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Alpine soundscapes: sounds and their consequences for perceived recreational quality – A case study of two Regional Nature Parks – Beverin Nature Park and Parc Ela in Switzerland

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Keywords: Alpine areas, anthropogenic sounds, outdoor recreation, noise

Abstract

Regional Nature Parks (RNPs) such as the Parc Ela and Beverin Nature Park are popular destinations for outdoor activities and recreation in the Alpine areas of Switzerland. As in many other mountain and peripheral regions, their soundscapes are being increasingly influenced by humans. Little is known about which sound types are perceived positively or negatively by visitors in Alpine areas and how sounds affect visitors' perceived recreational quality. To better understand this relationship, surveys were carried out in four areas of two RNPs, Beverin Nature Park and Parc Ela. Each area included two or three sites with different anthropogenic sound levels. Sounds with anthropogenic origins were found to be rated significantly more negatively than sounds with biophonic and geophonic origins. Using linear mixed models, this study confirmed that sound levels had the strongest effect on the perceived quality of visitors' recreation at sites with similar visual landscape features. Sites with low levels of anthropogenic sounds were perceived as having the least impact on recreational quality. However, no significant difference in the impact of sounds on perceived recreational quality was found between medium and high sound levels, indicating that there could be a threshold between 33.7 and 38.6 dBA above which noise has a negative impact on recreational quality.

Profile

Protected area

Regional Nature Parks

Beverin and Ela

Mountain range

Alps

Country

Switzerland

Introduction

Soundscape refers to the interplay of all sounds perceived at a specific place and time (Schafer 1977). To standardize the widely used term *soundscape*, the definition has been given as *"[the] acoustic environment as perceived or experienced and/or understood by a person or people, in context"* (ISO 12913-1 2014). Sounds within a soundscape are classified according to their origin, either natural or anthropogenic. Natural sounds can be further divided into biophonic sounds produced by biological organisms other than humans, and geophonic sounds, which have geophysical or non-biological environmental causes (Krause 1987; Pijanowski et al. 2011a).

A tranquil soundscape is not characterized by the complete absence of sound. Low levels of biophonic and geophonic sounds enhance the feeling of tranquillity (Botteldooren & Coensel 2006). People seek natural acoustic environments that are not influenced by anthropogenic sounds as these environments have a positive effect on their health and psychological wellbeing, and help people to feel more connected to nature (Miller 2008; von Lindern 2015; Aletta et al. 2018).

Just what contributes to recreational quality when spending time in nature has been the subject of scientific research for some time and is still not yet fully understood. One explanation is the Attention Restoration Theory, according to which spending time in nature restores our ability to concentrate and perform (Kaplan & Kaplan 1989). Acoustics as an external stimulus also contribute to this effect. Natural sounds can activate our attention by creating a sense of distance from noisy everyday life.

Natural landscapes and acoustic environments are increasingly influenced by human activities. The growth of leisure activities and the resulting increase in traffic have led to natural acoustic environments becoming a scarce resource (Lynch et al. 2011). People spend more of their leisure time in nature to get away from everyday life (Iglesias Merchan & Diaz-Balteiro 2013; Leeb et al. 2020), and during the Covid 19 pandemic the trend towards outdoor recreation continued to expand (Geng et al. 2021). Since few local, easily-accessible, tranquil recreation areas remain, outdoor sports enthusiasts in search of seclusion and tranquillity are drawn to remote areas – notably to the Alps in Central Europe (Willibald et al. 2019; Leeb et al. 2020). According to the European Environment Agency (2016), the few remaining quiet areas in Europe are found mainly in mountainous regions, but tourism itself might endanger those quiet areas, especially if it is not developed sustainably (Weber & Rosenberg-Taufer 2017).

Regional Nature Parks (RNPs) are popular excursion and holiday destinations of sustainable tourism in the Alpine areas of Switzerland (Knaus 2018). Parks with the label RNP follow federal guidelines and are characterized by a sustainable approach to nature, the

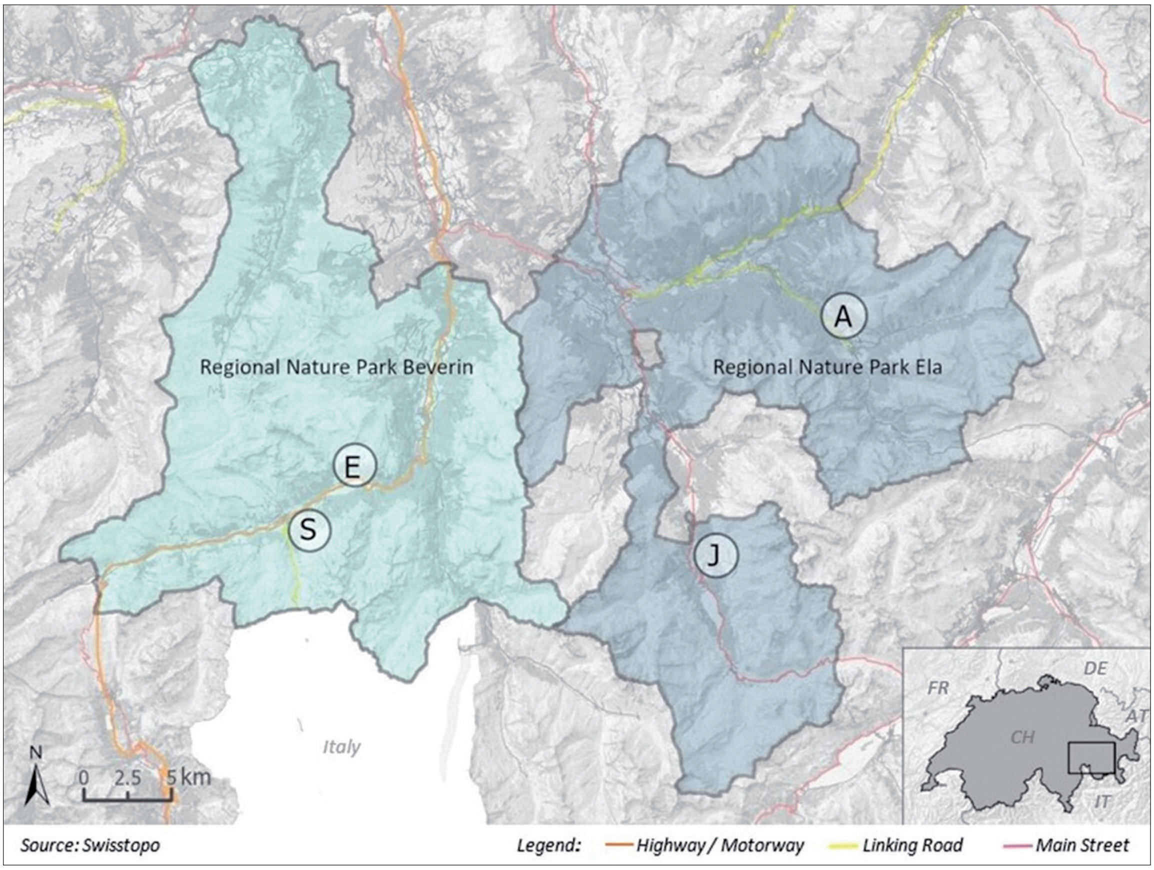

Figure 1 – Regional Nature Parks Beverin and Ela with the four study areas Albula (A), Julier (J), Andeer (E) and Splügen (S).

cultural landscape and the regional economy (Swiss Federal Council 2007/2018). The two largest RNPs in eastern Switzerland are Parc Ela and Beverin Nature Park (Figure 1). With a wide range of activities and cultural events as well as varied landscapes, the two parks offer ideal settings for recreation in Alpine areas (Verein Parc Ela 2021; Geschäftsstelle Naturpark Beverin 2021). At the same time, both RNPs are located in populated rural areas with transport infrastructure and are therefore excellent examples of anthropogenically influenced areas in the Alps. Parc Ela is crossed by two main Alpine passes, the Albula and Julier passes, and by the UNESCO World Heritage Albula railway line; the Beverin RNP is well connected by the A13 national highway (the Great Saint Bernard Pass) and the Splügen Pass.

In Switzerland, noise limits are regulated by the noise protection regulation (LSV), according to which noise of 55 dBA or more (decibels weighted by the sensitivity of human hearing at a given frequency) disturbs people considerably during daytime recreation. These regulations, however, are concerned with indoor protection in residential areas and are applicable to a limited extent only to outdoor activities in alpine recreation areas.

In 2002, for the protection of quiet areas within rural regions, the Environmental Noise Directive (END) proposed to use specific noise indicators and limits (European Noise Directive 2002). However, identifying quiet areas is a challenging task. According to END, a quiet area is defined as *"an area delimited by the competent authority that is undisturbed by noise from traffic, industry or recreational activities"* (European Noise Directive 2002). The difficulty is that the concept of quietness is influenced by factors such as human perception, visual interactions and expectations (European Environment Agency 2016).

The soundscape, that is to say the perception of the acoustic environment, is also context-dependent: it is never independent of non-acoustic factors such as psychological and physical aspects (Job & Hatfield 2001). Acoustics have been found to influence recreation to a similar or greater extent than visual landscape features such as the sight of a natural or open landscape (Jackson 2008; Lynch et al. 2011; Buxton et al. 2017, Leeb et al. 2020). A very important psychological factor is visitors' expectations regarding their stay in nature, including their expectations of the soundscape as a whole and of individual sounds (Bruce & Davies 2014).

In contrast to urban areas, where signal and background sounds are constantly present, individual sounds in natural areas can be heard over a greater distance (Schafer 1977). How sound is perceived also depends on spatial and topological conditions. Sound propagation decreases with increasing distance from the source, and the effect is intensified by barriers such as vegetation cover (Heimann et al. 2007). Addition-

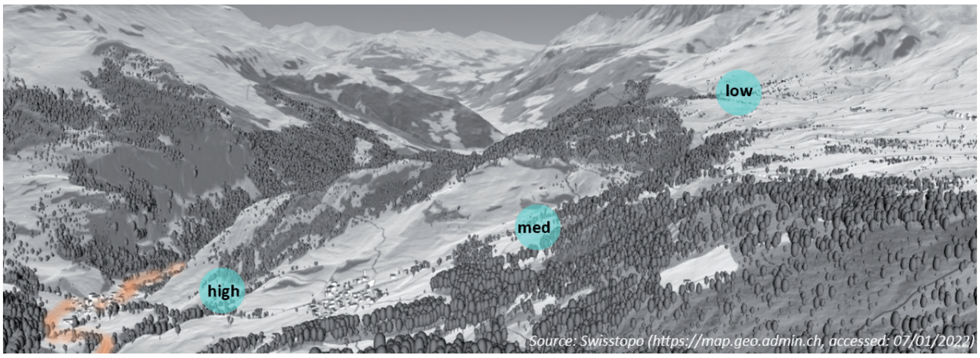

Figure 2 – Sites with sound levels (high, medium and low) in the Julier (J) study area. The main source of anthropogenic sound is the pass road, shown in orange.

ally, in Alpine areas sound emission propagates radially from the valley floor towards higher areas through open air, i.e. not along the ground (Heimann et al. 2007). As a result, sounds from the valley floor can still be clearly heard in elevated areas.

A number of studies have found a negative effect of anthropogenic sound in rural areas on the perceived quality of visitors' experience and recreation (Li et al. 2018; Yimprasert et al. 2021). However, there is a lack of research that specifically investigates the Alps, where the topography and the high level of human intervention in nature create unique conditions. A study in the Swiss National Park on visitors' general perception of disturbance concluded that about one in ten visitors felt disturbed by traffic sounds, especially motorbikes (Omlin & Brink 2010).

No nationwide mapping of quiet areas has been carried out by Swiss authorities. While a tranquillity map was developed by Leeb et al. (2020) for the flat Swiss midlands, there is no such map for the Alpine regions. Which sounds in Alpine areas are perceived negatively by visitors and to what extent anthropogenic sounds influence recreational quality remain largely unexplored. Through studying two different RNPs in the Swiss Alps, the aims of the present study were to analyse (i) which sounds are perceived positively or negatively by visitors, and (ii) whether the perceived negatively rated sounds affect the perceived quality of visitors' recreation.

Methods

Study area

This study was carried out in the Beverin and Parc Ela RNPs in the Alpine area of eastern Switzerland, in the canton of Grisons (Figure 1). Parc Ela is the largest RNP in Switzerland (660 km^2) and is known for its diverse landscapes, such as extensive dry meadows and pastures, floodplains and glacial forelands, as well as for its diverse culture and trilingualism (German, Rhaeto-Romanic and Italian) (Verein Parc Ela 2021). Beverin RNP (515 km^2) is also characterized by its diversity, with valuable alpine habitats like natural mountain streams, fens and deep canyons, as well as by two culturally and linguistically different settlement areas, German and Rhaeto-Romanic (Geschäftsstelle Naturpark Beverin 2021).

As a basis for the selection of the study areas within the Beverin and Parc Ela RNPs, a sound register was created in advance. Federal data from anthropogenic sound sources, such as roads and railways (BAFU 2018), and settlement areas (BFS 2013), were mapped in ArcGIS Pro to classify the two parks into zones of low, medium or high levels of anthropogenic sound. For each park, based on the sound register, we selected two areas (Beverin RNP: Andeer (E) and Splügen (S); Parc Ela: Albula (A) and Julier (J); see Figure 1). The conditions were that each area contained sites in a minimum of two different sound level zones (low, medium or high), forming a sound gradient. The sound gradients were produced not only by distance from the main anthropogenic sound source (pass road or highway), but also by the topographic features. Sites with low anthropogenic sound levels required the presence of a topographic knoll that acted as a barrier for sounds from the valley floor (Figure 2).

Sound measurements [dBA] and personal field observations as well as data about visitor frequency on hiking trails from the Strava Heatmap were used to finalize the selection of sites (Strava.com 2021). The aim was to keep all visual or psychological factors influencing recreational quality constant across the sites, with sound levels being the only factor to vary. Consequently, the surveys were carried out under similar weather conditions on hiking trails with similar landscape features (i.e. outside settlements, not in the immediate proximity of water elements, and in open non-forested areas) in order to ensure similar sound propagation.

Survey

The survey was conducted from July to September 2021. Hikers were consulted on 19 different days, spread over weekdays and weekends with good weather (Table 1). The questionnaire, which was identical for both parks and intended exclusively for hikers, comprised 14 closed questions. For the assessment, the acoustic environment was broken down into relevant

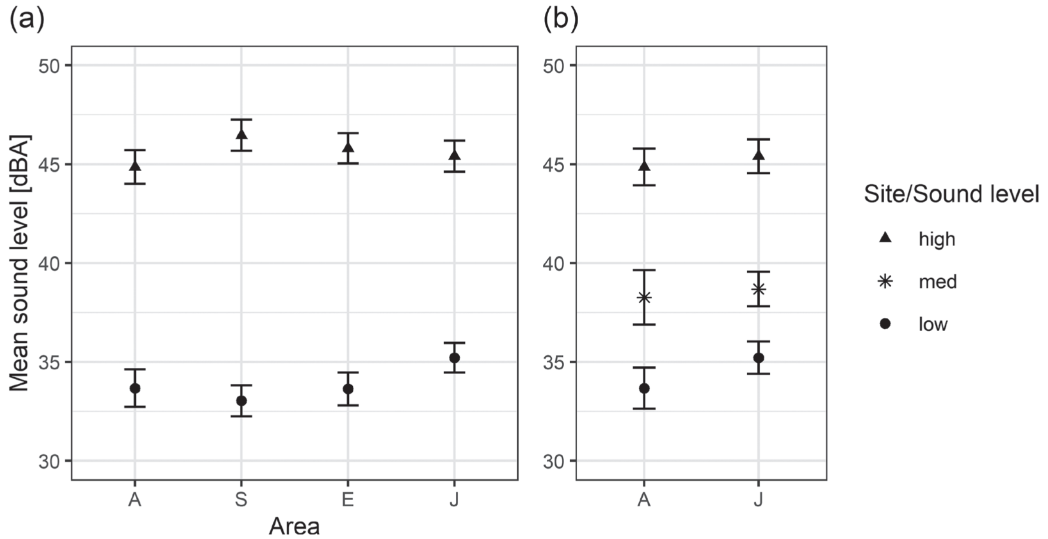

Figure 3 – Average estimates of the recorded sound levels [dBA] in (a) four areas (A: Albula; S: Splügen; E: Andeer; J: Julier), having two sound-level sites each (low and high), and in (b) two areas, each with three sound-level sites (low, medium and high).

sound indicators. Sound types were selected based on previous studies and the researchers' own observations (Jackson et al. 2008; Willibald et al. 2019; Leeb et al. 2020). A total of 17 sound types were included in the questionnaire; *rivers or streams, bird calls, other wildlife* and *wind* were classified as natural sounds, and the rest as being of anthropogenic origin. The respondents had to indicate whether and to what extent they had perceived and expected the 17 types of sounds on a 5-point Likert scale, from not perceived / expected at all (1), to strongly perceived / expected (5), during the last 20 minutes of their hike (Likert 1932). They then rated the sounds they had perceived on a 7-point Likert scale, from very negative (−3), to neutral (0), to very positive (3). In the final step, they indicated how much the positively and negatively rated sounds affected their recreational quality, using a Likert scale from not at all affected (1) to strongly affected (5). Questionnaires were excluded from the analysis if the respondents assessed their hearing capability as considerably reduced or their mood as bad, the latter on the assumption that psychological stress and the resulting introversion reduce the ability to perceive the acoustic environment.

In parallel to the survey, the number of passing visitors was recorded by hand in order to determine the visitor rate of response for each sound-level site per area. Sound level measurements [dBA] were also taken on site using a *UNI-T UT333-BT* sound-level meter. The recording device was placed about 100 metres away from the interview site to prevent our presence impacting the measurements. It recorded the acoustic environment between 30 and 130 dBA without differentiating between natural and anthropogenic sounds. The data were additionally validated using a calibrated *Velleman Dem 202* sound-level meter. It was therefore possible to calculate the average sound level during the 20 minutes prior to each participant starting to complete the questionnaire.

Data analysis

All statistical analyses were conducted using R, version 4.1.2 (R Core Team 2021). Linear and linear mixed models were run with the lme4 package (Bates et al. 2021). The dredge function (MuMIN package (Bartoń 2020)) was used to compute both the full model and all lower-level models with fewer parameters. The models were ranked according to their AICc (Akaike

Table 1 – Distribution of field days, survey participants and response rate of the four study areas (two or three sites per study area).

Regional Nature Parks	Area	Site / Sound level	Field days	Survey participants	Response rate [%]
Parc Ela	Albula (A)	Low	3	21	84.0
		Medium	2	15	87.5
		High	2	26	76.5
	Julier (J)	Low	1	34	82.9
		Medium	1	29	76.3
		High	2	31	68.8
Beverin	Andeer (E)	Low	2	28	91.6
		High	2	33	85.0
	Splügen (S)	Low	2	33	89.2
		High	2	34	70.8
Total			19	277	81.3

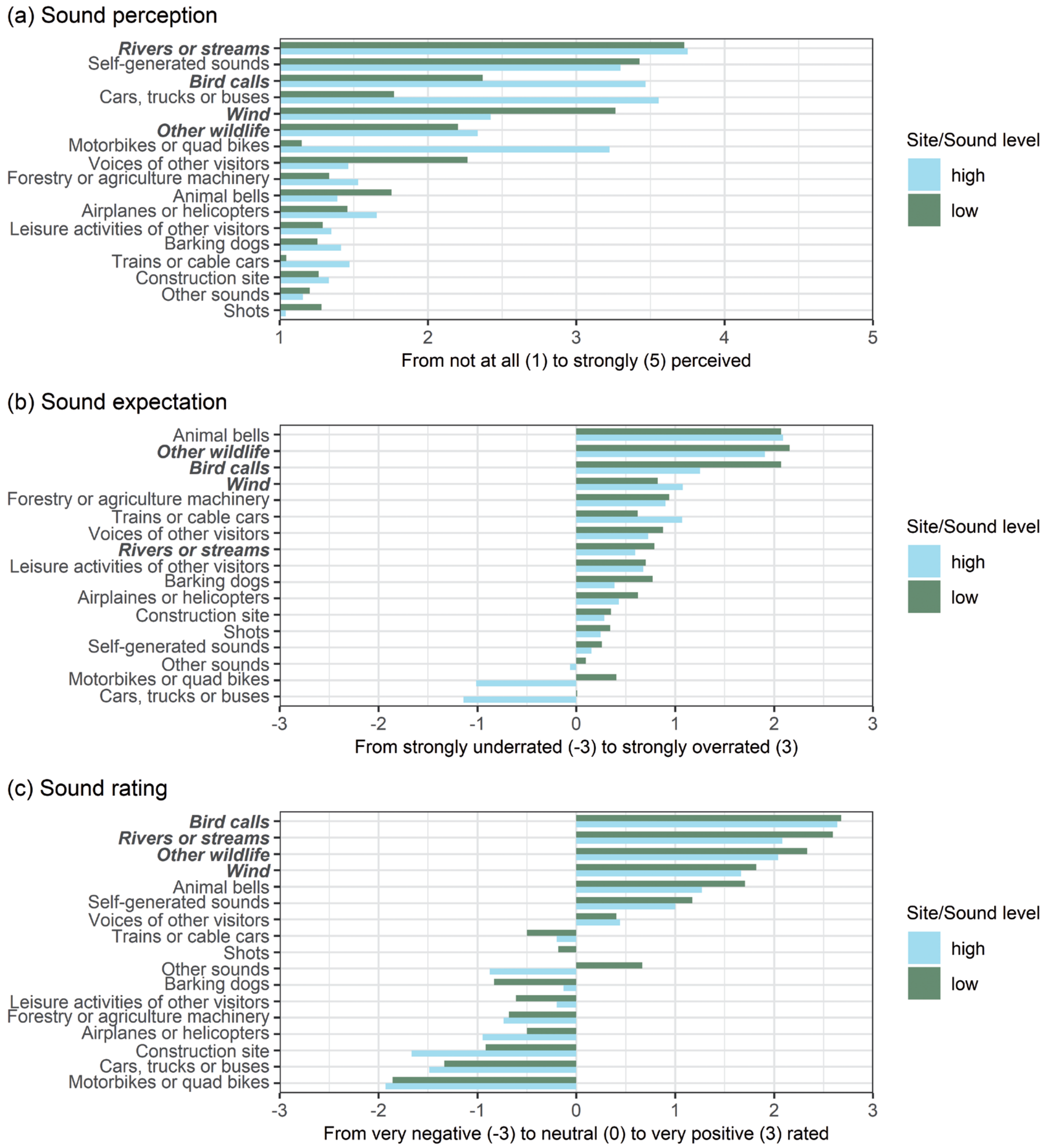

Figure 4 – Average survey responses regarding (a) perception of natural (bold/italic) and anthropogenic sounds, (b) deviation between expected and perceived sounds, and (c) rating of perceived sounds, at sites with low or high anthropogenic influence.

information criterion corrected for small sample size); following Grueber et al. (2011), an information-theoretic approach was used to account for uncertainty in model selection. Averaged parameter estimates (full average) were obtained by averaging across the top models (within ΔAICc of 4 from the best model) using Akaike weights. Fulfilment of model assumptions (normality and homoscedasticity of the residuals) was inspected visually.

Results

A total of 277 questionnaires were considered fully valid, of which 92.6% were in German and 7.4% in English. The average age of the respondents was 51, ranging from 16 to 87 years, with the most-represented age group being between 60 and 70 years (23.8%). Women preponderated over men (55.6% versus 44.0%), with one person identifying as neither male nor female. The distribution of the types of residential location was relatively balanced, with 38% of the participants classifying their place of residence as very or rather urban, 39% as very or rather rural, and 21% as semi-urban or semi-rural; 2% gave no answer. For the mode of arrival, almost half (126 people) travelled at least part of the way by car, 118 used public transport, and the rest arrived on foot (59), by bicycle (6) or by motorbike (2). Asked about their current motives for hiking, the three most common answers on a 5-point Likert scale were *enjoying nature and the landscape* (mean: 4.78), *finding tranquillity and recreation* (mean: 4.48), and *being active and doing something for one's health* (mean: 4.22).

Results from linear models showed that the sound measurement data [dBA] of the selected sites con-

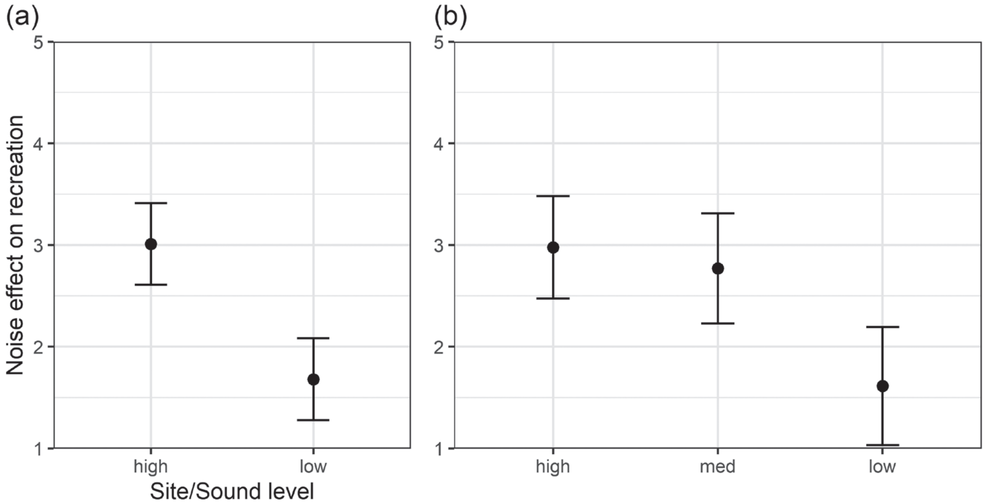

Figure 5 – Average estimates of the influence of noise on visitors' recreation (from 1 [not at all], to 5 [strongly affected]) in (a) four areas having two sound-level sites each (low and high), and (b) two areas with three sound-level sites (low, medium and high).

firmed the pre-defined sound level zones (*low, medium* and *high*). Across all areas, the measured mean value [dBA] differed significantly between the sites with *high* and *low* sound levels ($F = 1616.3$, $df = 1$ and $p < 0.001$). Overall, there were no significant differences between the areas. However, a significant interaction between area and sound level (*low* and *hig*h) was observed ($F = 5.96$, $df = 3$ and $p < 0.001$, Figure 3a), with the difference between *low* and *high* being larger in (S) than in (J).

A similar result was found when only a subset of the data was considered, namely for the areas Albula (A) and Julier (J), which each had three sound levels (*low, medium* and *high*, $F = 269.4$, $df = 2$, and $p < 0.001$; see Figure 3b). The sites with *high* (mean: 44.6 dBA), *medium* (mean: 38.6 dBA) and *low* (mean: 33.7 dBA) sound levels differed significantly from each other (between *low* – *med*: mean difference of 4.59 [95% *CI*: −6.32 to −2.85] and *med* – *high*: mean difference of 6.60 [95% *CI*: 4.93 to 8.27]).

As suspected, both *natural* and *anthropogenic* sounds were perceived in the Swiss RNPs (Figure 4a), although *anthropogenic* sounds were perceived less strongly at sites with *low* sound levels. Across all areas, visitors in Alpine nature parks generally underestimated road traffic sounds on sites with *high* sound levels – that is, they perceived the sound to be louder than they had expected in advance (Figure 4b).

Overall, *natural* sounds were rated more positively than *anthropogenic* sounds on the 5-point Likert scale, with a mean difference of 2.51 [95% *CI*: 2.40 to 2.63]. The mean difference was estimated from a linear mixed model using sound type (*anthropogenic* or *natural*) as explanatory variable. Survey participant ID was used as random effect in the mixed model.

The noise of *motorbikes* and *quad bikes* was rated worst by RNP visitors, followed by *cars*, *trucks* and *buses*. All negatively rated sounds were of anthropogenic origin (Figure 4c). Throughout the remainder of the article, *noise* will be used as a synonym for *negatively rated anthropogenic sounds*.

It was found that the deviation between expectation and perception of the specific sound type influenced its rating (linear regression coefficient = 0.69, 95% *CI* = 0.64 to 0.76, $F = 759.3$, $df = 1$, and $p < 0.001$). Sounds that had not been expected in the Alpine nature parks were more likely to be rated negatively by visitors.

Linear mixed models showed the average visitor assessment of how much sounds affected the quality of their recreation (given on a 5-point Likert scale) to be 3.9 for positively and 2.5 for negatively rated sounds. The full model contained the variables sound level (*high, medium* or *low*), gender and residential location, and all possible two- and three-way interactions. Data nested within area were used as random effects to correct for dependencies in the data.

When looking at how the perceived recreational quality was affected by noise, it was found that sound level was the most important factor (relative importance = 1). At *high* sound levels, noise had a stronger negative effect on recreation compared to sites with *low* sound levels (Figure 5a). The best models (within 4 ΔAICc of each other) contained the variables gender and residential location, and the interaction between gender and sound level. The relative importance of these factors, however, was considerably lower than the effect of sound level (gender = 0.36, gender : sound level = 0.17, residential location = 0.12). Similar results were found when analysing just two out of the four areas (Albula (A) and Julier (J)), but with an additional site with *medium* sound level (Figure 5b). Sound level proved again to be the factor with the highest relative importance (1), followed by residential location (0.59), gender (0.37), and the interaction between gender and sound level (0.12). No significant difference in the effect of noise on the perceived recreational quality was found between *medium* and *high* sound-level sites.

Discussion

Swiss studies on hikers (Lamprecht et al. 2020; Fischer et al. 2021) reveal their average age (50 years), the largest age group (55–64 years) and the gender ratio (53% women), which correspond with this study. A similar picture emerges regarding preferred means of transport. In RNPs, the largest number of visitors arrive by car, followed by public transport, and only a few use other means of transport (Knaus 2018). Experiencing nature, fresh air and escaping from everyday life are cited as the main reasons for visiting the natural environment in Switzerland (Hegetschweiler et al. 2022). Our study confirmed this, as the search for *tranquillity* and *recreation* was the most-mentioned motive in the survey after *experiencing nature*.

A potential limitation of the study could be the inability to fully control for visual and psychological factors that influence the quality of recreation at the study sites. Additionally, the respondents were mainly from German-speaking areas, i.e. from similar cultural backgrounds. Surveys in other mountain areas could result in different findings. One respondent further commented that she noticed more individual sounds and nuances of sounds after completing the questionnaire, which raises the question of how consciously people perceive acoustic environments in the first place and how long they remember them.

The study examined which sounds in an Alpine acoustic environment are perceived by RNP visitors and how the soundscapes are rated. A clear pattern emerged: only anthropogenic sounds were perceived negatively and therefore as noise. The results confirm the findings of other studies according to which natural sounds elicit positive emotions in visitors of rural landscapes, while anthropogenic sounds are often associated with negative emotions (Pijanowski et al. 2011b, Li et al. 2018, Yimprasert et al. 2021). Axelsson et al. (2010) suggested that individual sound associations are often more important than the actual volume or dominance of the sound within a soundscape.

The anthropogenic sound types rated most negatively were found to be cars and motorbikes. This corroborates the observation that sounds perceived as noise in rural areas are strongly linked to traffic (Buxton et al. 2017). Furthermore, the survey revealed an ironic contradiction, namely that the respondents rated cars, trucks and buses as the second most negative sound, but also preferred cars as the means of transport to get to the starting point of their hike. A possible explanation for this could be that many visitors underestimate the impact of their own activity, including the acoustic impact (Barber et al. 2011).

Additionally, the analysis was able to show that expectations play a decisive role in sound assessment of recreational areas. Sound types that visitors had not expected in advance were rated more negatively, as noted in earlier studies by Bruce and Davies (2014) and Li et al. (2018).

The second question of interest was how soundscapes affected RNP visitors' recreation. The study was able to provide new insights into the effects of negatively rated anthropogenic sounds on recreational quality in Alpine areas. In close proximity to anthropogenic sound sources and therefore in sites with *high* sound levels, visitors assessed noise as having a medium impact on recreation. Compared to sites with *medium* or *high* sound levels, noise had a clearly weaker negative effect on the perceived recreational quality in sites with *low* sound levels. There was no significant difference in the effect noise had on recreational quality between sites with *medium* and *high* sound levels, indicating that there might be a threshold level of noise (between 33.7 and 38.6 dBA) above which noise starts to have a stronger negative effect on perceived recreational quality. In the four study areas, *low* noise levels (below the threshold) were found only behind hilltops. However, those results must be considered with caution as there were only a few data points for sites with *medium* sound levels (for just 2 of the 4 areas).

Even though the impact of noise on the perceived recreational quality was not found to be very strong at any of the sites studied, the finding that medium influences are present at all sites without topological shielding is of concern.

Conclusion

Most quiet areas in Europe are located in mountain regions (European Environment Agency 2016). However, even Alpine soundscapes are influenced by anthropogenic sounds. Traffic noise from the valley floor can affect the perceived recreational quality of visitors even at higher altitudes, unless they are topologically shielded. Natural soundscapes including quiet areas are an essential part of park experiences and play a key role in people deciding where to spend leisure time in nature (Lynch et al. 2011). The demand for outdoor activities and recreation, and thus also traffic, will continue to increase due to demographic development (Willibald et al. 2019). It is therefore important for RNPs to take measures in advance.

Firstly, as popular destinations for sustainable tourism, RNPs should take pro-active measures to protect the natural acoustic environment by reducing noise and sensitizing visitors to the effects of noise; one possibility would be to introduce quiet areas or hours. Since sounds that had not been expected are evaluated more negatively, it would also be advisable to inform visitors on the website about possible noise exposure during a hike. Such mitigations might prevent the negative impact of unexpected noise on the quality of recreation. Second, if RNPs highlight the richness and diversity of their natural sounds, e.g. through themed trails with special listening stations, auditory walks or information boards, this could contribute to higher auditory awareness and thus to a more positive quality of experience and recreation.

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