable car and ski area on the landscape. The consequences of fulfilling visitors' expectations can be used practically by the managers of the protected areas.

Profile

Protected area

Tatra Mountain

National Parks

Mountain range

Carpathians

Country

Poland & Slovakia

Introduction

Mountain areas are particularly attractive for the development of winter activities such as skiing, owing to both morphological and climatic conditions (slope length and gradient, duration of snow cover; Falarz 2002; Krzan et al. 2002; Holko et al. 2009; Pribullová et al. 2009). Landscape values also play an important role and attract visitors to these areas, not only in the winter season (Pütz et al. 2011). The intensive development of ski resorts has been observed since the mid-20th century, especially in the Alps and other high European mountains, such as the Tatras (Krzesiwo 2015). This has brought many economic as well as social benefits to the local communities (Koenig & Abegg 1997; Vanham et al. 2009; Tsuyuzaki 1995; Ries 1996; Tsuyuzaki 2002; Watson & Moss 2004; Braunisch et al. 2011; Morrison & Pickering 2013; Pröbstl-Haider et al. 2016; Cremer-Schulte et al. 2017; Mayer & Mose 2017). Managers of ski resorts strive for the continuous development of the resorts (Holden 2000; Krzesiwo 2015; Mayer & Mose 2017) in order to maximize their profits and to satisfy skiers' needs and goals, such as the availability of good snow conditions, diversification of the ski area, and a choice of ski routes in one ski resort (Gilbert & Hudson 2000; Dickson & Faulks 2007; Żemła 2008; Konu et al. 2011; Krzesiwo & Mika 2011; Dorocki et al. 2014; Nowacki 2016). In the last 20 years, many ski resorts have noted shorter skiing seasons owing to insufficient snow cover (Koenig & Abegg 1997; Falarz 2002; Krzan et al. 2002; Scott et al. 2003; Abegg et al. 2008; Holko et al. 2009; Vanham et al. 2009; Madziková et al. 2011; Szczerbińska & Pociask-Karteczka 2015). Artificial snow-making is a common adaptive strategy to climate warming (Hennessy et al. 2008; Steiger & Mayer 2008; Pütz et al. 2011; Rixen et al. 2011; Steiger 2012).

However, the development of ski resorts is one of the major threats to the conservation of the high-mountain environment. Building and maintaining cable cars, ski lifts, ski slopes and trails involves changes in relief and degradation of soil cover: the removal of rock and soil during construction works (to eliminate obstructions on the runs, for example), and changes in geomorphic processes and the physical properties of soil (Fahey & Wardle 1998; Fahey et al. 1999; Rixen et al. 2003, 2008; Delgado et al. 2007; David et al. 2009; Roux-Fouillet et al. 2011; Ristić et al. 2012). Artificial snow-making as well as slope grooming results in significant changes in water balance: longer presence and greater depth of snow cover on ski slopes, increased water consumption and run-off, and decreased ground-water levels (Berbeka & Berbeka 2010; Roux-Fouillet et al. 2011; Rixen & Rolando 2013). It may also lead to changes in vegetation (e.g. loss of biodiversity) and habitats (Titus & Tsuyuzaki 1999; Wipf et al. 2005; Caravello et al. 2006; Caprio et al. 2011), and impacts on wildlife (Laiolo & Rolando 2005; Rolando et al. 2007; Negro et al. 2009). Ski resorts with their related infrastructure and the direct impact of skiers (e.g. noise, littering) are also distinct ecological barriers, causing landscape fragmentation and disturbing migration corridors. The environmental impact of skiing and ski resorts as well as the visual impact of cable cars and ski slopes, perceived as dominant landscape features, have been confirmed by numerous studies in the Tatra Mountains (Mirek 1996; Balon 2002; Guzik et al. 2002; Tylek 2009; Jančura et al. 2009a; Jančura et

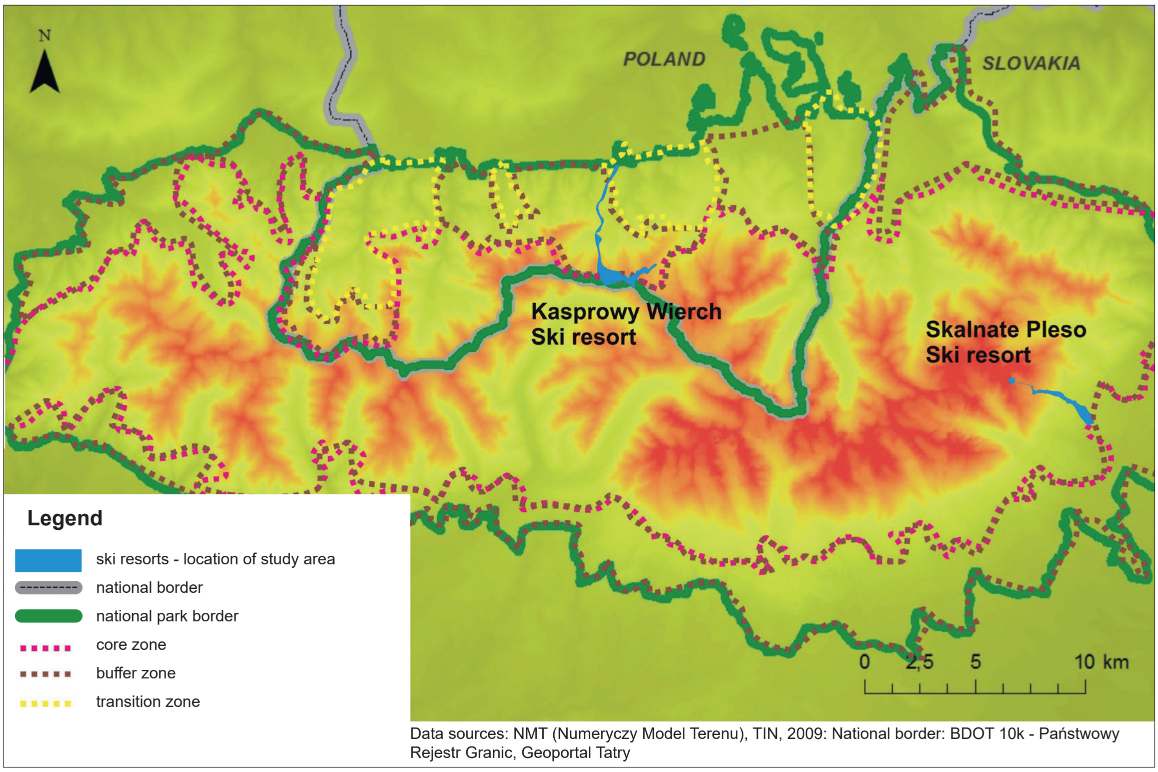

Figure 1 – The study area.

al. 2009b; Rączkowska & Kozłowska 2010; Hrčková & Holubová 2011; Zwijacz-Kozica et al. 2013).

In order to protect vulnerable high-mountain ecosystems from human impact as well as to preserve their environment unaltered or only slightly transformed, a dense network of protected areas has been created in Europe since the beginning of the 20th century, with national parks (NPs) playing the most important role. The development of ski resorts in core zones of NPs is in contradiction with IUCN guidelines and is forbidden by law in most European countries (Dudley 2008; IUCN 2016; Jodłowski 2019). This has resulted in many conflicts between stakeholders in nature conservation (NP authorities, environmental offices, scientists, but also mountaineering organizations) and the ski resort industry (resort operators, local and regional authorities and ski organizations) (Thompson 1999; Holden 2000; Bauch & Lainer 2014; Krzesiwo 2015; Mayer & Mose 2017). Although the establishing of NPs in the Alps (e.g. Hohe Tauern in 1981, Berchtesgaden Alps in 1978 see Pichler-Koban & Jungmeier in 2017) restricted the development of ski resorts in the areas with the highest bio- and geodiversity, cable cars, ski lifts and ski slopes were often located in the close vicinity of protected areas. However, in the Carpathians and the Sudetes, the high-mountain ranges are relatively small and present a unique value in their respective countries. In these two areas, the NPs encompass most of the area above the timberline. Therefore, the development potential for the ski resort industry is very limited there. In most cases, in the high mountains of Poland, Slovakia and Czechia the cable cars and ski runs were built before the NPs were established, and the creation of protected areas has slowed down their development (Krzesiwo 2014, 2015; Jodłowski 2019).

The challenges for the operators of ski resorts located within the protected areas encompass legal constraints, over-exploitation of the natural environment as a result of artificial snow-making (decreasing water supplies), together with growing economic costs. This could in future lead to a decline in the resorts' competitiveness on the market. Thus, change in the ski-resort development paradigm and reassessment of earlier adaptive strategies relating to climate warming in close co-operation between ski-resort operators, the local authorities and managers of protected areas is necessary (Flagestad & Hope 2001; Steiger & Mayer 2008; Pütz et al. 2011; Rixen et al. 2011). Such a paradigm change is particularly relevant for NPs in Central and Southern Europe, where the conflict between nature conservation and the development of ski resorts is particularly marked (Jodłowski 2019).

One way to reduce the negative environmental impact of tourism, including skiing, is the introduction of restrictions, in terms of infrastructure construction and development, as well as of visitors' mobility. However, the results from many protected areas show that the regulations and limitations introduced by their managers are broken by tourists because of a lack of understanding of their legitimacy (Eagles et al. 2002; Witkowski et al. 2010; Spenceley et al. 2015; Bielański et al. 2017; Jodłowski 2019). Only increasing visitors' environmental awareness through campaigns

Table 1 – Cable cars and ski runs in the Kasprowy Wierch and Skalnaté Pleso ski resorts (based on: Kasprowy Wierch 2017a; Kasprowy Wierch 2017b; Vysoke Tatry 2017a; Vysoke Tatry 2017a).

	Kasprowy Wierch			Skalnaté Pleso		
	Name	**Capacity [p/hour]**		**Name**	**Capacity [p/hour]**	
Cable cars	Kuźnice – Kasprowy Wierch	360 (winter season)		T. Lomnica – Štart	900	
				Štart – Skalnaté Pleso	2 400	
Chair-lifts	Kasprowy Wierch – Gąsienicowa	2 400		Lomnické Sedlo – Skalnaté Pleso	900 (winter season)	
	Kasprowy Wierch – Goryczkowa	720		Skalnaté Pleso – Čučoriedky	2 400	
				Štart – T. Lomnica	2 600	
				Buková Hora	2 400	
				Maxiland I – for children	-	
				Maxiland II – for children	-	
	Name	**Difficulty level**	**Length [m]**	**Name**	**Difficulty level**	**Length [m]**
Ski runs	Gąsienicowa	Difficult	1 200	Lomnické Sedlo	Difficult	1 240
	Goryczkowa	Difficult	1 770	Francúzska Mulda	Difficult – freeride zone	-
	Goryczkowa – Kuźnice	Easy downhill course	3 500	Esíčka	Medium	1 300
	Hala Gąsienicowa – ski routes	-	8 500	Generál	Medium	1 350
	Hala Kondratowa – ski routes	-		Čučoriedky východ	Medium	960
				Čučoriedky zapad	Medium	880
				Buková hora východ	Medium	700
				Javorova cesta – I and II	Easy	450/250
				Grand Slnečna	Easy	1 100
				Štart zapad	Easy	2 000
				Štart východ	Easy	850

which promote environmentally-friendly behaviour brings positive results. Additionally, it is important to take into account the opinions of various stakeholders, both managers of protected areas and entrepreneurs, and visitors who are interested in practising specific winter sports (Eagles et al. 2002; Sterl et al. 2010; Imoos & Hunziker 2015; Cremer-Schulte et al. 2017; Jodłowski 2019).

The main aim of this study is to gain information on skiers' expectations and criticisms regarding two important ski resorts in the High Tatras: Kasprowy Wierch (Poland) and Skalnate Pleso (Slovakia). A further aim is to examine whether the fulfilment of skiers' expectations could have negative consequences for the environment. The article also includes recommendations for how to meet skiers' expectations without significant impact on the natural environment. An additional aim is to compare the two ski resorts.

Study area

Both ski resorts are located in the Tatra Mountains – the highest mountain range in the Carpathians, on the border between Poland and Slovakia (Figure 1). The whole area is protected within NPs (Poland's Tatrzański Park Narodowy (TPN) and the Slovakian Tatranský Národný Park (TANAP). The protective regimes and regulations regarding tourism management in both parks differ significantly. However, in both it is forbidden to leave marked trails or ski outside designated trails and slopes (TANAP 2019; TPN 2019; Jodłowski 2019). Since 1993, both parks together have been protected as a single UNESCO Biosphere Reserve, and since 2004 as Natura 2000 sites (PLC120001, SKCHVU030, SKUEV0307).

TPN (211.97 km²) was established in 1954 and is visited by a vast and growing number of tourists (approximately 2.75 million between 2000 and 2010, 3.7 million in 2016, and 4.0 million in 2018; Tatrzański Park Narodowy 2018). Approximately 14% of visits took place during the winter season. The authors have not been able to obtain specific data on the number of skiers among winter visitors to Kasprowy Wierch (KW), but the majority of winter visits are connected with skiing (Taczanowska et al 2019; TPN 2019; TPN STATISTIC 2019). TANAP was established in 1949 and has more than three times the area of TPN (738 km²). There are no entrance fees to TANAP, nor any other systematic register of visits, and so there are no detailed annual data on the number of visitors, which is roughly estimated at 3.5 million (Šturcel & Švajda 2005; Švajda 2009; TANAP 2019). Around 45% of tickets for cable cars to the Skalnate Pleso (SP) area were bought during winter seasons. However, as for the KW area, the authors have not been able to obtain specific data on the number of skiers among winter visitors.

The cable car from Kuźnice (Zakopane) to KW (1 949 m a.s.l.) was built in 1936, despite opposition from organizations connected with the protection of nature and those involved in tourism and mountaineering (Konieczniak 2010). The cable car and the resort were owned by a public company until 2013, when KW ski resort was sold to a private enterprise founded by an international investment fund. Since 2018, the resort has again been under the management of a public company, owned by the State Treasury. In the 1960s, two additional chairlifts were built, which extended the opportunities for skiing in the area. Altogether, there are 15 km of runs, of which less than 3 km are located above the timberline. The rest are relatively narrow ski runs and trails in the forest (Table 1; Skawiński 2005; Laszczyk et al. 2007; Kasprowy Wierch 2017a). The whole area of KW ski resort (excluding the buildings of the upper cable car station) is located in a zone of strict nature protection (the highest protection regime in Poland). However, it is also designated as the buffer zone of the UNESCO Biosphere Reserve. Despite numerous discussions, artificial snow-making is not allowed there (Nowacki 2016), and slope grooming is conducted only in one part of the area designated for skiing. Skiers do not have to pay any additional entrance fee to the NP; this is included in the ski pass price.

The first cable car from Tatranska Lomnica to Lomnický štít (2632 m a.s.l.), with a mid-station at SP, was built in 1938 and caused public protests, especially from conservation groups (Muntág 2007; Bohuš & Bohuš 2008). An additional chairlift to Lomnické sedlo (2190 m a.s.l.) was built in 1957. Since 2009, SP ski resort has been owned by one of the biggest tourism companies in Central Europe – Tatra Mountain Resorts (which also owns Jasna ski resort in the Nizke Tatry NP in Slovakia, and the Špindlerův Mlýn ski resort in the Krkonoše NP in Czechia). There are 12.4 km of ski slopes and ski trails available for skiers (Table 1; Vysoke Tatry 2017a). The SP resort is mostly located in the core zone of the UNESCO Biosphere Reserve as well as within the Skalnatá Dolina national nature reserve. Only the lower part of the slopes is located in the buffer zone of the Biosphere Reserve.

In November 2004, over 12000 ha of montane forest in the Tatras were flattened by strong wind (the so-called *Veľká kalamita*; Balon & Maciejowski 2005). Since this natural disaster, the whole of SP ski resort (as well as the other ski resorts in TANAP which do not have windbreaks) has been excluded from the Natura 2000 site. This made the extension of ski runs and the modernization of ski lifts possible. It also raised numerous protests, including objections from the IUCN (Švajda 2006; TATRA MAB 2019). Currently, all the runs in the ski resorts are groomed, and snow-making takes place on 86% of them, mostly in the lower parts (Nowacki 2016).

KW and SP are the most popular ski resorts in Poland and Slovakia, with only a few competitive resorts in the high-mountain area: Chopok-Jasna in the Nizke Tatry NP, and Vratna in the Mala Fatra NP in Slovakia; Szrenica in the Karkonosze NP in Poland. In TANAP, there are three ski resorts in addition to SP (Štrbské Pleso, Roháče and Hrebienok); however, SP is the highest ski resort in Slovakia. There are also a few ski resorts near Zakopane (Poland), in the mid-mountain area outside the NP. The best of these is Białka Tatrzańska, a well-developed modern ski resort. However, the upper station is located 1000 metres lower than in KW, which is therefore often preferred by skiers (Krzesiwo 2014; Nowacki 2016).

Methods

An on-site survey (Paper-and-Pencil Interviewing technique (PAPI)) was conducted by skilled interviewers in the two cable car areas to gather data using a non-random, accidental sampling method. The survey was conducted in the winter seasons 2013 / 2014 and 2014 / 2015. A total of 404 questionnaires were collected (KW: 197; SP: 207). The questionnaire was divided into four thematic sections: (I) general information about the trip; (II) motivations; (III) opinions; (IV) mountain experience and safety. Additionally, general information about the respondents was collected. One of the purposes of the surveys was to obtain visitors' opinions about particular ski resorts as well as about ski trail preparations. Respondents were also asked for their opinions on the number of people carried by the cable cars, and on the visual impact of the cable car and ski area on the mountain landscape. All the questions were based on a 5-point Likert scale (Babbie 2003). Respondents who were less satisfied with their visit to a particular ski resort (3 points or less on the Likert scale for general opinions about the ski resort and / or ski trail preparations) were also asked to explain their dissatisfaction. At KW, 67 visitors submitted 111 comments; at SP, 53 visitors submitted 83 comments. In the next step, statistical analyses using SPSS software were conducted. In order to verify whether there was any relationship between skiers' opinions and criticisms regarding selected ski resorts on the one hand and socio-demographic variables on the other, two types of statistical test were used: Spearman's rank correlation coefficient (rS) and Chi-square.

Results

Opinions about the ski resorts

More than half of the respondents (KW: 53%; SP: 57%) declared that the cable car capacity was adequate. Therefore, they did not wish to see any changes. However, around 20% of the respondents from KW believed that the cable car's capacity should be increased. Only a small percentage of respondents stated that cable car capacity should be reduced (KW: 10%; SP: 8%; Figure 2). According to the majority of respondents (KW: 70%; SP: 64%), the cable cars fit well with the mountain landscape. About 12% of respondents believed that the cable cars in SP did not go well with the landscape (Figure 3).

The results show that only about half of the respondents evaluated KW ski resort as either good or very good (35% and 17% respectively). The trend is reversed in SP, where almost 90% of visitors felt satisfied with their visit (Figure 4). The more negative feelings about KW were probably the result of a

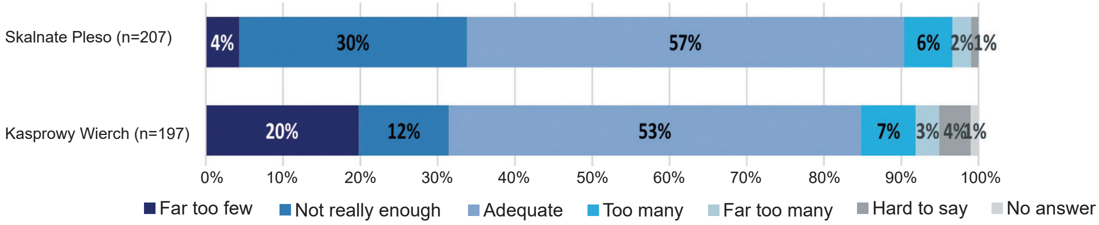

Figure 2 – Opinions about the number of people carried by the cable cars.

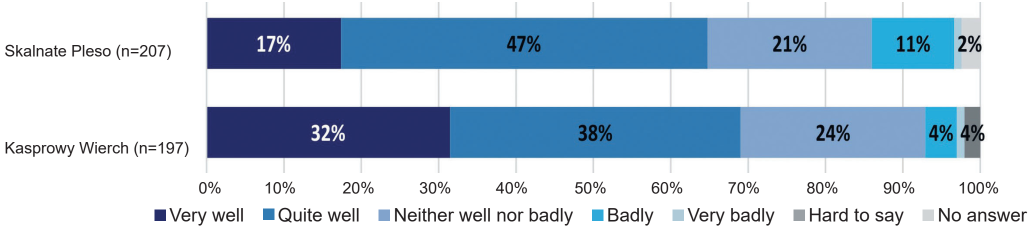

Figure 3 – How the cable cars fit into the landscape, according to respondents.

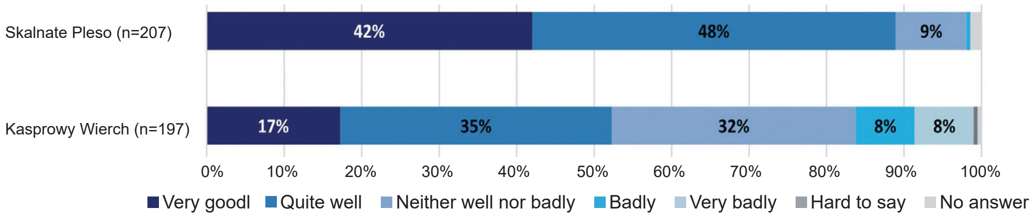

Figure 4 – Opinions about the ski resorts.

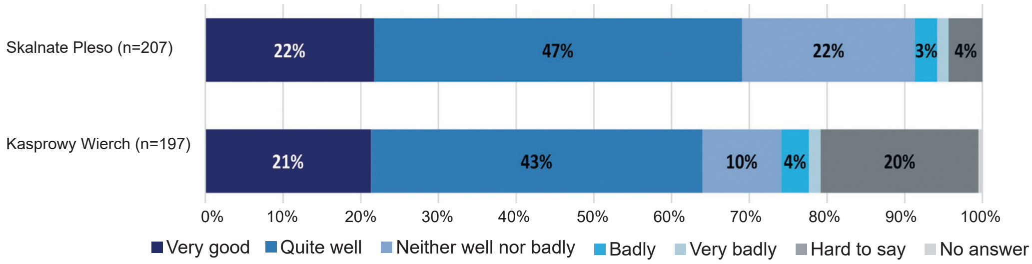

Figure 5 – Opinions about the preparation of the ski trails.

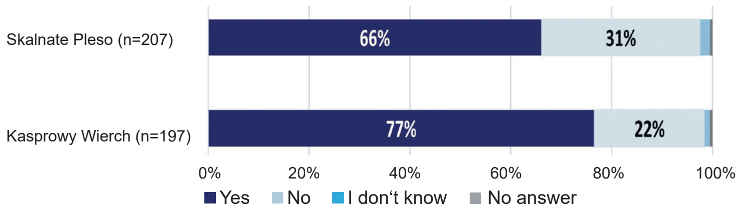

Figure 6 – Should new cable cars / chairlifts be built in the research area? – Respondents' opinions.

comparison with other ski resorts in the Alps and Slovakia which have modern infrastructure and greater skiing opportunities. However, the criticism of KW could also reflect a negative attitude towards the cable car managers, because prices were often thought to be too high in comparison to the quality of service, as emerged in discussion with visitors. A slightly different trend was observed regarding the preparation of ski trails. In both resorts, about 60% of respondents considered it good or very good (Figure 5).

The majority of respondents accepted development of the ski resort, including the building of new cable cars. However, some differences between ski resorts were observed. Approximately 77% of respondents from KW stated that new cable cars and chairlifts should be built in TPN. Slightly fewer respondents (66%) supported building new cable cars in TANAP (Figure 6).

Complaints regarding the ski resorts

Complaints were divided into four categories:

1. comments on the preparation of the ski trails,
2. comments on new investments within the resorts,
3. socio-economic comments,

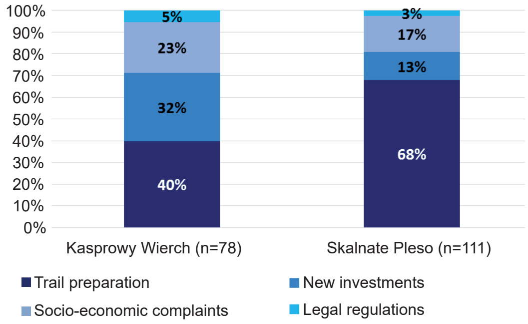

Figure 7 – Types of complaint.

4. comments on the legal regulations (which are different in the two resorts).

The results differ slightly between the two resorts – primarily, a greater number of comments by visitors to KW, where 111 comments made by 67 visitors, compared to 83 comments from 53 respondents at SP.

In KW, where snow-making is forbidden, approximately 40% of complaints concerned the preparation of the ski slopes, especially the need to maintain acceptable snow cover. A few respondents (3%) requested the opening of all ski trails (there are frequent problems with chairlift operation on Goryczkowa ski trail due to strong wind, where there is also at times insufficient snow cover). Individual comments also concerned the extension and presence of obstructions on the trails (1% and 2% of respondents respectively). 32% of all responses concerned new investments. Approximately 10% of respondents suggested the modernization of the chairlift at the Goryczkowa ski trail. Some respondents also wanted to see an increase in the number of ski trails (3%), the construction of new chairlifts (2%), and increased capacity of the existing chairlifts (2%). Individual respondents suggested also increasing the speed of the chairlift, and the demolition of the old hut in the valley. 23% of comments referred to socio-economic questions. The majority of complaints within this category concerned excessive prices (8% of all responses). Other comments referred to improving the ticket sales system, generally improving the quality of service, enriching the gastronomic offer, and restoring the old historical restaurant decor. Respondents also asked for improvement in the punctuality of the chairlifts (the main cable car should run every 10 minutes during high winter season) and free maps. Some visitors complained about crowding on the ski slopes. 5% of responses dealt with legal regulations, suggesting that a freeride zone might be introduced there (3%) (i.e. an area for free, even extreme, skiing), and changes near the start of the Goryczkowa trail (1%; Figure 7).

Criticisms in SP were more homogeneous. Approximately 68% of comments concerned the preparation of the ski trails, notably the need to improve the quality of snow grooming (16% of all respondents). Comments also concerned bumps and protruding rocks (7%), the extension of trails, and improving trail marking (1%). Approximately 17% of negative comments made in SP were of a socio-economic nature. Respondents complained mainly about crowding on the ski slopes and high prices, and the need to improve the ticket sales system, the quality of service, and the gastronomic offer. Only 13% of comments concerned new investments – for example, modernization of the old chairlift to Lomnické sedlo (3%), increasing the number of ski trails and chairlifts, and demolition of the old unused cable car buildings (1%). Only 3% of all comments considered legal regulations. Respondents argued for lifting the ban on ski-touring on ski runs after 4:00 p.m. (Figure 7).

In order to obtain information about the relationship between opinions and complaints on the one hand, and other socio-demographic variables, Spearman's rank correlation coefficient (rS) and x2 test (Pearson's chi-squared test (x2); Table 2) were used. The results of the rS show that there are only weak negative correlations between (1) opinions on the ski resort and the frequency of stay in SP during the skiing season (−0.2), and (2) opinions on the preparation of ski trails and the frequency of stay in the Tatra Mountains outside the skiing season (−0.225). A negative correlation in these cases means that respondents who were less likely to ski in SP or to visit the Tatras outside the skiing season evaluated the preparation of the ski trails negatively.

The results of the x2 test show the following correlations: (1) between respondents' type of activity in the ski resorts, their opinions on the number of persons carried by cable cars, and their opinions on the ski trails; (2) between the respondents' type of activity in the ski resorts and their opinions about building new cable cars in KW; (3) between frequency of stay in the ski resorts during the skiing season, their general opinions on these specific ski resorts, and their opinions on the preparation of the ski trails; (4) between complaints and opinions about ski resorts, as well as opinions on the preparation of the ski trails for both SP and KW. However, for the majority of the complaints, there were poor data distributions, which means that too many cells had an expected number of less than 5 (Table 2).

Discussion

Comparison with other studies

As this research shows, good snow conditions on the ski slopes are the most important factor affecting respondents' satisfaction levels. Similar conclusions can be found in other research (Dickson & Faulks 2007). Gilbert & Hudson (2000) emphasize that the lack of good snow conditions and crowding on the slopes discourage visitors, even those skiers who to date have been very active. Konu et al. (2011) note that good snow conditions as well as the diversification of the ski area are among the most important factors which determine respondents' choice of ski resort. It is worth emphasizing that the main objection in both research areas was the inadequate preparation of ski trails in terms of snow cover.

The majority of other studies include a wider range of elements used to assess ski resorts. Nevertheless, there are similarities between our findings and those of other researchers. Dorocki et al. (2014) also showed that ticket prices were important: in their study area in the Podhale region of the Carpathians, ski resorts with lower-priced tickets were highly rated. In the Czech region of Beskydy (Havrlant 2011), slightly different criticisms, relating mostly to complementary services in ski resorts, were made by respondents. The overall level of satisfaction was similar in our research.

Similar research was conducted by Krzesiwo & Mika (2011) in the Silesian Beskids as well as in the Podhale region. However, they included wider and more detailed elements when assessing skiing conditions. Their results showed that the relatively new, modern ski resort in Białka Tatrzańska (Podhale region), which is close to the Tatra NP, is evaluated much more highly than either of the ski resorts analysed in the present study. The main objections concerned over-crowding.

Interesting research has also been conducted in Tyrolean ski resorts by Pröbstl-Haider et al. (2016). Their work was not intended to assess the ski infrastructure, but to analyse opinions on the potential reduction in size of the protected areas in order to expand the ski resorts. A similar question was also asked in this research ("*Should new cable cars / chairlifts be built in the research area?*"). If we compare the results from our own and Pröbstl-Haider et al.'s studies, we note that substantially more respondents from the Tyrolean ski resorts than in KW were opposed to further expansion of the resort. However, in the Tyrolean research, the authors emphasized that further expansion could take place only by limiting the protected area. Similar results were noted when comparing the Tyrolean ski resorts and SP.

Nowacki (2016) compared Polish, Czech and Slovak ski resorts using the hedonistic pricing method. The results showed that KW definitely does not represent good value for money. Similar objections were made by respondents from KW in this research. Furthermore, according to Nowacki (2016), the best ski resort among all the Polish, Czech and Slovak resorts is located in SP.

Implications for PA management

One of the key objectives for managers of protected areas is to reconcile preserving the natural and cultural values of an area with enabling its recreational use. This could be achieved either by enforcing legal regulations or through direct and indirect soft management measures (Eagles et al. 2002). The legal regulations on a national level concerning the recreational use of NPs in Poland and Slovakia are relatively strict compared with those in Alpine countries. Not only is it forbidden to build any infrastructure which may cause a threat to the natural environment, but there are also far-reaching limits on mountaineering, climbing and skiing (both ski-touring and alpine skiing) (Jodłowski 2019). Thus, the possibility of fulfilling skiers' expectations concerning both the current functioning of the ski resorts in the Tatra Mountains as well as proposed changes must take into account economic, social and environmental factors, as well as current legal regulations.

The recurring ideas for the development of ski resorts in the Tatra Mountains (new cable cars, chairlifts, and an expanded network of ski runs and trails), even if they might be economically viable, must be strongly rejected because of their potential environmental impact. In Poland, such developments are almost impossible to carry out owing to regulations on Natura 2000 sites concerning nature conservation and environmental impact (Ustawa 2004; Ustawa 2008). In Slovakia, such plans are more feasible, since ski resorts were excluded from Natura 2000.

Old infrastructure in poor condition not only requires proper maintenance and repair works, but strongly affects visitors' satisfaction. Such infrastructure may also pose safety and environmental threats (noise, soil pollution). This is the case mainly for the Goryczkowa chairlift in KW. Thus, modernization is necessary, although it should be limited to replacing the old chairlift with a new one without increasing its capacity and length (which are in the plans of the ski resort's operator).

Owing to its environmental impact, artificial snowmaking is one of the most controversial matters in relation to ski resorts. However, it is carried out, to varying extents, in almost every ski resort in Europe, as well as in the NPs in Slovakia (including the Tatra NP) and Czechia, and in Karkonosze NP in Poland. In the Polish Tatra NP, it is forbidden under the terms of the environmental permit, which also regulates other aspects of infrastructure, such as the start of the skiing season (Jodłowski 2019). The tendency to use artificial snow on the slopes will probably get stronger, in view of a warming climate. The limited natural water sources in the Tatra Mountains (Kot 2010) and increased water demand in winter will eventually lead to the construction of reservoirs and a piping system. Such works would require the use of heavy equipment and cause largely unpredictable environmental damage. Cautious slope grooming as well as snow gathering on leeward slopes and its relocation might be a solution for lack of snow cover in the most sensitive parts of ski trails, although it will not solve the problem in the long term. Therefore, we recommend that artificial snow in NPs should be avoided or at least minimized, even if this leads to decreasing ski resorts' incomes due to a shorter skiing season.

However, the results show that further development of ski resorts in the Tatra Mountains is generally accepted by their users, with a high level of acceptance

Table 2 – x2 test – respondents' opinions analysed in terms of sociodemographic and characteristic variables of visit. (*) but poor data distribution

	opinions about number of people in cable cars		opinions about how the cable car fits into the landscape		opinions about the ski resort		opinions about the ski trail preparations		opinions – should new cable cars be built in the research area?		complaints	
	Asymp. Sig. 2-sided											
	SP	KW	SP	KW	SP	KW	SP	KW	SP	KW	SP	KW
gender	0.932	0.200	0.262	0.118	0.269	0.106	0.223	0.132	0.699	0.655	0.843	0.032
age	0.199	0.49	0.662	0.306	0.874	0.830	0.016	0.682	0.394	0.408	0.300	0.573
level of education	0.814	0.035	0.945	0.939	0.945	0.506	0.879	0.059	0.300	0.615	0.387	0.857
place of residence (size)	0.906	0.888	0.946	0.220	0.693	0.393	0.863	0.181	0.468	0.402	0.088	0.871
type of physical activity	0.003 (*)	0.179	0.327	0.022	0.468	0.005	0.002 (*)	0.086	0.048	0.000 (*)	0.545	0.639
frequency of skiing in research areas	0.279	0.171	0.873	0.142	0.004 (*)	0.194	0.004 (*)	0.046	0.748	0.006	0.055	0.088
frequency of visit out of skiing season	0.725	0.321	0.779	0.720	0.075	0.842	0.030	0.982	0.833	0.234	0.111	0.455
complaints	0.477	0.174	0.686	0.754	0.000 (*)	0.000	0.000 (*)	0.000 (*)	0.343	0.153	x	x

of artificial snow-making as well. Additionally, most respondents do not perceive the skiing infrastructure as a factor that decreases landscape value. Thus, a management strategy that limits the use of artificial snow might be considered unsympathetic towards skiers and ski resorts. Hence, an educational campaign raising environmental awareness, but also promoting ski resorts in the Tatra Mountains as *environmentally friendly*, is needed, pointing to the unique opportunities for skiing in pristine high-mountain landscapes on natural snow.

Educational campaigns, however, are hard to implement without the close co-operation of stakeholders. Managers of NPs, environmental offices, scientists, ski-resort operators, the skiers themselves and tourism organizations are all crucial to ensure the effectiveness of any campaign. In 1996, one such broad-ranging campaign aimed at ski tourers (*Skibergsteigen umweltfreundlich*) was launched in the German Alps by the German Alpine Association (DAV) together with the Bavarian environmental office. After running for almost 20 years, it was expanded to address other outdoor activities in the mountains (Deutscher Alpenverein 2014). In the Polish Tatra Mountains, a few educational campaigns have been launched in recent years focusing mostly on wildlife protection and addressed to all NP visitors (Jodłowski 2019). In order to reach skiers specifically, the buildings of cable car stations might be partially adapted as visitor centres, which would also enforce close co-operation between ski resort operators and NP managers. Such projects are being carried out in the Berchtesgaden NP (Germany) and the Sierra Nevada NP (Spain), where higher cable-car stations (Jenner and Hoya de la Mora) are located on the NPs' borders (Jodłowski 2019).

A strategy of this type might be effective in the Polish NP, where KW is not perceived by Poles as a typical ski resort but as the *Holy Mountain for Skiers* – a historical, almost legendary place (Nasz Kasprowy 2018). The designation of freeride zones (without grooming and artificial snow-making) in the vicinity of existing ski slopes, and relaxing restrictions for ski-touring would be part of the strategy. However, such ideas are controversial because of the possible impact on wildlife (Thiel et al. 2008; Bielański 2010; Zwijacz-Kozica 2008; Zwijacz-Kozica et al. 2013). Detailed regulations would need to be drawn up, followed by improving ski slopes and ski trails, and an informational and educational campaign.

Another suggested management strategy is *place demarketing* (Kern 2006; Wearing et al. 2007; Bradley & Blythe 2013; Koniorczyk & Wiechoczek 2014), which would lead to a reduction in the number of ski resort users in NPs and changing their social profile. The technical difficulties of ski slopes in a high-mountain environment should be underlined in the marketing policy of both NPs and ski resorts to discourage inexperienced skiers. At the same time, outside NPs, other ski resorts, with easier ski runs and modern infrastructure, should be developed and promoted along with other outdoor activities and tourist attractions. Although demarketing strategies as such based on economic tools (e. g. higher ticket prices) are rarely used in European NPs, a combination of informational and place demarketing is quite common, even if it is not called such – for example, giving information about current weather and snow conditions as well as the difficulties of particular trails in order to discourage less experienced tourists (Eagles et al. 2002; Jodłowski 2019). Demarketing strategies are also used in combination with direct regulations (legal restrictions).

The Hauts-Plateaux du Vercors nature reserve (French Alps) is promoted as a wild area unsuitable for inexperienced visitors. Cross-country skiing and ski touring (especially guided tours) are preferred activities, but investments in ski resorts are not allowed (Dupuis 2004). In Gesäuse NP (Austria), special zones (*Winterruhezone*) were established in 2007 to protect the winter habitats of galliforms (*Tetrao urogallus* and *Lyrurus tetrix*), which were threatened by ski touring. In order to reinforce formal restrictions, NP managers promote nature-friendly winter activities outside these zones through educational tools, also creating ski trails that bypass threatened habitats (Sterl et al. 2010).

In Tatra NP, no such strategies have been implemented so far. However, in the Polish Tatra NP, a small but successful campaign has been launched recently to protect *Crocus scepusiensis*, a charismatic species found in mountain pastures in the Western Carpathians, threatened by massive trampling. NP managers and local authorities not only use various media as well as repressive measures to discourage tourists from visiting meadows in the NP, but also promote visiting similar locations outside the protected area (TPN 2018).

Strengths and weaknesses of the research

An important strength of this research is the selection of the ski resorts included in the analysis. Both ski resorts are located in the same mountain range. Furthermore, the historical development of both started in the 1930s, and both KW and SP are protected as NPs. However, the protection regimes in the two parks and the extent of restrictions are different, which is a result partly of political and economic pressure. Therefore, despite a similar historical development, the ski resorts have developed in distinct ways. Thus, their perception by tourists also varies.

This research does not include a detailed assessment of the elements affecting the perceived quality of a ski resort, which limits the possibility of comparing our results with other studies. A further significant limitation of this research was the absence of a specific question to identify the resorts' weak points. Comments on this were limited to those made by respondents who were less satisfied with their visit to a particular resort. It would also be worthwhile asking respondents about the strengths of the ski resorts, and about their knowledge and awareness of protected area status and regulations.

Conclusions

The KW ski resort was definitely less favourably evaluated by visitors. A higher percentage of respondents evaluated both the cable car capacity and the overall functioning of the resort as very poor, and reported what they considered to be necessary changes. These comments related mostly to the limited number of cable cars and chairlifts operating in KW. Significantly fewer ski trails compared to the SP ski resort and prices that do not reflect the limited offer and quality of service also had a negative impact on the general opinions about KW. However, KW was more favourably assessed in terms of how well it sits in the surrounding mountain landscape. This is related to the fact that SP offers more ski trails and chairlifts, and hence its impact on the environment is greater and more visible. A similar correlation is noted when it comes to the comments about the construction of new chairlifts. Respondents from SP were less willing to accept the idea of building new chairlifts, because the existing ski resorts on the Slovak side of the Tatra Mountains are considerably more developed. The investor (TMR – the owner of SP ski resort) presented a project for a new cable car, which would have connected the SP and Hrebeniok areas, but the project was rejected owing to social protests (Portal Tatrzański 2019).

SP, with its extensive offer, does not significantly differ from the standards of Alpine ski resorts. The majority of skiers in SP were satisfied with their visit, and complaints here concerned mainly technical issues related to the maintenance of the ski trails. The implementation of further restrictions in the functioning of the ski resort, although a reasonable management strategy concerning environmental factors, is unlikely owing to political and economic pressure. Thus, management actions should be aimed at limiting the expansion of the ski resort (Portal Tatrzański 2019).

Compared to other modern ski resorts, KW is poorly developed and attracts mainly local visitors. According to the results (respondents' opinions and criticisms), in order to reach the standard of another Tatra resort, SP, KW should implement many far-reaching changes, which would have a significant impact on the natural environment.

From the skiers' point of view, expanding the KW resort would be the proper strategy. This would undoubtedly raise its standard to that prevailing in Alpine ski resorts. However, such investment is not only in strong contradiction with the general concept of a NP, but also impossible to implement according to Polish law. Management strategies that we recommend could change the quantitative and qualitative structure of skiing activity in the NP, minimizing its environmental impact, and raising ecological awareness and support for nature conservation strategies. The crucial factor in implementing such strategies is close co-operation between the various interest groups, with NP managers and local authorities being key stakeholders who, in an optimal scenario, would share the ownership of cable cars and ski lifts. Such changes in the ownership structure are currently a subject of political debate (Portal Samorządowy 2017).

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Introducing the Hiking Suitability Index to evaluate mountain forest roads as potential hiking routes – a case study in Hatila Valley National Park, Turkey

Hilal Turgut, Ayse Yavuz Ozalp & Halil Akinci

Keywords: National Park, outdoor activities, geographic information system, analytic hierarchy process

Abstract

Planning recreational areas for a conservation–use balance is important in the sustainable use of national parks. This study was conducted to determine the suitability of forest roads as hiking routes in Hatila Valley National Park, northeastern Turkey. The indicators used as evaluation criteria were determined using the natural characteristics and landscape values of the National Park. A multi-criteria decision analysis (the Analytic Hierarchy Process; AHP) was used, with route length, slope, altitude, aspect, walking time, landscape quality and access to clean water as the main parameters. Experts were consulted to determine the weights of parameters and the linear scoring functions. Expert opinions were also used for scoring measurable and unmeasurable sub-parameters. A Hiking Suitability Index (HSI) was formulated using these parameters to score the suitability of existing roads for hiking. A Geographic Information System (GIS) was used to map the parameters and hiking routes. Results showed that slope was the most important parameter in assessing suitability. We concluded that forest roads can be used for hiking in protected areas without harming nature, and the suitability of routes can be determined using AHP.

Profile

Protected area

Hatila Valley National Park

Mountain range

Kaçkar Mountains

Country

Turkey

Introduction

Hiking, trekking and mountaineering are often used as synonyms. In particular, hiking and trekking are often used interchangeably, though in fact they refer to different things. Trekking is an outdoor walking activity with a duration of more than a day; daytrips are called *hiking* (Oksuz 2020). Hiking is perceived as light walking to commune with nature and is practised especially as a weekend activity to get away from the pace of life in big cities.

People undertake nature sports to acquire and develop physical, social and mental skills, to commune with nature, ease stress and promote health (Ardahan & Mert 2013; Kaplan & Ardahan 2013). After walking, people report feeling mentally rested, having better control over their lives, a sense of pride, a boost in self-confidence, and having felt close to nature (Arnberger et al. 2002; den Breejen 2007); some develop a greater awareness of nature conservation (Solnit 2001). In recent years, many protected areas have become destinations for nature-based tourism activities (Mason 2005). National parks (NP) are the most popular areas for such activities (Kaczynski & Henderson 2007). Furthermore, it is known that using NPs for nature sports increases visitor satisfaction and the demand for these areas (Ping et al. 2017; Schirpke et al. 2018).

The careful planning of recreation areas is necessary because the demand for outdoor recreation has grown continuously. People's expectations of what the landscape has to offer (and the limitations that they will accept) have to be met by recreation planners, and this depends on the extent of the land base and its current uses, its variety and robustness, the climate, and alternative opportunities (Bell 1997). Recent studies on recreational areas have focused on issues such as sustainability in natural areas with a high potential for recreational activities, landscape metrics, diversity of use, the identification of suitable areas, and the ecological impacts that might result from recreational uses. In these studies, Geographic Information Systems (GIS) and remote sensing techniques were used extensively (Weaver 2002; Beedie & Hudson 2003; Nyaupane et al. 2004; Báez 2002 Nepal 2006; Tsaur et al. 2006; den Breejen 2007; Gunes & Hens 2007; García-Frapolli et al. 2007, Chakrabarty 2011; Hai-ling et al. 2011; Bunruamkaew & Murayama 2011; Kiper 2011; Tomczyk 2011; Li et al. 2012; Ween & Abram 2012; Nahuelhual et al. 2013).

In early studies on hiking activities, duration emerged as a consideration, and thus Naismith (1892) developed the theory of walking time. Subsequent studies focused on parameters affecting walking, such as ground conditions, weather conditions, physical conditions of hikers, fatigue, and the load carried by hikers (Fritz & Carver 1998; Rees 2004; Scarf & Grehan 2005; Scarf 2007; Sonneveld et al. 2009; Erbaş et al. 2011; Magyari-Saska & Dombay 2012; Pitman et al. 2012). Outdoor sports in natural areas are favourite recreational activities. In a study carried out to determine the spatial requirements of outdoor activities, Kramer and Roth (2002) used morphological properties such as slope, aspect and altitude, landscape characteristics such as vegetation, use of the landscape by agriculture, forestry and settlement, as well as climatic parameters such as temperature and pre-

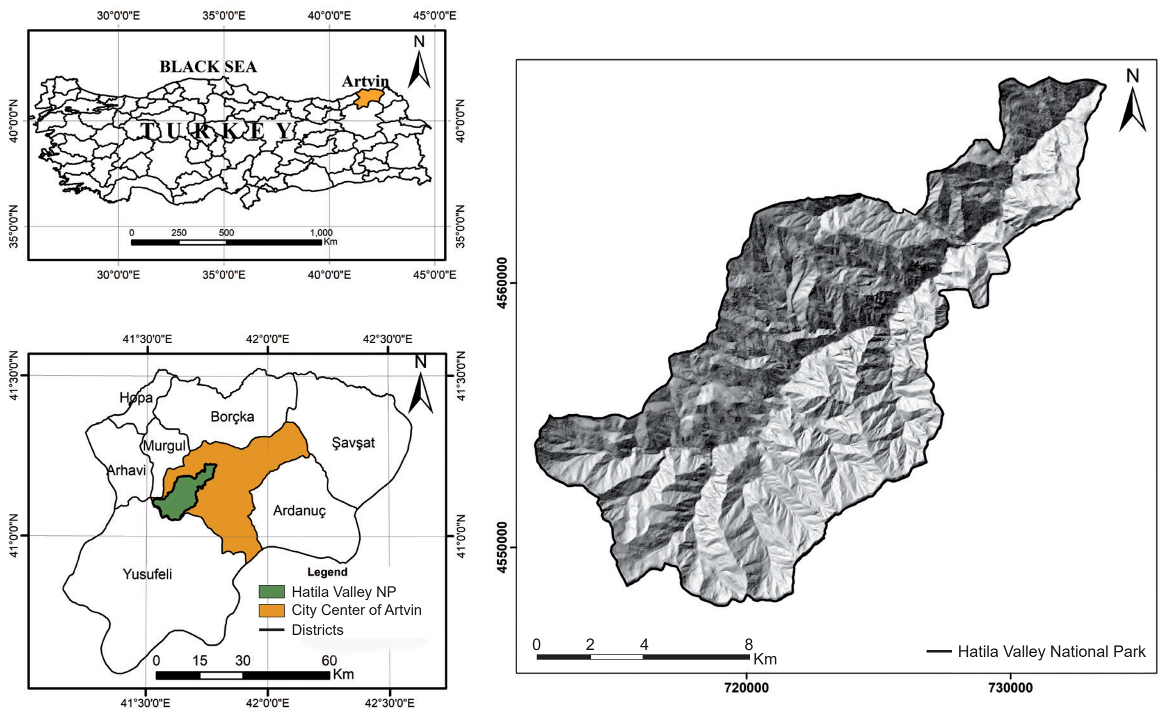

Figure 1 – Location of the study area. © 2020 General directorate of mapping

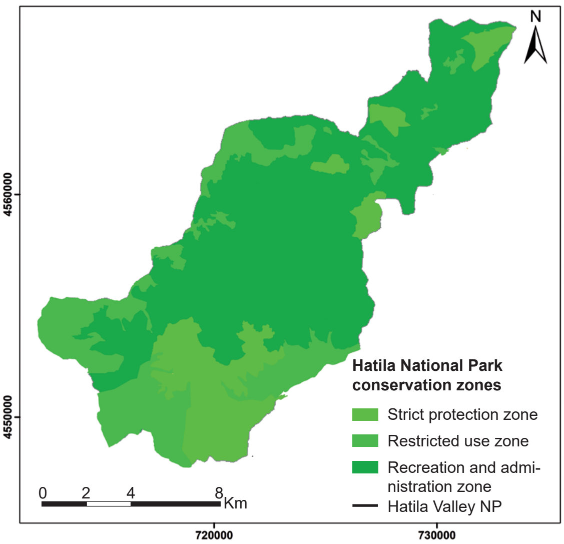

Figure 2 – The conservation zones of Hatila Valley National Park. © 2020 General directorate of mapping

cipitation in the evaluation process (Kramer & Roth 2002). A study conducted by De Valck et al. (2017) to determine the effects of landscape characteristics on people's outdoor activity preferences used distance from home, facilities, trail quality, tranquility, presence of water, and landscape openness, naturalness and diversity as evaluation criteria. In determining suitable routes for hiking, in addition to the topography, the share of landscape types (e.g. riverine forest, pine forest, bushes, meadows, agriculture, water, industry, buildings), infrastructure (e.g. number of benches), and attractions (e.g. picnic spot, restaurant, museum of natural history) were also taken into consideration (Taczanowska et al. 2008a). In Vias et al. (2018), route suitability was evaluated by applying criteria such as choice of the start- and endpoints of the route, suitability of the sections that constitute the route, route circularity, inclusion or not of a section of the trail in paths used by the general public or in the livestock trail. It is well known that route planning and the development of activities increase walkers' satisfaction and interest in natural areas, and encourage people to do outdoor sports (Ping et al. 2017).

Hatila Valley NP, which received its conservation status in 1994, is important for its rich biodiversity (Anşin et al. 2000; Kurdoğlu & Çokçalışkan 2011), scenery with high landscape value, geological and geomorphological formations, and the presence of water. Home to important ecosystems, the area offers educational and recreational activities. The settlements within the boundaries of the Hatila Valley NP and the paths and forest roads that connect them constitute important opportunities for hiking. This study aimed to determine the suitability of forest roads as hiking routes in Hatila Valley NP using the Analytical Hierarchy Process (AHP) and GIS. The main reason for choosing the Hatila Valley NP as our study area was the fact that it is the most preferred area for outdoor activities.

Materials and method

Study area

Located in Turkey's Eastern Black Sea Region, Artvin is a city of approximately 7 367 km^2. Hatila Valley NP is located 6.8 km northwest of the city centre, between 41° 02' 49.74" and 41° 13' 58.64" North, and

41°31'21.06" and 41°47'12.89" East (Figure 1). The total area of the study field is 16 944 ha. Hatila Valley NP, where 135 floristically rare endemic taxa are found, is one of the few areas where Mediterranean, Black Sea and Alpine meadow vegetation are all found, as well as a considerable number of medical and aromatic plants (Anşin et al. 2000). The Hatila Valley NP includes three conservation zones: the strict protection zone, a restricted-use zone, and a recreation and administration zone (Figure 2). While the annual number of visitors to the Hatila Valley NP was just 500 until 2016, it increased to 30 000 after infrastructure and facilities were built in 2016.

The physical properties of the field

The altitude in the Hatila Valley NP ranges between 170 m and 3 220 m, averaging 1 724 m (Figure 3a). Differences in altitude over short distances increase the attractiveness of the area for hiking by creating rich route options. Hatila Valley NP, through which the Hatila stream flows, is a young V-shaped valley. The valley sides are quite steep because of the strong vertical erosion (Figure 3b). The valley is covered with natural old forests. 38% of the forest area is sunny; 62% is shady (Figure 3c).

Materials

The materials of this study were forest roads that connect the remotest parts of the forest to the main road in the Hatila Valley NP. They provide access to the forest for timber management, fish and wildlife habitat improvement, fire control, hunting, and a variety of recreational activities (Northern Research Station n.d.). This study looked at the suitability for hiking of 11 routes (walking time up to 8 hours, with different start- and endpoints, and safe) along the forest road network within the borders of Hatila Valley NP (Figure 4).

Method

The Analytic Hierarchy Process (AHP) was used to determine the level of suitability of potential hiking routes in Hatila Valley NP, in a four-stage process:

- choosing the main parameters;
- weighting the main parameters using AHP;
- scoring the sub-parameters using linear scoring functions and expert opinion;
- calculating the hiking suitability index using GIS.

Choosing the main parameters

The first stage of the AHP was to determine the parameters to be used in decision-making and the evaluation of the hiking routes. The opinions of 30 members of the Patika hiking club were gathered. Participants were asked to score properties relating to morphology, infrastructure and landscape that affect their hiking preferences according to a 3-point Likert scale (not important, don't know, important). Seven parameters that respondents said were *important* were

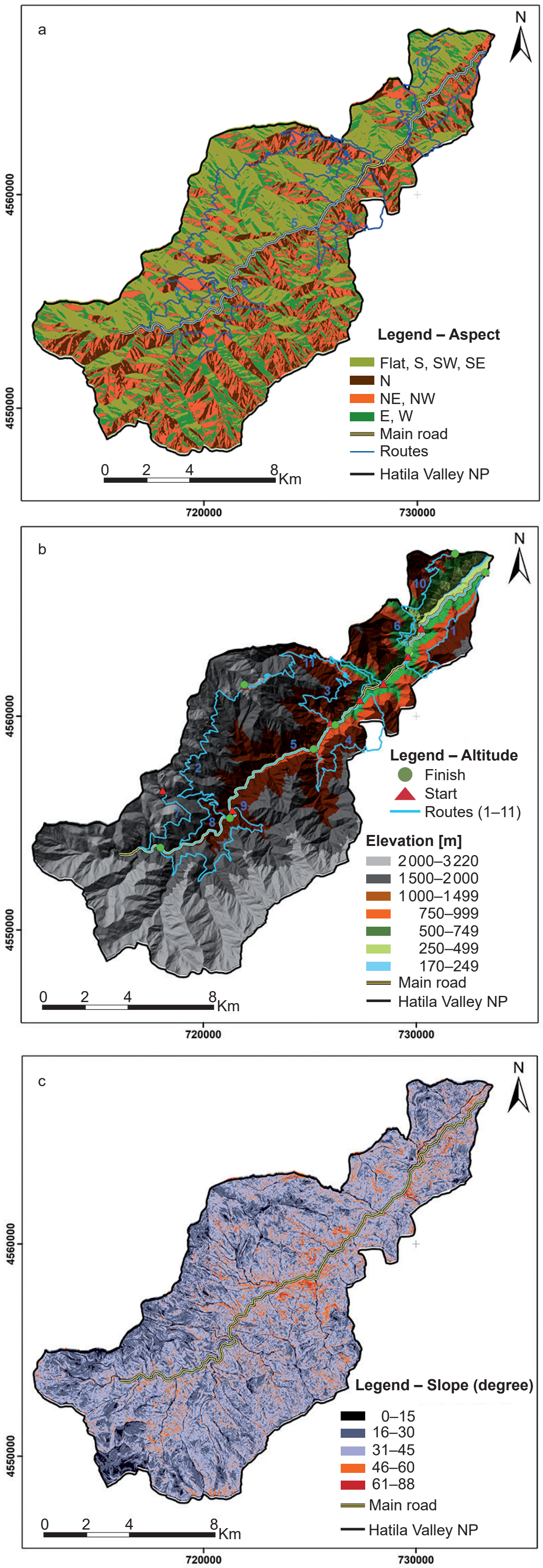

Figure 3 – Maps showing (a) aspect, (b) altitude, and (c) slope in Hatila Valley National Park. ©2020 General directorate of mapping

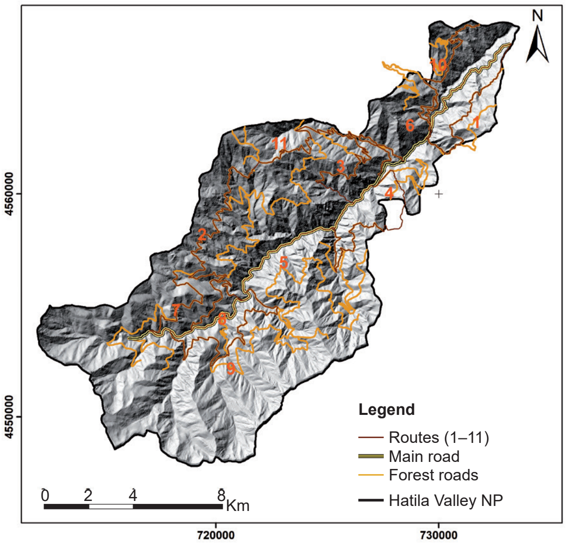

Figure 4 – The forest road network and routes. © 2020 General directorate of mapping

chosen as evaluation parameters (altitude, slope, aspect, walking time, distance, access to clean water, and landscape quality). ArcGIS 10.2 software was used to digitize the parameters and to create a digital elevation model (DEM) of the site. Some descriptive information of the main parameters, based on the views of experts, is given below.

Altitude

Areas between 1 500 m and 3 500 m are considered high; ones between 3 500 m and 5 000 m are considered very high. There are differences in body functions depending on altitude, due especially to decreased oxygen (O_2) levels in the air as altitude increases. While there are no differences in body functions up to 1 000 m, there are slight changes between 1 000 m and 1 500 m. Above 1 500 m, a decrease of 3–3.5% in O_2 for every altitude increase of 300 m negatively affects many body functions, especially blood pressure. At altitudes of over 3 000, a two-night stay is needed for every 300 m of ascent for blood pressure to adapt (Kanai et al. 2001; Wagner et al. 2006; Bhaumik et al. 2008).

Slope

Hiking routes consist of descents, ascents and level sections, depending on the topography. Continuous descents and ascents along a route and slopes affect a route's suitability. In this study, the routes were divided into line segments using the *Split Line at Vertices* geoprocessing method of ArcGIS 10.2. The start- and endpoints of each line segment were determined according to the direction of the route. Then, using the *Extract Values to Points* method in ArcGIS 10.2, the altitudes of the start- and endpoints of each segment were obtained. Using the altitude differences between these points and the length of the line segments, the slope of each segment was calculated, and finally the average slope.

Aspect

As discussed in the literature and as stated by the experts consulted for our study (see 1.4.2 below), aspect analysis becomes crucial when examining hiking in valleys as the two sides of a valley face in different directions (Yılmaz & Memluk 2008). The hemisphere where the hiking is taking place, the season, and the region's climate characteristics emerge as key factors. In the northern hemisphere, regions facing north and shady areas are preferred for summer hiking activities; regions facing south and sunny areas are preferred in winter. Because of snow cover, most activities are carried out in the summer.

Distance

The findings from the interviews showed that people preferred walking routes that were neither too long nor too short. The geological fault lines in Hatila Valley NP and the blind valley are characteristic of the area. When the actual lengths of the walking routes in the area and the projected lengths were compared, differences of between 170 m and 820 m were found. It is therefore more meaningful to use the actual lengths in calculations, which in our study ranged from 7 500 m to 17 000 m.

Walking time (Duration)

Under normal conditions, the distance that one person can cover in an hour is between 4 000 m and 5 000 m. However, the degree of slope affects this. In the literature, various approaches and rules are used to determine walking time (Naismith 1892; Langmuir 1984). However, in our study, the hiking function of Tobler (1993), which considers the slope of the land, was chosen to calculate the walking times of the routes:

$$\text{Time (hours)} = 0.000166666 * (\text{EXP}(3.5 * (\text{ABS}(\text{TAN}(\text{Slope}) + 0.05)))) \quad (1)$$

In the application stage, all routes were first divided into line segments. The slope of each line segment and its actual length in the terrain were then calculated. Then, the walking time for each line segment was estimated using the above formula. Finally, the walking times of all line segments forming a hiking route were summed.

Access to clean water

Access to clean water was one of the main parameters, with access or no access to a water resource used as sub-parameters. The need for clean drinking water, to maintain the body's fluid balance during long walks especially, is an important parameter for the safety of hikers.

Landscape Quality

It emerged from the interviews with the participants in hiking activities that landscape quality was a

Table 1 – Linear function types used to calculate the scores of continuous variables.

Main parameters	Linear function type	Equation	r_1	r_2
Altitude	Less is better	$f(x)=1-\frac{(x-x_1)}{(x_2-x_1)}$		
Slope	Optimum range	$f(x)=1-\frac{(x-x_1)}{(r_1-x_1)}$; $x_1 < x < r_1$ $f(x)=0$; $r_1 < x < r_2$ $f(x)=1-\frac{(x-r_2)}{(x_2-r_2)}$; $r_2 < x < x_2$	−5°	+12°
Distance			12 000 m	16 000 m
Walking time			4h	6h

In the equations, f(x) is the score of sub-parameters between 0.1 and 1, x is the identified value of the sub-parameter, x1 and x2 are the minimum and maximum values, and r1 and r2 are the lower and upper threshold values.

Table 2 – Scores of sub-parameters for discrete variables.

Main parameters	Sub-parameters	Score
Aspect	S, flat, SW, SE	0.2
	N	0.6
	NE, NW	0.8
	E, W	0.4
Access to clean water resources	Present	1
	Absent	0
Landscape	Good	1
	Average	0.6
	Bad	0.4

key factor in choosing walking routes in natural areas. Within the field of the study, aesthetically pleasing areas such as viewpoints, points of high visual value, and cultural landscape elements were considered important. Sub-parameters were evaluations of these as good, average or bad. Hatila Valley NP features a V-shaped valley offering unspoiled natural and cultural landscapes, with a richness of geological formations and vegetation.

The aspect parameter was defined using four groups of sub-parameters: (1) southerly, southeasterly, southwesterly and flat; (2) northerly aspects; (3) northeasterly and northwesterly aspects; (4) easterly and westerly aspects.

Weighting the main parameters

A pairwise comparison matrix was created to weight the parameters chosen based on the AHP. In this matrix, the relative importance of the parameters to each other was determined by face-to-face interviews with a group of 20 experts comprising academics from departments of landscape architecture, physical education and sports, and tour guides working in nature tourism. The significance scale developed by Saaty (1980) was used in the paired comparisons.

Scoring the sub-parameters

Continuous variables, such as altitude, slope, distance and walking time, were scored using linear scoring functions (Qi et al. 2009; Guo et al. 2017). The functions are listed in Table 1. Optimum range function was used for slope, distance and walking time, while *less is better* was used for altitude. On the other hand, discrete variables, such as aspect, access to clean water and landscape quality, which cannot be expressed by a numerical value, were scored on a scale of 0.1 to 1.0 (0.1, lowest; 1.0, highest), based on the opinions of the 20 experts (see Table 2). Sub-parameters that adversely affected the hiking activity had lower scores; sub-parameters with positive effects received higher scores.

Hiking Suitability Index of the routes

Raster maps of the parameters used in this study were prepared in ArcGIS 10.2. First, a DEM of the study area was generated in the TIN data structure by using the contour lines (10m interval) of a 1 / 25 000-scale topographical map covering the study area. The DEM was then converted to a raster format (ESRI GRID format) with 10 m x 10 m cell size using the *TIN to Raster* operation of ArcGIS 10.2; slope, aspect and altitude maps of the area were generated based on the DEM in raster format. The roads within the forest to be evaluated as hiking routes were digitized from the forest management maps of the study field and transferred to ArcGIS. The linear function scores for slopes, altitude, distances and walking times, and sub-parameter scores for landscape quality, access to clean water and aspects were entered into the ArcGIS database as attributes. After generating the maps for the parameters, the calculated weights and sub-parameter scores were assigned to the respective layers in ArcGIS, and then the Weighted Sum Overlay Analysis was used to calculate the Hiking Suitability Index (HSI) value of each route.

Table 3 – Pairwise comparison matrix.

Parameter	Slope	Altitude	Length	Walking time	Landscape	Water resources	Aspect	Weights
Slope	1	2	3	5	6	7	9	0.3712
Altitude	1/2	1	2	3	4	6	8	0.2389
Length	1/3	1/2	1	2	3	5	6	0.1586
Walking time	1/5	1/3	1/2	1	2	3	5	0.0993
Landscape	1/6	1/4	1/3	1/2	1	2	3	0.0629
Water resources	1/7	1/6	1/5	1/3	1/2	1	3	0.0440
Aspect	1/9	1/8	1/6	1/5	1/3	1/3	1	0.0251

Results and discussion

Weights of the main parameters

The pairwise comparison matrix for weighting the parameters used in this study showed that slope obtained the highest weight value and aspect the lowest (Table 3). In other words, slope was the most important parameter in determining the level of suitability of hiking routes. This was followed by altitude, length, walking time, landscape quality, access to clean water and aspect. The consistency ratio for the matrix was calculated as 0.0459. A consistency ratio value below 0.10 means that the decision matrix has a satisfactory level of consistency, and can be used without any adjustment (Zhang et al. 2004).

Scores of the sub-parameters

Two different approaches were used in the scoring of sub-parameters. In the first, length, walking time and slope sub-parameters were scored using standard, *optimal range*, scoring functions, while altitude was scored with a *less is better* function (Table 1). In the second approach, sub-parameters for aspect, water resources and landscape were scored according to expert opinions, reflecting their impact values on hiking (Table 2).

The optimum range function assigned 1 point to places with gentle descents and ascents, and where hiking was carried out comfortably (slopes between −5 and +12 degrees). The scoring function used for slope assigns a score in the range of 0-1 where the slope is less than −5 degrees and greater than +12 degrees. To calculate the slope scores of the routes, each route was first divided into line segments. Then, the slope of each segment was calculated according to the direction of the route, using the scoring functions. Finally, a route's slope score was calculated by taking the average of the slope scores of all the line segments for the route. The slope scores with the highest weight coefficient varied between 0.789 (route 4) and 0.939 (route 5), on a scale of 0-1 (Figure 5). These values showed that all roads in the Hatila Valley NP are suitable for hiking in terms of slope. Beeco et al. (2014), who looked at route preferences based on slopes, reported that hikers preferred routes with gentle ascents and descents.

An increase in altitude can reduce the suitability of a route for hiking, due to lower oxygen levels. Thus, in this study, altitude was scored using the *less is better* function. Researchers have reported that high-altitude areas are generally unsuitable for amateur hiking because of altitude sickness, especially at 2 500 m and above (Peterson et al. 2018; Imray et al. 2010; Reisman et al. 2017). The lowest (0.242) and highest (0.965) altitude scores were for routes 2 and 6, respectively

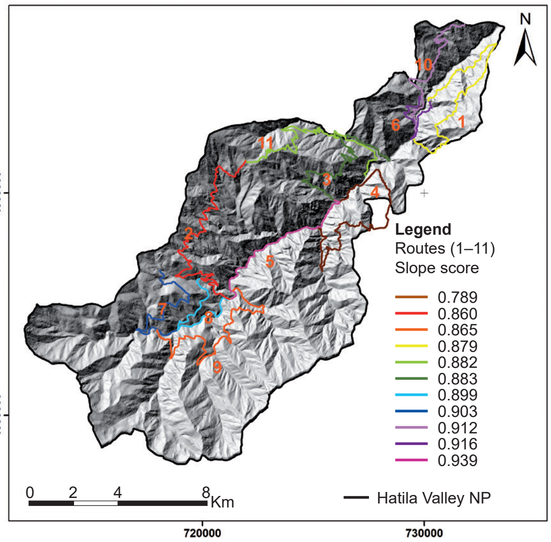

Figure 5 – Scores for the routes in terms of slope. © 2020 General directorate of mapping

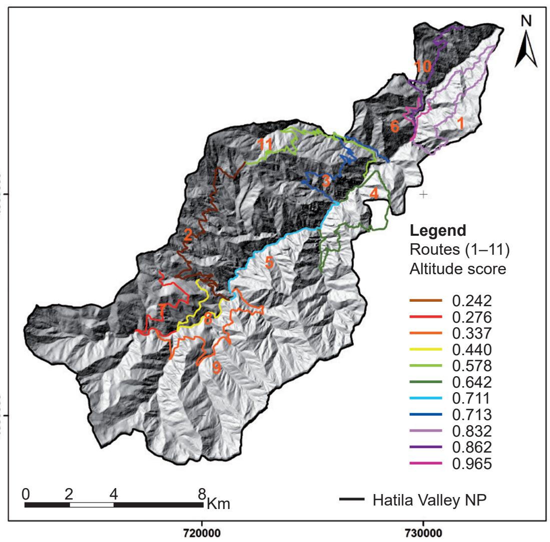

Figure 6 – Scores for the routes in terms of altitude. © 2020 General directorate of mapping

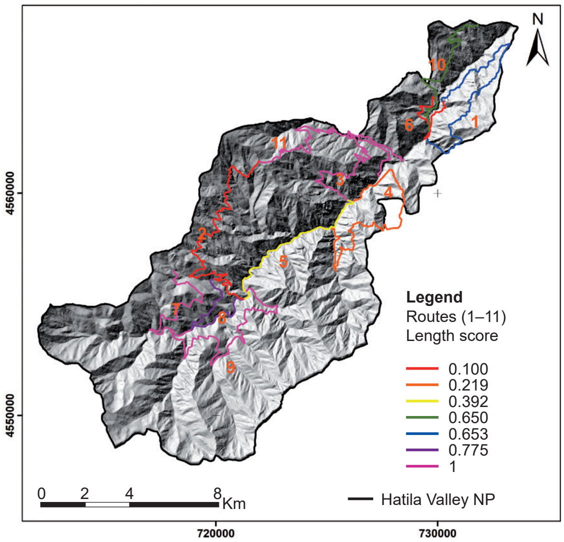

Figure 7 – Scores for the routes in terms of length. © 2020 General directorate of mapping

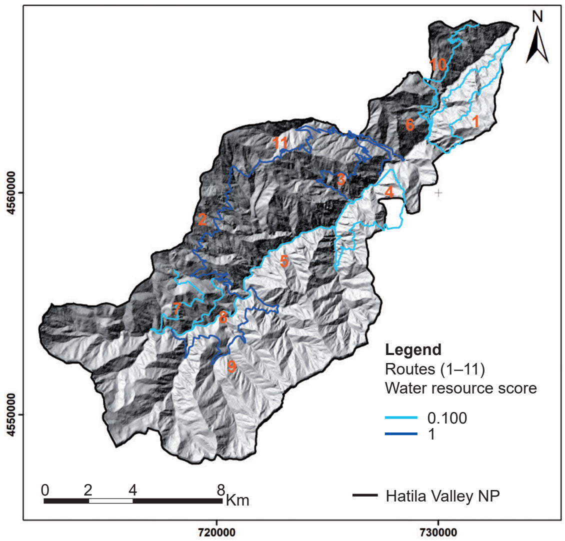

Figure 10 – Scores for the routes in terms of access to clean water. © 2020 General directorate of mapping

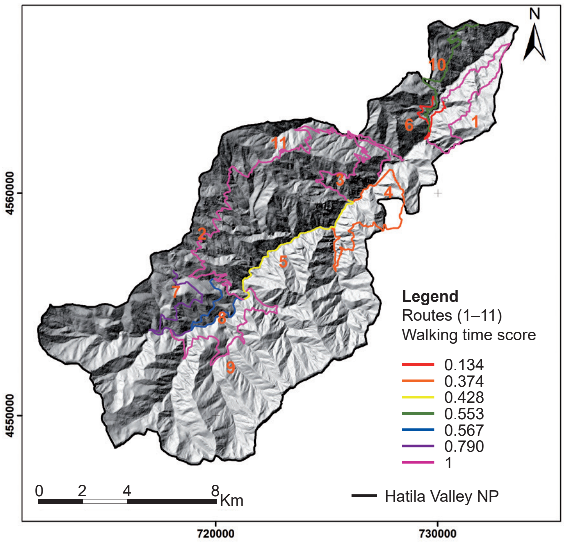

Figure 8 – Scores for the routes in terms of walking time. © 2020 General directorate of mapping

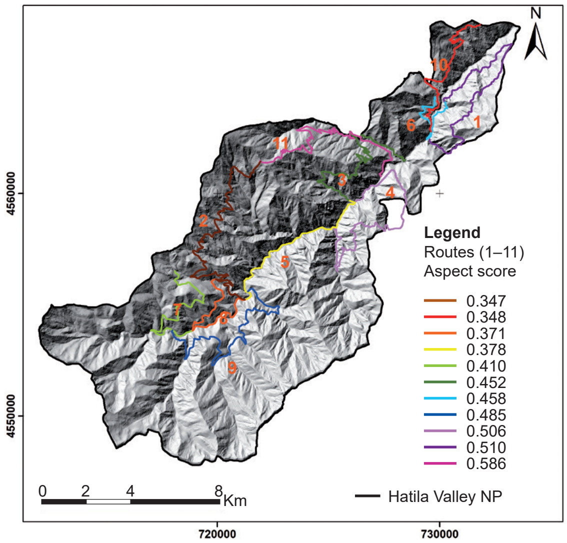

Figure 11 – Scores for the routes in terms of aspect. © 2020 General directorate of mapping

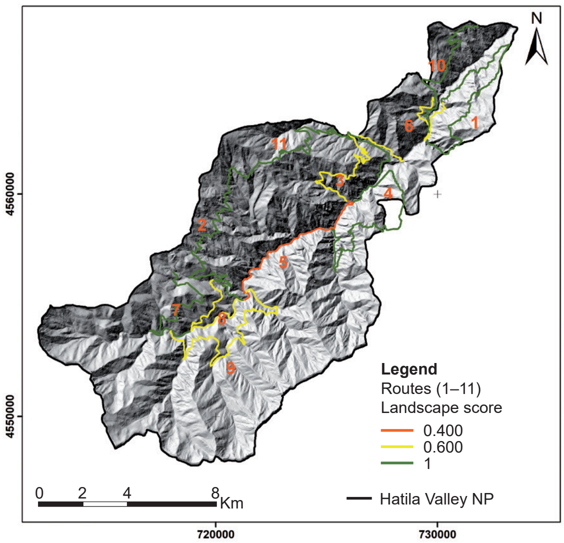

Figure 9 – Scores for the routes in terms of landscape quality. © 2020 General directorate of mapping

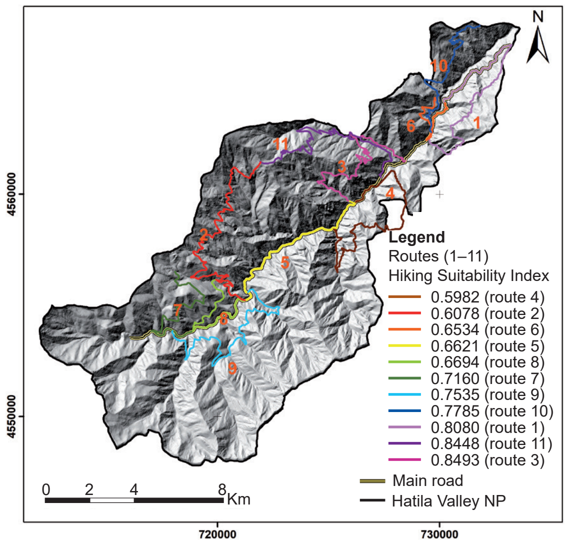

Figure 12 – Routes according to Hiking Suitability Index (HSI). © 2020 General directorate of mapping

(Figure 6). Since the altitude in the Hatila Valley NP varies widely due to the topography, the routes' scores also varied significantly.

Problems with motivation and a lack of pleasure in the hiking activity have been reported for distances of less than 8 000 m, and various health problems occur at distances above 16 000 m (Saayman & Vilioen 2016). Thus, the optimum range function was used to score length, and the highest score was assigned to the range 12 000–16 000 m. For distance, route scores ranged from 0.1 to 1.0. Routes 6 and 2 had the lowest scores because they are too short; routes 3, 11, 7 and 9 scored increasingly highly (Figure 7).

The optimum range function was used to score the walking time. The highest score was given to a walking time of between 4 and 6 hours, while the scores given to durations above and below this were gradually decreased. The lowest score for walking time was for route 6 (0.134), and the highest for routes 1, 2, 3, 9 and 11 (Figure 8). Route 6 had the lowest score because its walking time is much lower than the lower limit of the optimum range due its length. Saayman & Viljoen (2016) examined the success criteria for different routes in completely natural environments in Kruger NP and found that a walking time of less than one hour led to insufficient motivation. Other researchers have reported that participants in hikes stopped to look at the landscape, take photographs, taste edible plants and study animal behaviour (Korzeniewski et al. 2015), and therefore argued that the walking time could not be calculated on the basis of distance, as Naismith did (Scarf 2007).

Hikers prefer unspoiled natural areas, viewpoints, the existence of cultural landscape elements, and areas of high landscape value. 1 point was given for good landscapes based on expert opinions; areas with average and poor landscapes received 0.6 and 0.4 points, respectively. In terms of landscape quality, routes 1, 2, 4, 7 and 10 received the highest score (1.0), followed by routes 3, 6, 8 and 9 (0.6); route 5 received the lowest (0.4) (Figure 9). The study area in this research has high landscape quality, with properties such as intact natural and unique resource values, being home to rare geological formations and plant diversity, having a V-shaped valley, and having viewpoints throughout. Route 5 had the lowest score because it is located in the narrow valley bottom and therefore the view is blocked by the steep mountain slopes. Studies which investigated the effect of landscape on whether individuals carried out hiking found that natural and cultural landscape elements determined preferred hiking routes (Beeco et al. 2014; Mohd Taher et al. 2015; Van Berkel et al. 2018; Tieskens et al. 2018; Peterson et al. 2018).

Access to clean water was scored using two subparameters: access and no access. While hiking routes with potable water were assigned 1, routes without received 0.1 (Figure 10). Routes 2, 3, 9 and 11, which all allowed easy access to drinking water, scored with 1.0, while the score was 0.1 for routes 1, 4, 5, 6, 7, 8 and 10, where access to water was difficult. It is especially important to meet the body's water requirements during hiking activities. If the water lost through dehydration is not replaced by clean drinking water, the body will use metabolic water, and as a result fatigue and exhaustion will occur. Although carrying extra water may be a solution, the weight carried has an effect on walking performance, and accessible drinking water along the route positively affects route preferences (Andrus & Herbst 1979). In their study, Boulware et al. (2003) emphasized the importance of clean water during group activities.

As hiking was not possible in Hatila Valley NP in winter due to the difficulty of reaching the area, the evaluation was based on the spring and summer months. Because hiking activities are mainly conducted in summer months, shady areas are preferred. As a result, viewpoints facing northeast and northwest received 0.8, those facing north received 0.6, those facing east and west received 0.4, and 0.2 was assigned to those facing south, southeast, southwest and that were flat. As there are multiple viewpoints along each route, scoring was done by considering the orientation of viewpoints along each route. Based on this, route 11 received the highest score (0.586), and route 2 received the lowest (0.347) (Figure 11). Since north- and south-facing were the most common aspects throughout the Hatila Valley NP, aspect resulted in low scores on almost all routes.

The Hiking Suitability Index (HSI) of routes

The hiking suitability index (HSI) values of routes are given in Figure 12, and the scores of the parameters used in determining these values in Figure 13. Route 3, where the parameters for length, time and access to water all scored 1.0, was the most suitable forest road for hiking, giving it the highest HSI (0.8493).

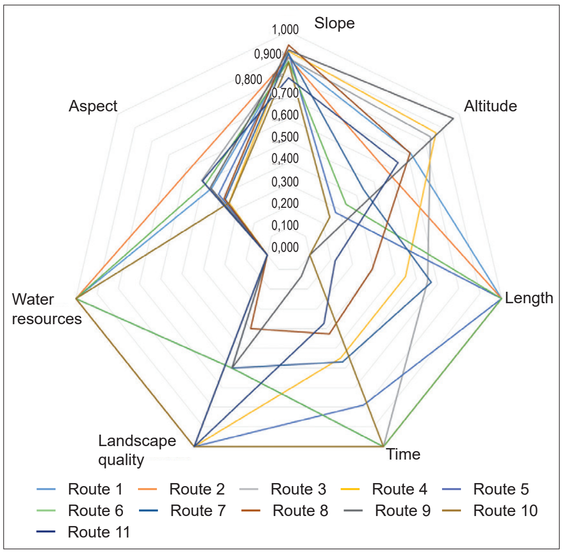

Figure 13 – Radar chart of parameter scores in Hiking Suitability Index (HSI).

It was a limiting factor that the altitude of route 11, which ranked second overall (0.8448), was above the optimum limits (Figure 13). Routes 1, 10 and 7 were in the third (0.8080), fourth (0.7785), and fifth (0.7160) places respectively. The limiting factor of the three routes was access to drinking water. For route 9, which ranked sixth with a score of 0.6857, the most significant limiting factor was altitude. The limiting factor for routes 8 and 5, ranked respectively seventh with a score of 0.6694 and eighth with 0.6621, was access to drinking water. Unlike the other routes, two different parameters (length and access to drinking water) reduced the score of route 6 (0.6534), which ranked ninth. Length was the most significant parameter in decreasing the score of route 2, which ranked tenth with 0.6078. Route 4 ranked last, with 0.5982; access to water was the most important limiting factor for this route. The most significant parameter governing the route ranking was access to drinking water, followed by length and altitude. Since a quantitative evaluation method based on weighting was used in this study, the low score of one parameter changed the suitability of the route, even if other parameters scored high.

Studies conducted to determine the reasons for choosing hiking routes and hiker behaviour state that the most important considerations are duration and length (Taczanowska et al. 2008b). Other studies have used properties such as distance, facilities and landscape characteristics (De Valck et al. 2017); personal characteristics of the hiker, such as gender, age, education, occupation, marital status and income, were also factors in user behaviour and route preferences (Ping et al. 2017).

In this study, the first of its type, we used a quantitative method to investigate the suitability of forest roads for hiking. Although Taczanowska et al. (2008b) reported that there was a match between the expected and actual behaviours of hikers in terms of the distance and duration of hikes, the empirical results of this study need to be verified using a quantitative method, which will increase the usability of the method in other areas.

In this study, summer conditions and the opinions of active hikers were taken into consideration in determining the evaluation parameters; the use of the area in other seasons and other user features, such as age and gender, were not evaluated. This situation may limit the use of the model elsewhere. However, age is decisive in individuals' behaviour and activity preferences. Tachel & Backhaus (2011) stated that older people as a visitor group were very interested in information about the NP, took their time on the trails, and spent more time on observation; what they most disliked was crowding and noise.

The landscape quality of routes was also evaluated and scored qualitatively in this study. To increase the reliability of the model, future studies will evaluate landscape properties quantitatively.

Conclusion

The current global pandemic has changed the recreational habits of people, encouraging them to move away from crowded urban environments towards natural areas. Ensuring the sustainable use of areas with sensitive resource value such as NPs has become even more important, and interest has increased in the fast and reliable assessment of infrastructure suitability for recreational activities in protected areas. Models created using GIS and multiple decision analyses such as AHP can be used for these purposes, as shown in this study, which evaluated the recreational potential of existing forest roads in Hatila Valley NP and concluded that they could be used for hiking. This study also concludes that GIS-based models could be used in the decision-making process and to measure the parameters. Finally, the reliability of the model could be enhanced by considering other user profiles in creating the parameters.

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On the impact of the COVID-19 pandemic on alpine research projects in Montana

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Abstract

Alpine field research often involves travel and hiking to steep but gorgeous mountain ranges where days are spent outdoors, and in our case, in botanical / ecological / sensor research. Under the usual conditions, alpine field researchers in Montana need to consider integral hazards such as cliffs, snow, stormy weather, the alpine sun, and bears. But what influence does a pandemic have on alpine field research?

Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) causes COVID-19 disease (Chen et al. 2020), which is now a pandemic that has caused the deaths of over one million people (Dong et al. 2020). Although Montana is relatively isolated, COVID-19 is still here and it is spreading rapidly, with 715 new cases reported on 9 October 2020 (Montana Dept. of Health and Human Services and Montana State Library 2020). Because there is no vaccination against COVID-19, and because it is an easily transmitted and potentially deadly virus, humans protect themselves and others by quarantines, social distancing, mask-wearing, and hand washing (Center for Disease Control 2020). Because of this very serious situation, ongoing changes have been made in the ways that humans conduct their activities. Still, politics influence whether people follow COVID-19 precautions and a dichotomy exists between people who wear masks and those who vocally oppose mask-wearing. Although on 15 July 2020 Montana Governor Steve Bullock issued a mandate for mask-wearing in Montana (Bullock 2020), people opposing the mandate have staged protests. It somewhat resembles the 1854 London cholera epidemic, when, in one of the world's first formal epidemiological studies, John Snow traced the epidemic's source to water from the Broad St. well. After his life-saving discovery the pump handle was removed, but authorities put the pump handle back on! (Brody et al. 2000).

A vast array of gatherings and events have been cancelled, postponed, or changed due to the COVID-19 pandemic. One example is that the Montana University System's fall semester started early, on 17 August, and will end in mid-November, with the idea that the early finish may reduce travel-related COVID-19 spread during the high-travel months of November and December. But this effectively reduces the number of available field days for professors.

Here I recount our summer 2020 alpine field research in light of the COVID-19 pandemic at the Montana field sites in the Anaconda-Pintler Wilderness, the Pioneer Mountains, the Highland Mountains, and at Glacier National Park.

Figure 1 – The trail from Goat Flat looking towards Storm Pass, 6 September 2020.

Montana field sites

Anaconda-Pintler Wilderness

Goat Flat, (2837 m; 46.3017° N, 113.1643° W), is a plateau of alpine tundra in the Pintler Mts. of the Anaconda-Pintler Wilderness in southwestern Montana. It has late-lying snowfields, solifluction lobes, and periglacial-patterned ground where we study plant functional traits and species distribution (Apple et al. 2019). Because Goat Flat is virtually inaccessible most of the year due to heavy snows and a steeply angled cirque, we are developing sensors and sensor networks to transmit soil moisture and temperature data remotely.

The trail to Goat Flat is 5.6 km long with an elevation gain of 296 m from the trailhead at Storm Lake to the periglacial patterned ground. While this trail is most sublime while walking past Storm Lake, through a forest, and ascending switchbacks to Storm Pass, the trail then cuts into the rock wall of a glacial cirque to make the dramatic crossing to Goat Flat (Figure 1). Along the glacial cirque the cliff rises sharply to the hiker's

Figure 2 – The Pioneer Mountains looking south, 18 July 2020.

right and falls away steeply to the hiker's left. There is room to pass people approaching from the opposite direction, but not enough room to attain the recommended two meters for proper social distancing. There is really no good way around this lack of distance. One way is to wear masks and avert faces from approaching people and another is to wait at Storm Pass or at Goat Flat until the trail is clear. It is no hardship to wait at Storm Pass or at Goat Flat because it allows time to take in the view, drink water, and have a snack.

A steeply angled snowfield on the glacial cirque blocks the trail (or at least impedes progress) until late summer, and the field season only lasts for approximately two months before the next season's snows arrive. It is in part because of the short field season at Goat Flat that we are developing a means of remotely accessing our sensor data, which involves laboratory work and field testing of sensors and sensor networks. This project is funded by the Earth Science Information Partnership (ESIP) Lab Program and began in March 2020, but the timetable was revised so that preliminary lab and fieldwork took place in the summer 2020, with student researchers participating during the 2020 / 2021 academic year and summer field season of 2021. One student currently works on this in an essentially solitary mode in the Fabrication Lab of Electrical Engineering at MTU. We hold in-person meetings but wear masks and stay two metres apart. Sensor design is almost ideally suited for solitary work alternating with periods of interactive feedback.

Although the Anaconda-Pintler Wilderness is in Montana, which is generally uncrowded, the trail to Goat Flat is popular in the summertime and it is a connector trail for hikers on the Continental Divide Trail from Mexico to Canada. Once on the alpine tundra at Goat Flat, there are usually other hikers present, but it is a large enough place for easy social distancing, even when curious hikers quizzically approach our group as we survey plants and install soil temperature sensors.

25 July brought the first Goat Flat trip of the season for James Gallagher and I, Jamison Ehlers (summer undergraduate research fellow / Electrical Engineering), Kevin Negus (collaborator in Electrical Engineering), Eva Negus (wife of Kevin) and their three border collies (Jess, Liz, and Meg). This five-person group was the largest of the summer. We limited group size to simplify logistics, avoid trampling the alpine plants, and reduce the likelihood of contracting COVID-19. Wearing masks on the 80 km drive to the research site cut down on coffee drinking and talking, so we had either a welcome silence or a lack of fun conversation, depending on your point of view. We began our hike on this cool Saturday by talking about things seen along the way (the beautiful lake, thistles, border collies, and snow), and a cheerful camaraderie ensued as we ascended the switchbacks to the Anaconda-Pintler Wilderness Boundary and up to Storm Pass. Along the trail from Storm Pass to Goat Flat, hikers approached from the other direction, so I sat down on a rocky ledge to obtain a safe distance. One hiker seemed not to realize why I was doing so, since he commented that it was nice to have a handy bench! Onward. We reached Goat Flat, and after lunch, we ventured down to the polygonal-patterned ground to take FLIR thermographic images of periglacial patterned ground and Krummholz trees, and to collect data on plant distribution. We practised social distancing and discussed ideas for remote sensing of snow data and ways to install sensor and LoWaRan (Long Range Wide Area Network) prototypes in the clay-rich, compacted soil of the patterned ground. Here it felt like a research trip from any era, except that the conversation inevitably veered towards the coronavirus pandemic, the upward spike of cases in Montana, and the plans to open the campus for in-person classes on 17 August 2020.

A hiker approached our group and I did a double take when I realized that it was one of my former students, who is also a friend of my son's. He was hiking with his dog, Macy, and after a round of introductions he conveyed that he works for Senator Jon Tester, a valuable proponent of human rights, education, and the environment. Well done, I said, and congratulated him on his field of employment. Only in Montana, I thought, would I be in the wilderness, meet up with a former student, and talk about politics during a pandemic. We finished gathering our samples and walked uphill to the late-summer snowfield. There we took more FLIR images, marvelled at the snow algae and the view, and began our return journey. On the way, we saw other groups of hikers, none of whom seemed particularly interested in social distancing. A little disturbing, but we were outside and had no contact with them.

Friday, 30 July brought the second trip to Goat Flat. Our crew consisted of Kurtiss Winscot, (undergraduate student / Biological Sciences), Jennifer Krueger (Physician's Assistant), her dog Gus, and me. In case you get the idea that Montanans like to hike with their dogs, you are correct! The upward hike was laborious on this hot day, although still enchanting. We saw a hummingbird but very few other people, as the weekend crowds were not there. Upon reaching Goat Flat, we went to the snowfield where I shoe-skied down the slope, Gus basked in the snow, and we then walked down to the patterned ground to talk about Krummholz trees and collect botanical data and soil samples. It was a relief to be at Goat Flat on an uncrowded day. By uncrowded I mean that we saw approximately eight other people the whole day, in comparison to the previous trip, when we saw approximately thirty other people. The ride home, after hiking in the hot sun, seemed strenuous as we had to stop the vehicle, establish safe distances and then remove masks before drinking water. Still, mask-wearing is far, far better than contracting COVID-19!

James Gallagher and I returned to Goat Flat on 6 September to test devices and to collect botanical data. Since it was September, the crowds had diminished and there was far less worry about coming too close to other hikers. We saw maybe five other people during our eight or so hours in the field. It probably helped that our field day was sandwiched between a very hot smoky day during which smoke arrived from fires on the west coast of North America and the next day, which brought the first snow day of the season.

Pioneer Mountains

The field season at the high mountain sites finally began in July when enough snow had melted off. The first field research day was at the highest of the four SW Montana Global Research Observational Initiative in Alpine Environments (GLORIA) Target Region summits in the Pioneer Mountains. GLORIA is a network of long-term sites on the world's mountains for monitoring alpine plants in the context of climate change (Lamprecht et al. 2018). Mt. Keokirk (2 987 m, 45.5938° N, 112.9510° W) is reached by travelling along a gravel road until it gets so rocky that it is just as easy, and safer, to walk the rest of the way to the summit. James Gallagher, my husband, and a collaborator on remote data networks and sensors, and I set out in the morning and made only one stop, which was at the Salmon Fly Fishing Access Site along the Big Hole River (a famous trout stream). We continued to the site and saw one man coming the other way in a pickup truck, and two people and a dog in an ATV 4 X 4 vehicle. We saw no one else at the site and were able to test our remote data access devices and survey the plants without having to worry about the virus. We did not see anyone else until we were almost back to the maintained part of the road, where we saw a bicyclist and two other trucks with people.

On 2 August, James Gallagher and I went to the treeline summit on Mt. Fleecer (2 873 m, 45.8264° N, 112.8019° W), home of the lower three summits of the SW Montana GLORIA site. On this hot Sunday we concentrated on hydration and shading. We brought a sampling grid, the FLIR camera, and a prototypical

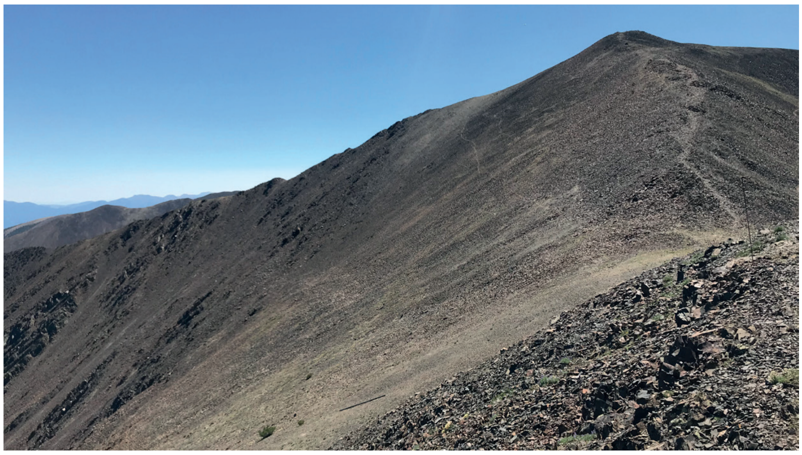

Figure 3 – The alpine scree of Red Mountain in the Highland Mountains of Montana, 4 August 2020.

test device for sending soil moisture data remotely. It worked! We saw no one else and only a few other vehicles on the road. The pandemic was not in evidence.

Highland Mountains

On Tuesday, 4 August Kurtiss Winscot and I ventured to Red Mountain (3 070 m, 45.4554° N, 112.2856° W) to collect FLIR images of Krummholz whitebark pine (*Pinus albicaulis*) and spruce (*Picea glauca*) near the treeline, at approximately 2 835 m. We walked upwards along a road on alpine scree to a forest fire lookout building at 2 926 m., where two hikers (seemingly brothers) ascended the steps. I quickly put on my mask. The unmasked brothers arrived, but there was enough room for distance. For the one-mile hike to the site, we still saw twenty people, which by Montana standards was fairly crowded. Some radio tower maintenance guys drove down the service road, where the steep drop-offs and shingled surface provide little margin for error!

Glacier National Park

Glacier National Park (GNP) has partially reopened in June. Although Montana trails have mostly stayed open, some eastern GNP trails did not open in 2020 because the Blackfeet Nation closed its western border with GNP to prevent an influx of COVID-19 (Scott 2020). In September I hiked through the 2017 Sprague forest fire burn to the Sperry Chalet with Jennifer Krueger and Sharon Holsapple. Sperry Chalet's exterior stone walls survived the fire, but the interior had to be rebuilt. Social distancing was in place for overnight guests, but the access trail was congested. We hiked beyond the chalet to Comeau Pass via steep stone steps and emerged at what was once the Sperry Glacier's edge but is now a landscape of rocks, puddles, snowfields and one lobe of the remaining glacier. The Crown of the Continent Research Learning Center at GNP granted approval to set and photograph sampling frames, in which moss was close to the steep snowfield's edge, and monocots and then dicots appeared with distance. A mountain goat (*Oreamnos americanus*) arrived at our site and it crossed my mind that that they are probably instrumental in dispersing seeds and establishing plants on terrain exposed by glacial retreat. We found an old can that looked to be a remnant of a picnic at the glacier's former edge.

Summary

In summary, and speaking just for our particular group, alpine field research for the summer of 2020 was minimally impacted by the pandemic, although we all felt and talked about the sadness of the pandemic. The impact on our project's field season was minimal thanks to our effective isolation at relatively remote mountain sites in Montana. All researchers and associates who went on the field research trips live in the area, so no extensive travel was necessary, and we reached our field sites via driving and hiking. Even so, we limited group size, planned our travel to the sites carefully, and maintained strict social distancing, mask-wearing, and hand-sanitizing protocols, following the recommendations of the Centers for Disease Control (2020). These recommendations are reflected in the Montana University System's requirements for mask-wearing, social distancing, hand sanitization, cleaning, contact tracing and quarantining (Montana University System 2020) as well as the Montana Governor's mandate for mask-wearing (Bullock 2020), and the Montana Department of Health and Human Services guidelines (2020). We travelled directly to the sites and back to reduce the likelihood of contracting or spreading COVID-19. Travel to GNP was somewhat uncertain at the beginning of the pandemic, so 2020 brought a shift away from the patterned-ground alpine field sites at the national park and towards the more localized patterned-ground sites for field research and expeditions. Still, the pandemic has had an impact on alpine field research in that the relevant conferences are (for now) virtual, and time will tell what effect this has on the collaborative spirit of generating scientific ideas and research.

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Muhar, S., A. Muhar, G. Egger & D. Sigrist (eds.) 2019. *Rivers of the Alps. Diversity in Nature and Culture.* Haupt. Berne. 512 pages. ISBN 978-3-258-08117-5.

Rivers play a very specific role in the Alps, their surrounding landscapes, and over large areas of Europe. They occur in various forms from mountain torrents to broad meandering watercourses and lakes, are highly interlinked, cover surfaces involving different countries and administrative levels, provide habitats for a rich and particular biodiversity, but also suffer from multiple demands and use. A wide spectrum of anthropogenic impacts has resulted in an alteration of certain river catchments and discharging waters, sometimes even in the complete disruption of a river system. Today, several national and international directives are in place for their protection and sustainable use, as well as for improvements to their ecological status. These issues contribute to a high conflict potential.

The ecological integrity of Alpine rivers, in its current status, mirrors alarmingly the effects of a variety of anthropogenic impacts. Ever-increasing demands in land use, water abstraction for energy, snow production and irrigation, water resource alterations, organic and inorganic pollution, as well as engineering activities for flood and hazard protection and for erosion control, have changed the structures and functions of river systems. River management today faces multi-dimensional conflicts as pressures continue and key legal frameworks come more strongly into play.

Nevertheless, the Alps are commonly considered *playgrounds* and the *water tower* of Europe, reflecting their pivotal role in sustaining the social and economic wellbeing of the whole continent. Several large European rivers, such as the Rhône, Rhine, Inn and Po, and their tributaries rise in the Alps, and connect the mountain arch with wide continental areas and finally the seas, providing multiple values and services for people, culture and nature.

Sustainable management and political decisions, including stakeholder engagement and public awareness, must be strongly knowledge-based, underpinned by scientific evidence. In this respect, it is a pleasure to present and discuss the book *Rivers of the Alps*, which integrates the collective knowledge of 150 dedicated authors from six Alpine countries as well as various disciplines and organizations. It provides a timely and comprehensive basis for developing a shared, bold vision, setting priorities for river and ecosystem management and sustaining the unique biocultural landscapes for which the Alps are famous. Indeed, the book will increase awareness of the cultural and biological heritage of the Alps.

The book comprises six main chapters, which are followed by portraits of 54 of the larger rivers of the Alps. Chapter 1 sets the scene, presenting terminology and the most significant geographical characteristics, and providing overviews of river names and their meanings, as well as the long history and variety of human use and interference. Chapter 2 covers the biophysical foundations, such as mountain geology, hydrology and sediment balance, and the morphology of Alpine rivers as a result of erosion, transport and sedimentation. In Chapter 3, Alpine rivers and their floodplains are presented as ecosystems and as specific habitats for diverse invertebrate and vertebrate communities (from spiders to crayfish, amphibians, fish and birds) as well as riparian and floodplain vegetation. The chapter focuses in some detail on invasive species. Chapter 4 provides a detailed overview of settlement and economic activities along Alpine rivers, such as land use, the significance of river crossings, floods and flood protection, as well as the rivers' use for energy production. Another aspect of the link between humans and rivers, riverine systems and landscapes is presented in Chapter 5, which discusses the specific roles of Alpine rivers in mythology, sensual experience and knowledge, inspiration for art, as well as in the variety of leisure and tourism activities. Chapter 6 gives a pan-Alpine overview of the environmental status and protection of rivers, the current hydrological and morphological pressures, the rivers' ecological status and value, the proportion of river stretches situated within protected areas, and a general consideration of protection priorities at the pan-Alpine level. The chapter is concluded by a debate on river restoration and its specifics in relation to Alpine rivers. This section includes suggestions for how to implement restoration, guidelines, innovative planning tools, and a presentation of larger projects and specific project activities on Alpine rivers: there are detailed outlines of five restoration examples in Austria, France, Germany and Switzerland.

While these six chapters examine the entirety of Alpine rivers from various professional perspectives, the remaining 150 pages provide descriptions of 54 individual rivers, emphasizing their unique characters and features, usage history and management challenges.

Rivers of the Alps is an excellent read and provides a huge variety of fascinating details about Alpine rivers and riverine landscapes. Its thematic coverage is particularly comprehensive and will be of outstanding value not only for professionals dealing with river ecology and management, conservation and sustainable development, but also for policy-makers, and University lecturers and students in the fields of ecology, geography, river engineering, and environmental and ecosystem management. I therefore warmly recommend this book – it will lead the reader from interest to knowledge, followed by understanding and appreciation!

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Kowarik, K. (with contributions from Grabner, M., J. Klammer, K. Mayer, H. Reschreiter, E. Wächter & G. Winner) 2019. *Hallstätter Beziehungsgeschichten Wirtschaftsstrukturen und Umfeldbeziehungen der bronze- und ältereisenzeitlichen Salzbergbaue von Hallstatt/OÖ*. 380 pages. ISBN 987-3-85474-353-8

The salt mines of Hallstatt are arguably one of the most significant late-prehistoric sites in the Alpine region. This is certainly related to the remarkable preservation and the staggering number of archaeological remains, which shed new light on prehistoric mining techniques, on the daily life of miners, and even on their diet and health. But these are not the only reasons. The mines are part of a complex archaeological landscape, whose relationship with salt mining is still poorly understood. Reconstructing the network that enabled the existence of these mines is paramount to investigating some of the key issues in European prehistory: the development of socio-economic inequalities, the increasing human impact on mountain environments, and the organization of labour and production. In order to achieve such an ambitious goal, attention must move from the mines themselves to the broader geographical and productive contexts to which they belong. And this is done remarkably well in Kerstin Kowarik's book.

The author analyses how the Bronze Age and Iron Age salt mines of Hallstatt and the outside world interact with each other. Her rationale is that mines are nodes of a larger socio-economic network, and the rich archaeological record available for the mines enables us to identify their interconnections. Mining requires tools, which are produced by specialized craftspeople using local and non-local resources (wood, wool, metal, etc.). Miners need food, and the data suggest that in some periods they were provided with high-calorie standardized meals. The salt is used for different purposes, such as salt-cured meat production, a practice which is documented in the region. Through archaeological analysis and numerical modelling, the author highlights the significant specialization of Hallstatt salt mining and its strong connections with the surrounding areas from the Bronze Age onwards. One of the most interesting hypotheses put forward in the book concerns the social status of the mining community. The author does not rule out the possibility that the wealthy graves found in the Iron Age cemetery of Hallstatt do not belong to an elite group who controlled the mining industry, but rather to the miners themselves. This hypothesis, together with all the evidence of specialization and large-scale connections, make Hallstatt a unique case-study for understanding how labour and society evolved from prehistoric times to historical periods.

If the identification of possible connections between the mine and the outside world is facilitated by the archaeological assemblage, it is more difficult for the author to reconstruct the human landscape around the mines. There is no clear evidence of permanent settlements in the valley of Hallstatt (Salzberg Valley), the closest substantial settlements being one to two days' walk from the mines. Furthermore, very little evidence of preliminary production processes can be found in the neighbouring area. Further investigations would clarify whether this represents a research or visibility bias, or whether other models of resource exploitation, perhaps associated with considerable mobility, should be surmised. Extremely intriguing is the archaeological and palaeo-ecological evidence for the pastoral occupation of the uplands of the Dachstein Plateau, south of Hallstatt, during the Bronze Age, which is seen by the author as functionally correlated with the development of the mines. A synergic relationship with pastoralism has already been assumed for other mining areas but is even more robust here, as salt is a key product in livestock rearing and (possibly) dairy production. Also interesting is the lack of Iron Age sites in Dachstein, which suggests a change in the relationship between the mines and the surrounding territory.

In conclusion, Kowarik's book is a thorough, well-documented analysis of the Hallstatt salt mines within their complex local and regional context. Some of the inferences presented are still tentative, for want of archaeological information or suitable interpretative models, but the innovative nature of the study enables the author to come up with new research questions, which will influence future investigations in Hallstatt. These questions revolve around some of the timeliest scientific issues of our discipline: sustainability, resilient economies, social inequalities, supply chains, communities of practice and place. The photos, maps and graphs are extremely informative, a perfect complement for the narrative. Particularly noteworthy are the cartography and the list of sites at the end of the book, which will enable other scholars to build on the results of this interesting research. All in all, *Hallstätter Beziehungsgeschichten* is a must-read for those interested in Alpine archaeology, prehistoric mining and, more generally, late prehistory in central Europe.

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New UNESCO biosphere reserves approved

The 32nd session of the International MAB Coordination Council (MAB-ICC) of UNESCO took place on 27–28 October 2020. The meeting was originally planned for June 2020 in Nigeria, but had to be postponed due to Covid-19 and was finally held as an online event. Due to the difficult conditions, the agenda had to be shortened and some decisions that would have required in-depth discussion had to be postponed until MAB-ICC 2021. Probably the most important agenda item for many countries of the MAB program's steering committee, which includes 34 countries, was certainly the announcement of the new UNESCO biosphere reserves (BRs). In total, MAB-ICC has added 25 new areas to the World Network of UNESCO BRs (WNBR; see list below). Andorra, Cabo Verde, Comoros, Luxembourg and Trinidad and Tobago join the WNBR with the designation of their first BRs. The transboundary BR *Complex W-Arly-Pendjari (WAP)*, which was formed from three existing national BRs and is now shared by the three West African countries Benin, Burkina Faso and Nigeria, certainly deserves special attention. As a result, the WNBR today consists of 714 BRs in 129 countries (including 21 transboundary BRs): Complex W-Arly-Pendjari WAP (Benin, Burkina Faso, Nigeria); Queme Lower Valley (Benin); Gishwati Mukura (Ruanda); Hadejia Nguru Bade (Nigeria); Oban (Nigeria); Okangwo (Nigeria); Fogo (Kap Verde); Maio (Kap Verde); Mwali (Komoren); Asterousia Mountain Range (Griechenland); Minett (Luxemburg); Island of Porto Santo (Portugal); Ordino (Andorra); Bunaken Tangkoko Minahasa (Indonesien); Karimunjawa-Jepara-Muria (Indonesien); Merapi Merbabu Menoreh Indonesien); Favahmulah (Malediven); Addu Atoll (Malediven); Kologrivsky Forest (Russland); Panna (Indien); Almaty (Kasachstan); West Altai (Kasachstan); Toson-Khulstai (Mongolei); Bosques de Neblina – Selva Central (Peru) and North-East Tobago (Trinidad und Tobago).

Another important issue on the agenda was the presentation of the MAB Young Scientist Awards. From a total of 46 submissions, six awards of about USD 5000 each were awarded to young scientists:

Radisti Ayu Praptiwi, Indonesia	Understanding the impact of climate change to cultural ecosystem services in tropical marine biosphere reserve Taka Bonerate Kepulauan Selayar
Opeyemi Adeyemi, Nigeria	Assessing and mapping communities' preferences for ecosystem services in Omo Biosphere Reserve, Nigeria: an approach to enhance sustainable management of Biosphere Reserve and promote people's livelihood
Babajide Charles Falemara, Nigeria	Economic valuation of tropical tree species and soil carbon sequestration potential as ecosystem services in the context of climate change in the core, buffer and transition zones of Omo biosphere reserve
Sandra Delfin De Leon, Cuba	Farming, propagation and assisted reproduction of stony corals for the study of reef restorsation in Cuba
Laure Thierry De Ville D'Avray, Philippines	The Influence of artificial reefs on fish communities and their potential socio-economic benefits. A study in Palawan Biosphere Reserve (Philippines)
Iolanda-Veronica Ganes, Rumania	Designing efficient strategies for the implementation of an ecotourism network in Sfântu Gheorghe Channel area of the Danube Delta Biosphere Reserve

The MAB Young Scientists Awards targets young researchers, in particular those from developing countries, carrying out interdisciplinary research in line with UNESCO's MAB Programme.Through these awards, the MAB Programme is investing in a new generation of scientists worldwide because well-trained and committed young people are key to addressing ecological and sustainability issues.

Günter Köck

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