Acta Sci. Pol.
Formatio Circumiectus 22 (3) 2023, 41–57
ENVIRONMENTAL PROCESSES

www.acta.urk.edu.pl ISSN 1644-0765 DOI: http://dx.doi.org/10.15576/ASP.FC/2023.22.3.10

ORIGINAL PAPER Accepted: 03.10.2023

ANALYSIS OF THE SOUNDSCAPE OF SKI RESORTS IN BAD HOFGASTEIN (AUSTRIA) AND BIAŁKA TATRZAŃSKA (POLAND)

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ABSTRACT

Aim of the study

Firstly, due to the different sizes and spatial organization of ski resorts, it is important to determine whether there is a local differentiation of the sound landscape within one resort. Secondly, due to the continuous expansion of the ski infrastructure, it is essential to develop methods for improving the quality of the acoustic environment. It is therefore necessary to determine whether there are acoustic differences between the different ski resorts.

Material and methods

The research we conducted consisted in measuring the sound levels, and inventorying various types of acoustic events. The examined ski resorts, despite the difference in size of the areas they occupy and the numbers of users, are in many aspects comparable to each other.

Results and conclusions

Ski resorts occupying a relatively small area but with a high concentration of infrastructure and skiers may exert a stronger environmental impact than resorts with a larger area and lesser density of infrastructure as well as a lower number of users per area. The skiers themselves, their manners, and their environmental consciousness have a great impact on the quality of the sound landscape.

Keywords: soundscape, noise, nature sounds, anthropogenic sounds, ski resort, skiing

INTRODUCTION

Nowadays, ubiquitous noise is one of the seemingly less dangerous but in fact significant civilization threats. Since noise was identified as another type of pollution, the European institutions increasingly have been paying attention to the serious impact of noise on the health of the population (Bradley and Lang, 2000; King and Davis, 2003; Bohatkiewicz, 2005; Sato et al., 2013; EEA, 2017; Tibone et al., 2020; www.noiseineu.eu). Humans are exposed to road, rail and air noise, which is mainly observed in large urban agglomerations. However, the noise problem is more and more often also found in non-urban areas, including rural areas, where tourism centres are located. In many holiday resorts, noise level is comparable to that recorded in cities. Tourist centres linked to winter sports are usually located in areas of high natural value, for instance, in national parks, nature reserves, Natura 2000 areas, and others. The noise generated in such places affects humans as well as wild animals and birds. In our article, we focus on

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the problem of pollution of the acoustic landscape by noise resulting from the operation of ski resorts in small mountain towns. This problem is poorly understood and there are insufficient studies addressing acoustic landscape and its disturbances in such areas. We consider the examined problem in two aspects: as a physical approach to the sound level expressed in decibels, and as psychological and sociological interactions. This approach is intended to reflect the fact that humans and animals do not perceive noise in objective manner, as is the case with sound level measuring devices (Southworth, 1969; Sztubecka et al., 2020). Apart from the sound level, an important element of the sound landscape is the nature of the sound events. Consequently, the mere reduction of noise levels, which is a frequently used remediation factor, may sometimes not be enough (Schulter-Fortkamp, 2002; Schomer, 2003). Currently, the concept of sound landscape is considered in a much more multifaceted way (Malec et al., 2023). Schulter-Fortkamp (2002) believes that interdisciplinary activities in the field of acoustics and physics but also psychology and sociology are needed to develop effective ways to combat the negative impact of noise. Sound is the most difficult component to describe in the multisensory landscape that surrounds us. It is variable in time and space, whereas its perception is affected by many factors – both physiological or anatomical and psychological in nature – specific to individual recipients. All animals and humans are constantly influenced by it, and they react to it according to their own individual ethogram, and depending on the given situation.

In the majority of works concerned with the impact of ski resorts and/or winter sports on the natural environment, the negative impact of winter sports on nature is particularly stressed, and only a few works (Lesiak and Tomek, 2008; Rolando et al., 2013; Sato et al., 2013) speak of their positive or indifferent impact. The impact of skiing on the natural environment is often marginalized due to the fact that in many cases the works on the subject fail to take into account the simultaneous, compounded influence of several factors acting together. The impact of skiing on the natural environment is not limited to its impact on the landscape structure and on the functioning of individual ecosystems. It is also important to perceive this impact in terms of acoustics (Okrasiński et al., 2016).

Our work concerns the problem of soundscape in ski resorts. Due to the fact that ski areas are typically associated with valuable natural areas, assessing the noise impact on their sound landscape is particularly important. In our article we cover several significant issues. Firstly, due to the different sizes and spatial organizations of the studied ski resorts, it is important to determine whether there is a local differentiation of the sound landscape within one resort. Secondly, due to the continuous expansion of skiing infrastructure, it is essential to develop methods to improve the quality of the acoustic environment. It is therefore necessary to determine whether there are acoustic differences between the different ski resorts. This is particularly important because the studied centres are characterized by the use of various technical solutions as well as varied spatial distribution. Further, it is important to determine the main categories of acoustic events registered in the studied ski resorts. In the future, such information can be helpful to local authorities in their decision making process regarding the planning of building new facilities and the modernization of existing ski resorts. In order to plan skiing infrastructure investment projects in accordance with the idea of sustainable development, it is also necessary to consider whether the size of the resort and/or the number of skiers has a significant impact on the variation in noise levels in the ski centres.

The reason behind the choice of ski resorts located in Białka Tatrzańska and in Bad Hofgastein for the present study was mainly their similarity. At the same time, the differences between them allow independent determination of the nature of their impact on the sound landscape. The sound level (dB) and the differentiation of acoustic event types were compared. The latter factor is important due to the perception of a given sound space by its habitants. It also facilitates elaboration of the characteristics of sound sources, which is particularly important in the case of those sounds, which considered unpleasant by people. Sources of differences between the acoustic environments of the studied areas were indicated, which may be significant when looking for solutions that minimize the negative impact of ski resorts on the sound landscapes of these resorts and their surroundings. The aim of the study was to analyse the diversity of the sound landscapes between the two ski resorts, which, despite significant similarities, differ in terms of the deployment and concept of use of their ski infrastructure. The following research hypotheses were formulated in the article: (i) that there are significant differences in the natural soundscape depending on the size and method of development of the areas used by skiers, (ii) that there are differences in the sound levels between the facilities used by tourists (slopes, ski lifts) and directly between individual locations themselves (Białka Tatrzańska, Bad Hofgastein). The results of this research may be helpful in the context of managing tourist areas in accordance with the principles of sustainable development.

MATERIALS AND METHODS

The tests that we have carried out consisted in measuring the sound level, that is, the physical parameter expressed by the value of instantaneous ambient sound pressure. The measurements were carried out separately for individual objects (ski slopes and small towns), located within the studied ski resorts in Poland and in Austria.

The database contains 748 cases, which are individual sound level measurements. Measurements and observations were made in the month of February. The sound level measurements were conducted using a digital decibel meter, with the following settings: 'A' correction characteristic, which corresponds to human hearing sensitivity, and 'FAST' time constant (125 ms). Sound level measurements should be carried out at the most favourable meteorological conditions from the point of view of propagation of acoustic waves. Such conditions are defined as: air temperature above –5.0°C; wind speed in the range of between 0 and 5 $m \cdot s^{-1}$ (which means practically no wind); no strong temperature inversion at the ground surface; and no precipitation (Bohatkiewicz, 2005). However, the tests and measurements we conducted did not concern only the sound level in the context of environmental protection against noise. They were also aimed at elaborating a wider characterization of the analysed areas in terms of acoustics. For this reason, measurements were also carried out on days when the wind speed significantly exceeded the value of 5 $m \cdot s^{-1}$. Choosing only windless days for testing would eliminate one of the most important elements of the sound landscape in the mountain areas. It is these characteristic sounds, such as the noise made by wind, that constitute an inseparable element of the genius loci of the high mountains.

The measuring points were evenly distributed, both in the areas of the examined cities, and in the areas of the ski slopes. This kind of system facilitates a better characterization of the sound landscape of the examined objects. During the peak of the winter season, excessive noise and acoustic events adversely affecting people and wildlife is likely to occur, both in the centre of the town and on the ski slopes. In the Austrian resort, 14 points were randomly selected: 7 points on the Schlossalm-Angertal-Stubnerkogel (SAS) ski slope, and 7 points in the centre of the Bad Hofgastein (BH) town (see: Figure 1). A total of 484 single measurements were taken using the sampling method. According to the same scheme, 11 characteristic points were selected in the area of the Polish ski resort: 6 points along the Kotelnica Białczańska and Bania (KBB) ski slopes, and 5 points in the centre of the Białka Tatrzańska (BT) town, in which 264 individual readings were recorded (Figure 2). Each single measurement was performed every 1 second, and the results were saved in the memory of the measuring device.

An important part of the research was the registration and classification of individual sounds that appeared during sound level measurements. The registration and classification of the sounds that occurred had mainly descriptive aim and function, but they might also help to draw attention to and eliminate those sounds that are unpleasant for the recipient, and to promote pleasant and soothing sounds instead. The acoustic events (sounds) subjected to the analysis were divided into two main categories: natural and anthropogenic, further subdivided into lower-order categories.

Anthropogenic acoustic events:

– socio-cultural – these are all sounds related to human speech, physiology, and musical activity, for instance: screaming, sneezing, coughing, laughing, singing etc.;

- human movement-related – these are sounds generated when people move, but without the use of combustion engines or electric motors, for instance: sounds of skis, sounds of steps, of bicycles, etc.;
- technical – for instance: ski lifts, snowmobiles, snowcats, car engines, agricultural machines, etc.;
- signals – these are semiotic sounds, such as a church bell, an ambulance signal, a signal warning against an avalanche, or against a passing scooter or a snowcat. Some of these sounds still serve as a warning message in an emergency situation, whereas the remaining sounds organize the space or create the atmosphere of a given place (Rodzik, 2008; Rogowski, 2008; Dziekanowska, 2015; Malec et al., 2017a, b).

Natural acoustic events:

- abiotic – this group includes all natural sounds associated with inanimate natural phenomena – such as atmospheric phenomena (wind, rain, thunder), sounds related to the movement of snow and ice – avalanches, cracking ice, etc. All the sounds related to water – such as the sound of a river or a stream, or of dripping water – can be counted among these. It is also possible to include the sounds, which somehow, indirectly, have an anthropogenic origin, such as sound of water dripping from the roof, sound of a fountain or of water in thermal taps, and so forth;
- biotic – these are sounds that are a product of animate nature, which we divide into:
  - zoogenic, for instance: birds singing, moving sounds of animals, barking of a dog, howl of a wolf, etc.;
  - phytogenic, for instance: leaves rustling, branches creaking, falling leaves, grain noise, etc. (Rodzik, 2008; Rogowski, 2008; Dziekanowska, 2015; Malec et al., 2017a, 2017b).

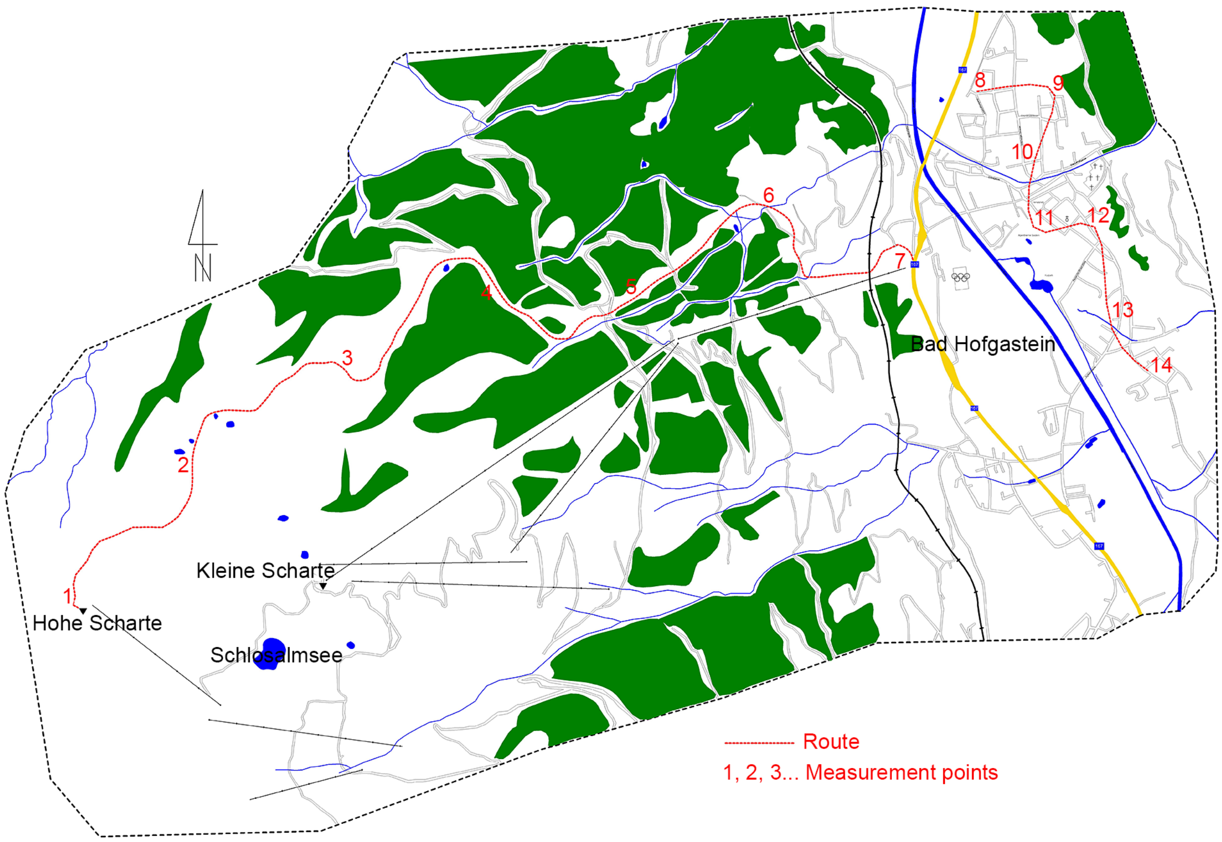


Fig. 1. Arrangement of measurement points along the ski slope and in the town of Bad Hofgastein (source: authors' own elaboration)

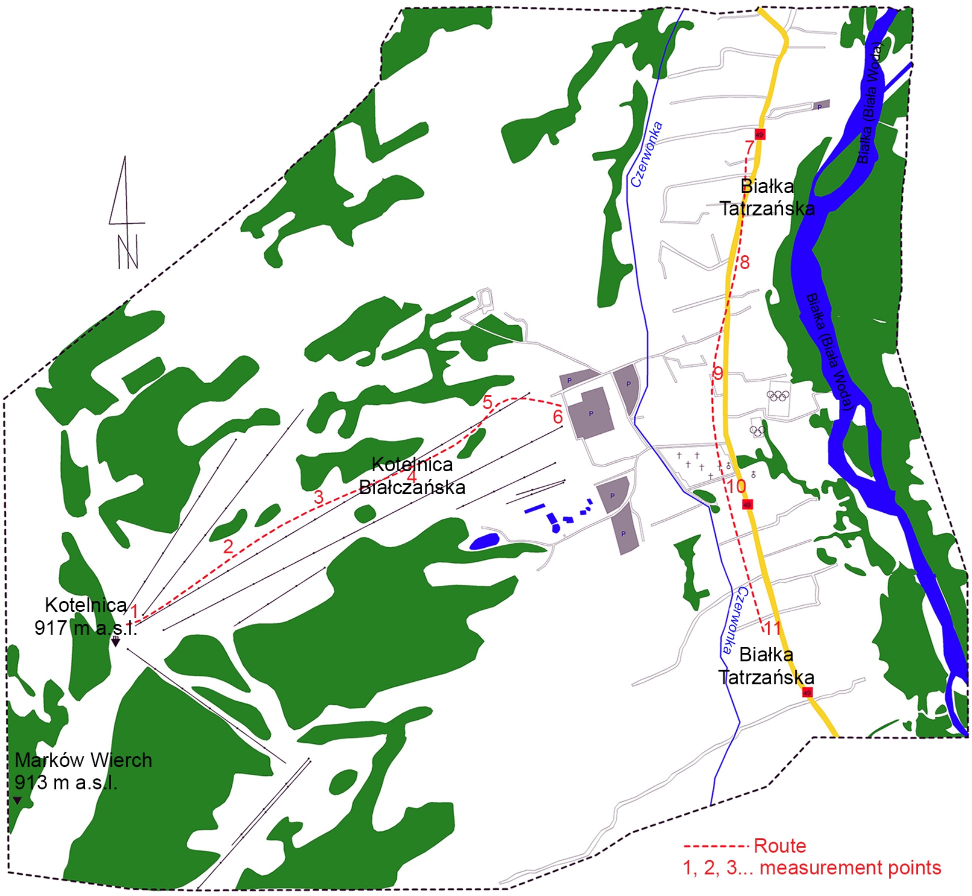


Fig. 2. Arrangement of measurement points along the ski slope and in the town of Białka Tatrzańska (source: authors' own elaboration)

During field research, observations were also carried out in order to locate traces of dwelling and feeding of wild animals. These observations were conducted by a two-person team, within the belts of ±200 m from the boundaries of the ski slopes. Members of the team moved on foot in the spacing allowing for visual observation of the belt with a width of approximately 50 m. Observations were made for 6 selected routes located both in wooded areas and in exposed areas lacking higher vegetation.

DESCRIPTION OF THE STUDIED AREAS

In Austria, field studies were conducted in the area of the Schlossalm-Angertal-Stubnerkogel ski slopes (SAS) and in the town of Bad Hofgastein (BH). Both studied objects are located within the Gastein Valley, at the foothill of the Hohe Tauern National Park in the Central Alps (see: Table 1). The Austrian ski resort covers areas from 860 m above sea level, up to 2300 m above sea level, with an average altitude difference of over 1000 m. The slopes and ski lifts are located between the Stubnerkogel (2251 m above sea level), Schlossalm (2050 m above sea level), and Hohe Scharte (2300 m above sea level). In total, the Austrian resort has 87 km of alpine skiing routes, and many places for classical skiing, free-riding, ski touring, winter hiking and snowshoeing. In the winter season of 2016/2017, Bad Hofgastein was visited by an estimated number of 570 thousand tourists (www.badhofgastein.riskommunal.met).

Fig. 3. Location of the studied areas (source: authors' own elaboration)

In Poland, the field studies were conducted in the area of Kotelnica Białczańska and Bania (KBB) ski slopes as well as in the town of Białka Tatrzańska (BT). Białka Tatrzańska is located in the immediate vicinity of the Tatra National Park, in the Tatra Mountains (Inner Carpathians). Białka Tatrzańska is one of the most dynamically developing holiday resorts in all of the Tatra region. The Polish ski resort is frequented both during the summer and during the winter. In the winter season of 2014/2015, between 318 and 342 thousand people have visited the resort in question (Krzesiwo, 2016). There are 13 ski lifts available for tourists during the winter, which serve 18 routes with a total length of 15 km, as well as 14 km of cross-country skiing trails. The routes for alpine skiing are focused on Kotelnica Białczańska, Bania and Kaniówka. The complex covers the neighbouring hills: Kotelnica (917 m above sea level), Jankulakowski Wierch (934 m above sea level), and Wysoki Wierch (934 m above sea level).

Descriptive characteristics of the ski resorts studied are summarized in Table 1.

Both ski resorts are among the largest in their respective regions, and they are both located in close proximity of protected areas. Consideration should be given also to further similarities of the analysed ski resorts. These include similar distances of both resorts to large urban agglomerations (Poland → Kraków, Austria → Salzburg). In both cases, the distance is about 100 km. Furthermore, there are additional tourist attractions in both regions, such as geothermal water sources and pools that increase tourist traffic.

Table 1. Characteristics of the studied areas (source: own research)

Description of the area	Bad Hofgastein	Białka Tatrzańska
Geographical region	Central Alps (Hohe Tauern)	High Tatra Mountains (Podhale)
Nature	Hohe Tauern National Park	Tatra National Park
State	Austria	Poland
Region (Land/Voivodeship)	Federal State of Salzburg	Małopolska Region
County	Sankt Johann im Pongau	Powiat Tatrzański
Municipality	Bad Hofgastein	Bukowina Tatrzańska
Population	6786 (in 2015)	2261 (in 2011)
Density of population	65 person/km^2 (town)	99 person/km^2 (municipality)
Surface area	103.75 km^2	–
Height above sea level	859–2300 m above sea level	650–934 m above sea level

RESULTS

Sound (noise) level

The variation in sound measurements for individual objects is shown in Figure 4.

There is considerable variation in the dynamics of the sound level on the slopes and in the towns, as well as a different characteristic of the variability of this parameter for the same objects (slopes/towns) in respective locations. Table 2 presents basic descriptive statistics for the analysed data.

Distributions of sound level values and diagrams of deviations for normal distribution of individual variables are presented in Figure 5. In case of close-to-normal distributions (KBB and SAS), the sound levels corresponding to 16th and 84th percentile present the lower and upper limits of the range (±1σ) of sound level variation for individual objects, and can be treated as a characteristic range of sound level variation for these objects. Consequently, the values above/below may be treated as sound anomalies.

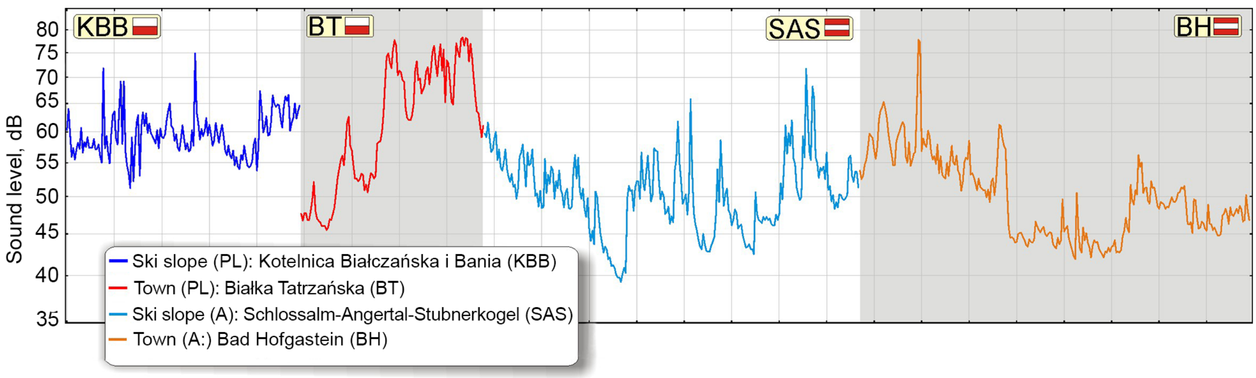


Fig. 4. Differentiation of sound level measurement values in the studied locations (source: own research)

Table 2. Descriptive statistics of data (source: own research)

Location	N	Mean[a)]	Median[a)]	Min.[a)]	Max.[a)]	Percentile 16[a)]	Percentile 84[a)]	Skewness	Kurtosis
KBB	148	59.61	59.15	51.2	74.9	56.2	63.4	0.9	1.7
BT	116	62.03	62.70	45.5	78.3	48.0	74.1	–0.1	–1.4
SAS	237	50.62	50.30	39.3	71.7	45.1	55.8	0.5	0.8
BH	247	50.28	49.20	41.9	77.8	44.2	56.6	1.1	1.8

a) values in (dB)

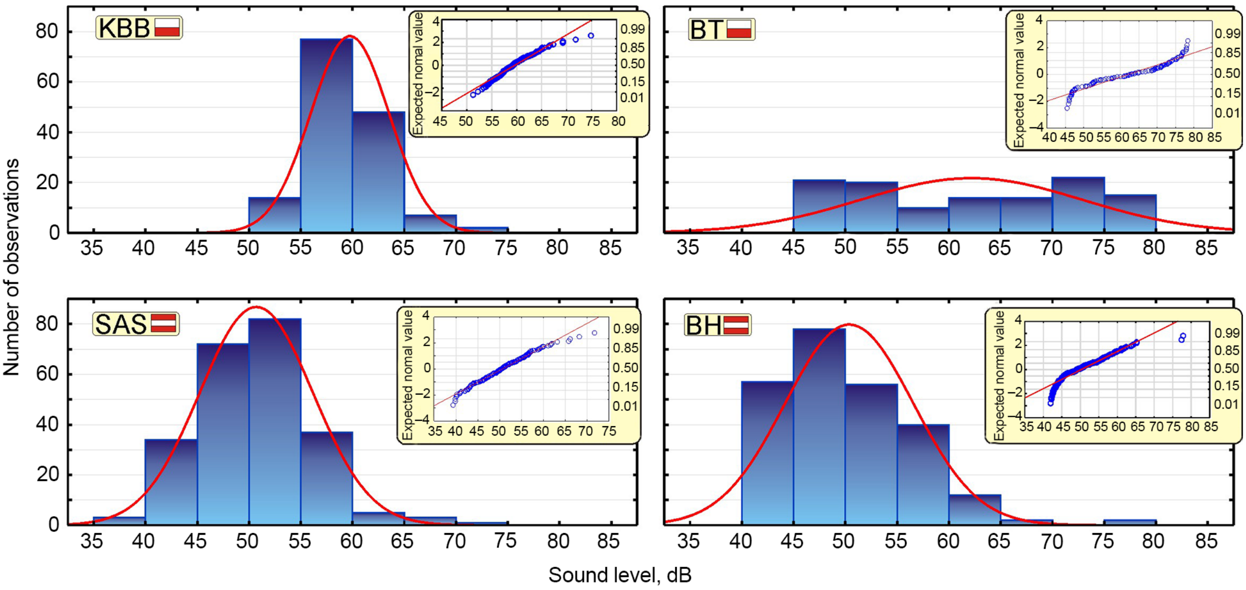


Fig. 5. Histograms of the studied data (source: own research)

The applied Shapiro-Wilk test (S-W) demonstrated that all the analysed variables are characterized by distributions that diverge from the normal distribution (see: Table 3).

Table 3. Normality test (S-W) (source: own research)

Variable	N	S-W	p
KBB	148	0.96	3.8E-04
BT	116	0.92	3.0E-06
SAS	237	0.98	4.6E-03
BH	247	0.92	1.7E-10

The results of Box-Cox transformation and the Hartley, Bartlett and Cochran tests indicated that nonparametric methods should be used for further statistical analysis. The results obtained using the abovementioned tests can be exposed to the occurrence of type I and II errors (false positive, false negative), however, the use of parametric methods is not possible in this case. To determine whether there is regional and/or local variation in the sound level between the ski resorts under study or within them, variance analysis is likely most effective. Therefore, the Kruskal-Wallis (K-W) test was used in order to analyse the sound level measurements. The K-W test is a nonparametric equivalent of a one-way analysis of variance (ANOVA), and it also facilitates the comparison between populations of different numbers. The interpretation of the test results is based on calculated ranks. The locations of the conducted measurements (KBB, BT, SAS and BH) were adopted as grouping (independent) variables. Obtained results of the K-W test are presented in Table 4.

Table 4. Results of the Kruskal-Wallis test (source: own research)

Dependent variable	Kruskal-Wallis ANOVA by ranks: H (3, N = 748) = 273; probability $p < 1.0 \cdot 10^{-4}$		
	Valid N	Sum of Ranks	Mean Rank
KBB	148	83 646	565
BT	116	61 709	532
SAS	237	68 025	287
BH	247	66 747	270

The value of the K-W test (H = 273) and the test probability level ($p < 1.0 \cdot 10^{-4}$) indicate that the variabilities of the sound level in different objects are statistically significantly different from each other. As a consequence of this fact, post-hoc tests (Dunn's test) were conducted (see: Table 5). The column headers included mean ranks (R) for individual locations. The results obtained are summarized in Table 5, whereas those results that are statistically significantly different from the others were marked in red.

Table 5. Results of multiple comparison tests (source: own research)

Dependent variable	Multiple Comparisons p values (2-tailed);			
	KBB R:565	BT R:532	SAS R:287	BH R:270
KBB	–	1.24	12.29	13.13
BT	1.24	–	10.00	10.76
SAS	12.29	10.00	–	0.85
BH	13.13	10.76	0.85	–

Analysis of post-hoc test results shows that statistically significant differentiation of sound level occurs between objects (towns and slopes) located in different ski resorts (the Polish and the Austrian one). However, no such difference has been observed in the level of sound variation between objects (the town and the slopes) within individual ski resorts. This indicates the existence of significant local conditions that have a meaningful impact on the sound landscape of the analysed ski resorts.

According to the guidelines of the World Health Organization (WHO), it is recommended that the sound level does not exceed 50–55 dB during the day, which has been recognized as safe for the mental and physical health of humans (Berglund et al., 1999). When analysing the results in this context, it was found that in the area of the SAS ski slope, in 46 cases out of 237 measurements, the measured values exceeded 55 dB. In the town of BH, the number of exceedances was 56 per 247 measurements (see: Figure 6).

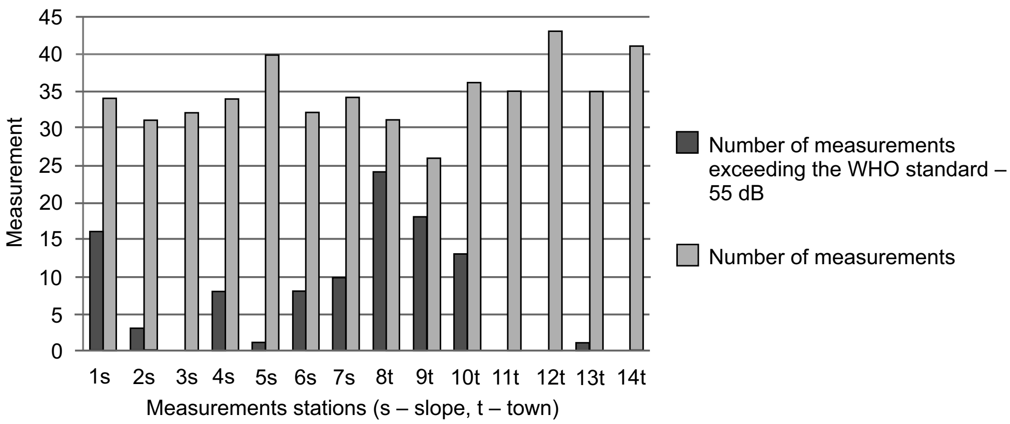


Fig. 6. Exceeding the limit set by the WHO (> 55 dB) in Bad Hofgastein area (source: own research)

There were many more cases of exceeding the value of 55 dB in Poland – the KBB ski slope had as many as 134 exceedances out of the total 148 measurements, while in the town of BT, 75 exceedances were recorded for the total of 116 measurements (see: Figure 7).

The problem of people's exposure to excessive noise, and hence adverse impact of that noise on human health, drew the attention of many authors: Berglund et al. (1999); King and Davis (2003); Dreger et al. (2015); Khaiwal et al. (2016), Ongel and Sezgin (2016). According to the authors listed above, the impact of excessive noise on the human body may manifest in: hearing loss, sleep problems, irritability, problems with concentration, respiratory disorders, changes in heart rhythm, and many more. The noise problem is mainly highlighted in the aspect of urbanized areas. However, noise is also a serious disturbing factor in natural areas. Considering the location of both resort towns, which are close to valuable natural areas, attention should be paid also to the impact of noise on wildlife, especially on mammals and birds. In many regions of the world, attempts have been made to assess the impact of mountain land use during the winter on the behaviour of animals living in these areas. For example, Pickering et al. (2003) drew attention to the adverse impact of noise on animals in the Kosciuszko National Park in Australia. This noise originated mainly from snow cannons, ski lifts, snowmakers, snowmobiles, helicopters or sounds generated by skiers and other tourists.

In addition, music is played on most slopes. This means that the animals living in the area are exposed to strong stressors for much longer. However, this kind of noise pollution negatively affects not only nature, but also the inhabitants of the region, as well as tourists themselves. For this reason, it is worth paying more attention to this aspect of the impact of ski resorts.

Authors such as Bradley and Lang (2000); Royet et al. (2000); Rylander (2004, 2006); and Alvarsson et al. (2010) emphasize the individual (ontogenetic) perception and impact on the brain and the entire nervous system of sounds of various origins, for instance, sounds of nature, traffic, sounds associated with danger or negative emotions, and so forth. For example, Mace et al. (1999) during the research they carried out in the Grand Canyon National Park stated, among other things, that the noise caused by helicopters transporting skiers to higher parts of the mountains was equally negatively perceived by tourists when it was at the level of 80 dB as when it was at the level of 40 dB.

Acoustic events

the soundscape of a given place is not only its physical aspect assessed on the basis of the sound level, as expressed by the number of decibels. It is also a wealth of various sounds, depending on many factors, including: the shape of the terrain, the form of land use, the seasons, or the weather. For this reason, an inventory of all sound sources is very important. Establishing the percentage share of natural and anthropogenic sounds makes it possible to determine the

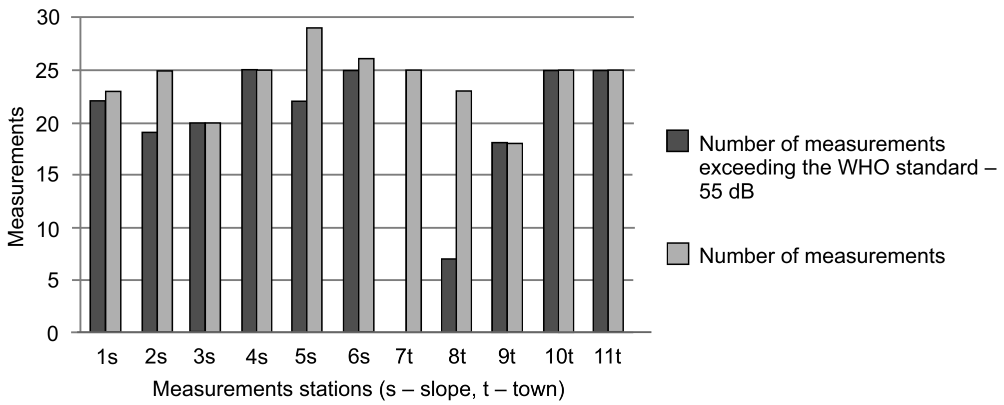


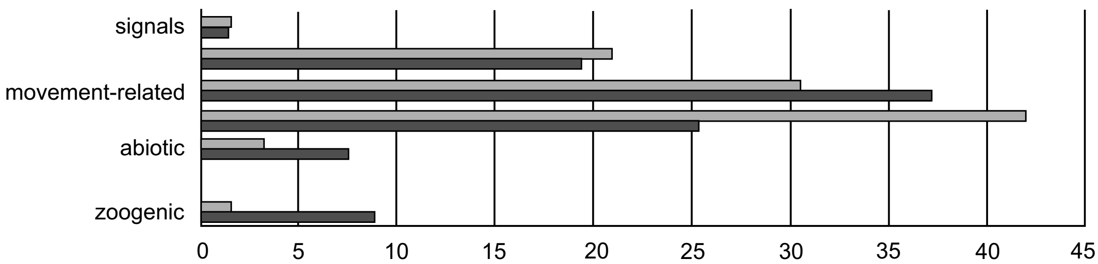
Fig. 7. Exceeding the limit set by the WHO (> 55 dB) in Białka Tatrzańska area (source: own research)

degree of anthropogenic transformation of the natural environment in the acoustic aspect. However, during the winter, this is much more difficult to establish due to the lower activity of animals, especially singing birds. Therefore, the number of acoustic events with zoogenic character is much lower in winter than it is in summer or in spring (Aletta et al., 2016; Kang, et al., 2016; Kang, 2019).

Considering that there is no observed variation in sound level variability between objects (the towns and the slopes) within the particular studied ski resorts, the analysis of the genesis of acoustic events was conducted separately for the resorts in Poland and those in Austria, without distinguishing between individual objects. It is also a significant fact that the sounds measured on the slopes are more or less overlapping; namely those whose source is remote and located in the town, and vice versa. Figure 8 presents a summary of the percentage share of individual sound events in each of the studied ski resorts.

In neither of the two studied locations were phytogenic sounds recorded. On the one hand, this is due to the specificity of the given season, and on the other hand, it can also be the effect of the masking influence of other, much clearer noises such as music or loud conversations between skiers. The sounds of the phytogenic type are usually very quiet and subtle in reception, which causes them to disappear from the sound landscape as a result of the pressure from other elements. In the Austrian resort, sounds of the "zoogenic" kind were recorded in 6 measuring points (one of those sounds was the barking of a dog, the other was the singing of birds and the sound of their wings). In the Polish resort, birds were heard only at one point.

In both resorts, anthropogenic sounds were most frequently recorded. Both in the Polish and in the Austrian ski resort, one "semiotic sound" was recorded; in both cases this was church bells. Of all technical sounds in both ski resorts, the biggest share belongs to the sounds of passing cars or sounds related to the operation and exploitation of lifts and cableways that carry skiers up the slope. However, in the case of the Polish resort, the sounds of ski lifts and queues of skiers were heard more often and they were more intensively audible than in the Austrian resort. Of all the recorded sounds, the most numerous group were socio-cultural sounds. At seven measurement points located in the Polish ski resort, you could hear loud music played both in restaurants at the lower station of the ski lift, and from loudspeakers deployed along downhill runs and lifts. In the case of the Austrian resort, only in one point (the last point at the lower station of the lift) quiet sound of music was recorded, coming from the centre of the village. In the Austrian centre, we have not observed any music played from loudspeakers on the downhill tracks. In the case of loud "conversations" between people in Białka Tatrzańska, only one observation point was free from that sound. In addition, in 6 out of 11 points, loud "shouts and screams"



	zoogenic	phytogenic	abiotic	socio-cultural	movement-related	technical	signals
Białka Tatrzańska	1.6	0	3.2	42	30.6	21	1.6
Bad Hofgastein	8.9	0	7.5	25.4	37.3	19.4	1.5

Fig. 8. Percentage of particular types of acoustic events in each of the two towns (source: own research)

were also recorded. In the case of an Austrian resort, there were no "conversation" sounds in 4 locations, and no loud "screams" whatsoever in any of the locations. Sounds such as music or any sounds of "human" origin have a huge impact on wild animals. This applies to both avifauna and mammals. For example, Huebel (2012) observed that in British Columbia and North Idaho, the Rangifer tarandus caribou temporarily leave their lands disturbed, among others, by skiers and their helicopters. The aforementioned author noticed that snowmobiles might constitute another strongly influencing factor. Also according to other authors, for example Simpson (1987); Simpson and Terry (2000); Fortin and Andruskiw (2003); Quinn et al. (2006); Huebel (2012), the sounds of helicopters carrying skiers, sounds of snowmobiles, snowmakers, or the mere presence of skiers can significantly affect the number, as well as the changes in behaviour and health status of many species of mammals inhabiting mountainous areas.

Spatial concentration and density of infrastructure

Significant factors characterizing the environmental impact of both analysed ski resorts is the size of the area occupied, the number of skiers using the slopes, and the density of the skiing infrastructure (ski routes, ski lifts, etc.). The comparison of these factors for the studied ski resorts is presented in Table 6.

As we can see, the Austrian ski resort is in many respects a bigger one, and ski lifts have a greater total throughput. While all the 13 lifts located in the Polish resort can transport about 23,550 skiers every hour, the 19 lifts of the Austrian centre export 34,160 people within the same time. In terms of both the area size and the number of kilometres of ski routes, the Austrian resort is much larger: in terms of area, it is more than 4 times larger, and in terms of routes' length, it is almost 6 times larger. In the Austrian resort, there are only 0.96 km of ski pistes (routes) per 1 km^2, in the Polish resort, this proportion is as much as 2.65 km of ski pistes per 1 km^2. Large disparities can be noted by comparing the number of ski lifts, which corresponds to the total length of all ski runs. In the Austrian resort, there are 87 km of pistes (Not counting the 1.3 km of the so-called cross-country ski route, intended for skiing on unequipped routes), with 19 lifts, which results in the ratio of about 0.22 km of a ski lift per 1 km of a downhill run. There are only 15 km of routes in the Polish resort, which are served by as many as 13 lifts, which results in an average of about 0.87 km of a lift per 1 km of a downhill run. As a result, in the Polish ski resort, the sounds of technical origin – such as, for instance, striking hooks of a plate lift, or security mechanism of the chairlift – constitute one of the main factors disturbing the silence. We obtain similar data by comparing the average length of routes in both

Table 6. Comparison of the area and infrastructure of the two ski resorts studied. Huebel (2012). Assessing the impacts of Heli-skiing on the behaviour and spatial distrbution of mounatin caribou (Rangifer Tarandus Caribou), A thesis Masters of Science in Environmental Science Thompson Rivers University

Development of the facility	BIAŁKA TATRZAŃSKA (Kotelnica, Bania)	BAD HOFGASTEIN (Schlossalm-Angertal-Stubnerkogel)
Area size of the ski resort (km2)	6.80	31.3
Number of ski slopes	18	30
The total number of lifts including: aerial lifts chairlifts surface lifts ropeways	13 – 8 5 –	19 6 8 4 1
The total length of ski slopes (km)	15	87

resorts. In the Polish resort, the average length of the route is about 830 m, the shortest being 110 m, and the longest, 1900 m. In the Austrian resort, the average is 2900 m, with the shortest route being 400 m and the longest, 7000 m. All the factors mentioned above indicate an even distribution of ski traffic in the Austrian resort, and hence also a smaller individual impact on the natural environment. Tourists, who are using the routes and ski infrastructure at the same time, are distributed across spacious area and between different the slopes, which are very often separated from each other by woodland. In the Polish resort, large numbers of both the skiers and the technical infrastructure are located within a small space, and on relatively short slopes. In addition, most routes are marked out on one large surface, often criss-crossing each other. For example, as many as 7 out of 13 lifts have their top stations located on one peak (Kotelnica). This results in very high density of skiers using individual routes simultaneously. Summing up the above observations, it can be concluded that in the Polish ski resort, there are about 3463 skiers per 1 km^2, whereas in the Austrian ski resort, the average is only 1091 people per 1 km^2. The same applies to the comparison between the number of kilometres of downhill runs per 1 km^2 (in Austria, it is 0.96, whereas in Poland, it is 2.65) as well as the number of kilometres of lifts serving 1 km of the route (in Austria – 0.22, in Poland – 0.87). The results of the research indicate the presence of a large number of skiers and a significant density of infrastructure in the Polish ski resort.

DISCUSSION

The two analysed ski resorts are similar in many respects. The basic differences between the studied ski resorts are in the size of their areas, and in the number of skiers using them. In both ski resorts, during the day, there are exceedances of the average sound level that is recommended as safe for people by the WHO (see: Figure 6 and Figure 7). This applies to individual slopes as well as the resort towns. Having said that, these exceedances are more frequently recorded within the Polish ski resort (see: Figure 6 and Figure 7). This observation may be somewhat surprising if we compare the area sizes of the analysed ski resorts, and the number of skiers per hour who can be taken by ski lifts to all the peaks in both ski resorts. There are several reasons for this. The high concentration of both the users and the technical infrastructure within the small area occupied by the Polish ski resort has a negative impact on its soundscape. It is clearly visible both in terms of the sound level, and the characteristic acoustic events that we have recorded (see: Figure 6, Figure 7, and Figure 8). Similar observations and insights have also been reported by other researchers. For example, according to Simpson (1987); Simpson and Terry (2000); Huebel (2016), the number of skiers staying at the same or similar time within a relatively small area has a significant impact on the sound level in the immediate surroundings. Flousek and Harčarik (2009) determined that in ski areas, during night-time maintenance works, the noise reaches values between 60 and 115 dB. In the same publication, attention was also paid to the harmful effects that music broadcast on the slopes has on the fauna. It is significant because another important factor affecting the higher sound level recorded in the Polish ski resort is the music playing from loudspeakers located along the ski slopes. This is an additional element that can affect changes in the behaviour and migration of wild animals, as well as disturbing the peace of residents and vacationing tourists.

Factors that have not yet been sufficiently studied and analysed in the scientific works on ski resorts include socio-cultural conditions and the behaviour of the skiers themselves. According to our research, both the sound level and the type of acoustic events largely depend on the socio-cultural conditioning of the inhabitants and users of the area. For this reason, among the factors that determine the overall higher sound level in the Polish ski resort we can list, for example, the shouting and loud conversations of skiers and snowboarders – whereas nothing of the kind has been recorded in Bad Hofgastein (see: Figure 8).

All of the insights presented above are confirmed by observations made by the authors within the belts surrounding the ski slopes. In both of the analysed ski resorts, only few traces of wild animals staying or feeding have been observed along the routes. These were mainly traces of various species of ungulate mammals and various species of birds. In the case of mammals, only traces and tracks were observed. In the area of the Austrian ski resort, the birds' singing was heard along the less frequented routes. Although the observations made were of an auxiliary nature to the measurements of sound levels, the results of these observations indicate a very likely negative impact of the ski resorts on the natural environment. Changes in wild animal behaviour caused by skiing tourism have been extensively discussed in scientific papers. For example, excessive concentration of skiers or snowmobiles within a small area can cause an increase in the concentration of stress hormones and temporary abandonment of habitats and places of winter hibernation by the animals (Goodrich and Berger, 1994; Creel et al., 2002; Arlettaz et al., 2007; Thiel et al., 2008). Currently, the acoustic environment is considered primarily in terms of threat and minimizing the impact of noise in the sense of its physical aspect. However, reducing the sound level in the human environment is not always sufficient, and the noise from which people escape by choosing natural areas (e.g. mountain areas) is also present in these places (Alvarsson et al., 2010; Gale et al., 2021a, b). The significant problem is the lack of systematized guidelines regarding noise standards in naturally valuable areas, especially those used for tourism. The issue that is particularly noticeable is the often inadequate and/or inconsistent soundscape research methods, for instance, the provisions contained in ISO 12913 (ISO/DIS 12913-2:2017, ISO/TS 12913-2:2018, ISO/WD TS 12913-3), which concern mainly urbanized areas and are based largely on subjective feelings of the recipients. Therefore, there exists a need for more research study assessing the soundscape in terms of its naturalness, without too much subjectivity, such as the soundscape naturalness curve method (Malec et al., 2023). This applies to both soundscapes in urbanized areas and in natural areas, where noise is generated to varying degrees by human activities. For research on soundscape, the availability to refer to the results of other research conducted in different environmental settings would also be important. This type of comparison might be possible, for instance, by analysing raw data, that is, specific types of sound events without their subjective assessment. Such procedure would facilitate a largely objective comparison of the results of research conducted in different conditions and cultural contexts.

CONCLUSIONS

The research we conducted allowed us to answer the research questions posed in the introduction. There is a differentiation of sound landscape (both in terms of sound levels and acoustic events) between study objects (towns and slopes) in different locations, i.e. there exists regional diversity of sound landscapes. However, there is no local differentiation in sound level between objects (town versus slope) within the same locations. Lack of local differentiation indicates a kind of penetration and overlapping of soundscapes for distant objects, i.e. the slope and the town in individual ski resorts. This emphasizes the local character of the sound events occurring in the analysed ski resorts even more clearly. Each resort has its own characteristic sound landscape, which is conditioned primarily by factors such as: spatial distribution of the ski infrastructure and the concentration of skiers within a specific area, as well as socio-cultural conditions. Despite some similarities between the two studied ski resorts, there are no universal factors that would significantly affect the sound landscape of these ski resorts.

One of the factors affecting the soundscape of the studied ski resorts lies in the users of the ski resorts themselves. It is noted that the acoustic quality of a given area is also significantly influenced by the personal culture and lifestyle of the users of this particular area. Therefore it is also important to promote this information, and to draw the attention of tourists and skiers to the fact that they themselves are an important source of noise. Furthermore, changing their behaviour can be important in reducing the negative impact of skiing on the natural environment.

The results of the studies we have conducted also indicate that relatively small ski resorts, which are nevertheless concentrated within a small area, may potentially have a much stronger environmental impact. In general, taking into account the number of exceedances of the average sound level during the day, and the degree of anthropogenic transformation of the natural environment in acoustic terms, both analysed ski resorts are likely to have a negative impact on the natural environment, albeit not to the same degree.

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ANALIZA KRAJOBRAZU DŹWIĘKOWEGO OŚRODKÓW NARCIARSKICH W BAD HOFGASTEIN (AUSTRIA) I BIAŁCE TATRZAŃSKIEJ (POLSKA)

ABSTRAKT

Cel pracy

Głównym celem pracy było ustalenie, czy wielkość oraz zagospodarowanie i funkcjonowanie ośrodka narciarskiego ma wpływ na krajobraz dźwiękowy. W związku z tym do badań wytypowano dwa ośrodki: jeden zlokalizowany w Polsce, drugi w Austrii. Poza tym autorzy chcieli odpowiedzieć na pytanie, czy istnieją różnicę zarówno w natężeniu dźwięku, jak i typach zdarzeń akustycznych w obrębie ośrodków (miasto–stok) oraz pomiędzy dwoma badanymi ośrodkami narciarskimi.

Materiał i metody

Przeprowadzone badania polegały na pomiarze natężenia dźwięku oraz inwentaryzacji zdarzeń akustycznych. Badane ośrodki narciarskie, pomimo różnicy w wielkości zajmowanych przez nie obszarów i liczbie użytkowników, są pod wieloma względami porównywalne ze sobą.

Wyniki i wnioski

Wyniki wskazują, że różnice w poziomie zmienności dźwięku występują pomiędzy obiektami (miejscowościami i stokami) zlokalizowanymi w poszczególnych ośrodkach narciarskich. Najczęściej rejestrowane były dźwięki antropogeniczne, a wśród nich najliczniejszą grupę stanowiły dźwięki społeczno-kulturowe. W austriackim kurorcie stanowiły one 25% wszystkich pomiarów, natomiast w polskim kurorcie wyniosły aż 42%.

Słowa kluczowe: hałas, krajobraz dźwiękowy, dźwięki antropogeniczne, dźwięki naturalne, ośrodki narciarskie