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Acoustic studies of tourist sites in Longyearbyen identified by respondents

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Abstract Svalbard is a Norwegian province in the Arctic, covering the Svalbard archipelago and islands within 71°– 81° N and 10°– 35° E. The largest town on the largest island – Spitsbergen – is Longyearbyen, with a population of around 2100. It is the main centre of administration for the governor's office, and there are many public buildings, housing estate, a harbour, and an airport. This paper presents the results of acoustic measurements conducted at selected popular tourist destinations near Longyearbyen. The sites for this study were chosen based on the analysis of a survey aimed at identifying preferences in tourism activities in the Longyearbyen area. Based on the responses, three groups of tourist activities were identified: (1) Longyearbyen activity: a round trip to town, a visit to the Svalbard Museum, historic Coal Mine no. 3 and the University Centre in Svalbard UNIS, (2) Snowmobile trips: to Barentsburg, East Cost and Elveneset, (3) Nature hikes: trips to the summits of the Sarkofagen and Trollsteinen peaks, hiking on the Lars Glacier, the Longyear Glacier and the Tell Glacier and visits to glacier caves. Of these sites, acoustic analyses (sound pressure level – time and frequency characteristics) were conducted at the following locations: Longyear Valley: UNIS area and city centre, Advent Valley: dog sleds and snowmobile rides, Nature hike: Sarkofagen peak and caves in the Lars Glacier and the Longyear Glacier.

Keywords: environmental measurements, soundscape studies, sound pressure level, noise.

1. Introduction

Svalbard is a Norwegian province in the Arctic, encompassing the Svalbard Archipelago and additional islands not included in the archipelago within 71°–81° N and 10°–35° E. The Svalbard Archipelago covers 62700 km^2. The archipelago is located between Greenland and New Earth and is surrounded by the Greenland Sea to the west, the Barents Sea to the east, the Norwegian Sea to the south and the polar Arctic field (Arctic Sea) to the north, about 800 km north of Norway and about 1100 km from the North Pole [1-3].

The largest island of the Svalbard Archipelago is Spitsbergen, and the largest town in Svalbard is the town-settlement of Longyearbyen, with a population of around 2100. The history of Longyearbyen dates to 1905, when the first settlement was built for the workers of the established mine [4]. Today it is a major centre of administration with the governor's office, there is a housing estate and a harbour. There are two permanent research centres operating in Svalbard: the Norwegian research station at Ny-Ålesund and the Polish polar station at Hornsund, where a team of ten scientists is based [5].

Svalbard has been a significant arena for polar research for more than two centuries. The most important scientific areas in Svalbard are climate change, glaciology, biodiversity, ocean currents and the Earth's magnetic field. Ny-Ålesund is an ideal place for monitoring of global atmospheric gasses and long-transported contaminants because the influence of local contamination sources on the measurements is minimal [6].

Previous acoustic research in Arctic areas was mostly focused on underwater recordings of animal activity [7–10], infrasound measurements of glacier activity [11–17] and underwater ambient noise monitoring and propagation modelling [18, 19].

The papers [11–13] describe the use of hydroacoustic methods to monitor the presence of sea ice and icebergs on the surface of an Arctic fjord and the effects of iceberg break-up. Since 2010, Russian scientists have carried out continuous monitoring of the occurrence of infrasound in the environment [14–17]. The research is carried out using a special low-frequency measurement system. This system was installed near the BRBB seismic station, located 4 km from Barentsburg. The systems built allow detection of seismic events in the frequency range 3–17 Hz and infrasound events in the range 1–20 Hz. The main objective of the research is to record acoustic waves from glacial calving and compare them with seismic signals.

The monograph [20] discusses selected issues related to the Spitsbergen's acoustic environment concerning: the analysis of sound levels in temporal and spatial terms, and the recording of the soundscape using ambisonic technology. The soundscape analysis of selected valleys is shown in articles [21, 22]. The analysis shows a local contamination of human activity on the soundscape as well as the variability and characteristic features of the natural Arctic soundscape. The paper [23] shows results of spatial impulse measurements in four different glacier caves of the Svalbard archipelago located close to Longyearbyen. The results show the diversity of the acoustic environment inside the glacier caves that strongly depends on the morphology and dimensions of the caves. The design process of acoustic panels inspired by Spitsbergen nature is presented in [24].

A study of the acoustic environment on the island of Spitsbergen in the Svalbard archipelago was conducted in the Management Area 10. Management Area 10 is an area in central Spitsbergen where non-residents can travel independently without a permit from the Governor. This paper presents results of acoustic measurements of selected sites near Longyearbyen. The sites for the acoustic study were selected based on an analysis of results from a survey for the identification of tourism activity preferences in the Longyearbyen area.

2. Materials and methods

Longyearbyen is a small town where almost all tourism passes through. A continuous increase in the number of tourists in the Spitsbergen area has been noticeable more or less since the late 1950s. Key factors for the development of tourism have been the expansion of the airport, the opening of scheduled flights by Norwegian airlines, political changes, and the commercialisation of tourism [25–27]. The occurring increase in the number of overnight stays is also indicative of the scale of sightseeing tours, organised excursions, and unorganised outdoor recreation. From one side, the tourism industry contributes significantly to the local economy, but from the other side, increased tourism also poses serious threats to the natural and acoustic environment.

Therefore, the researchers aimed to conduct acoustic analyses of the soundscapes in popular tourist locations in Longyearbyen – the administrative capital region of Svalbard. To identify preferences in tourism activities, a survey was conducted. Survey in the form of paper questionnaires was conducted in winter 2019 by participants of the AGH University research expedition. The survey was conducted among randomly selected people: tourists and temporary residents, as there are almost no long-permanent residents in Longyearbyen. The survey took place at popular locations in the centre of Longyearbyen, including the museum entrance, the main hall of the university, and the largest supermarket. The general part of the survey included three questions:

1. Is it your first visit in Svalbard?
– Yes, – No, it is my ... visit. Last time I was here ... years/months ago, – No, I am a resident of Svalbard.
2. How long are you going to stay in this area? (number of days)
3. List places you have visited during your stay in Svalbard, starting from the one which you like the best.

The survey was conducted among 91 people, mainly tourists. The distribution of answers to the individual questions are shown in Figures 1–3.

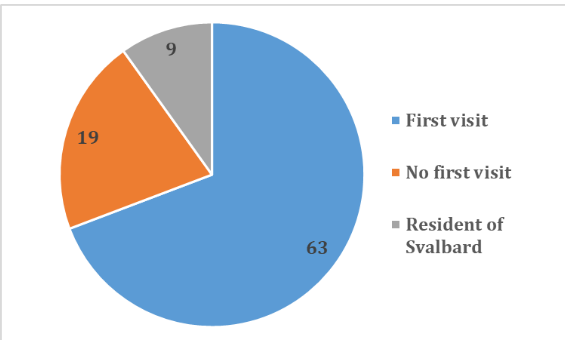

Figure 1. The distribution of answers [numbers of respondents] for question 1: Is it your first visit to Svalbard?

Based on the analysis of the answers to the first question (see Fig. 1), it can be concluded that 10% of the respondents were residents, 69% of the respondents visited Svalbard for the first time, and 21% of the people visited several times (from 2 to 11 times).

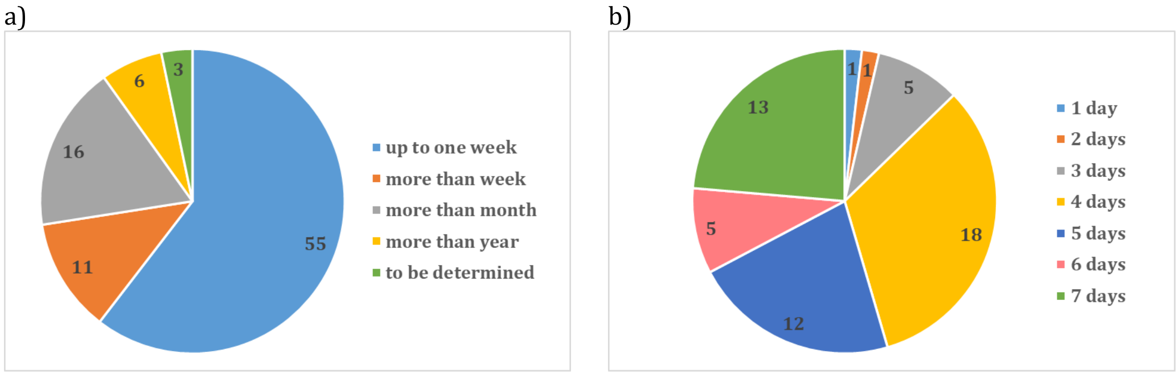

Figure 2. The distribution of answers [numbers of respondents] for question 2: How long are you going to stay in this area? a) all answers; b) number of days up to one week.

Based on the analysis of the answers to the second question (see Fig. 2), the length of stay depends on the reasons for going to Svalbard. The largest group intended to spend between 1 and 7 days on the island, with a modal value of 4 days. However, there were also people who spent between one week and one month on the island. The second largest group intended to stay in Svalbard for several months.

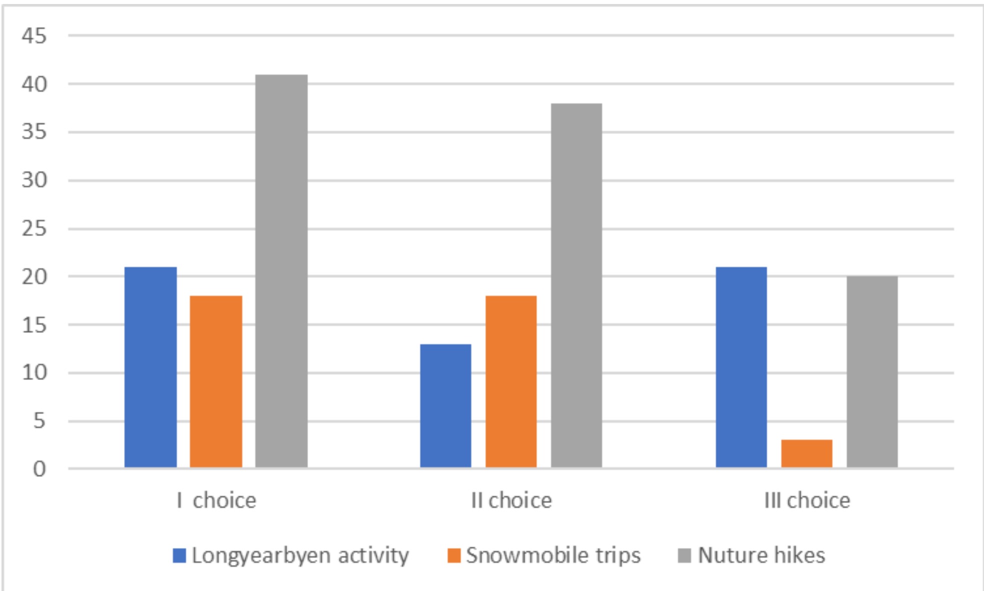

Figure 3. The distribution of answers [numbers of respondents] for question 3: List places you have visited during your stay in Svalbard, starting from the one which you like the best.

A detailed analysis of the answers to third question and an analysis of the preference of tourist activities made it possible to identify three types of most popular activity (see Fig.3). The activities of the respondents can be divided into three main types:

- Longyearbyen activities: a round trip to town, a visit to the Svalbard Museum, historic Coal Mine no. 3 and the University Centre in Svalbard UNIS,
- Snowmobile trips: to Barentsburg, East Cost and Elveneset,
- Nature hikes: trips to the summits of the Sarkofagen and Trollsteinen peaks, hiking on the Lars Glacier, the Longyear Glacier and the Tell Glacier, and visits to glacier caves.

3. Acoustics measurements

Based on the identified tourism activity preferences in Longyearbyen area, the following sites were selected for further analysis of the acoustic environment (see Fig. 4):

- Longyear Valley: UNIS (measurement point I) area and city centre (measurement point II),
- Advent Valley: dog sleds (measurement point III) and snowmobile rides (measurement point IV),
- Nature hike to Sarkofagen peak (measurement point V),
- Glacier caves in the Lars Glacier (measurement point VI) and the Longyear Glacier (measurement point VII).

Sound pressure level (SPL) measurements were carried out at the listed sites. SPL measurements were made using the SVAN 977 Class 1 sound level meter. Measurements were made in the broadband range, taking into account all required frequency-correction characteristics. Octave and 1/3-octave spectra in the audio-acoustic bandwidth were also determined using this meter. A SVAN SV 277 PRO monitoring station equipped with a Class 1 sound level meter was used for long-term monitoring of sound level changes in Longyearbyen. The measurement system was housed in all-weather housing that contained the sound level meter, power battery, 3G modem, and a control system.

The soundscape analyses of the selected sites are presented in the following subchapters. Due to the variations in the sounds identified at each site, their temporal characteristics (including diurnal), and measurement capabilities, the corresponding and best suited acoustic analysis tools were applied to each site.

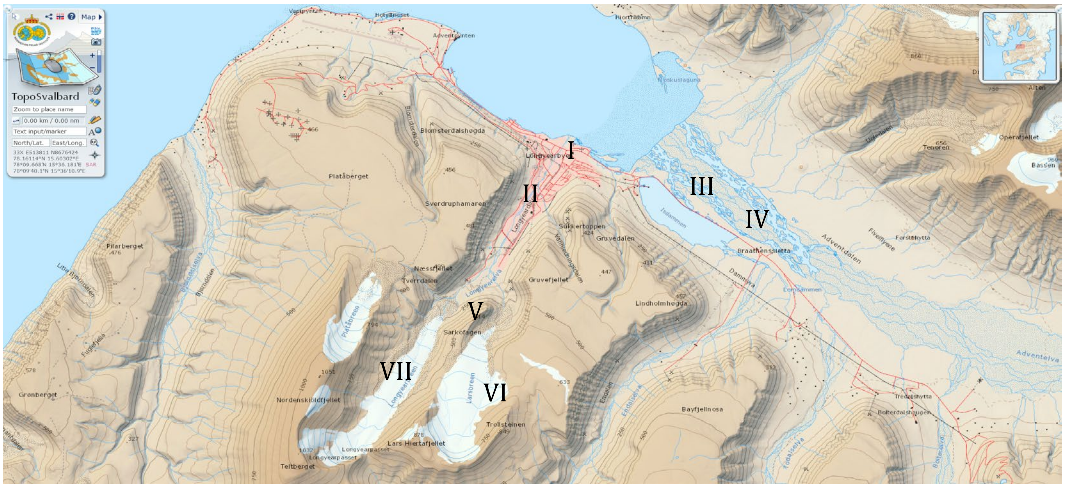

Figure 4. Localization of the measurement's points: I – the Longyear Valley: UNIS, II – the Longyear Valley: city centre, III – the Advent Valley: dog sleds, IV – the Advent Valley: snowmobile rides, V– Nature hike: Sarkofagen peak, VI – Glacier cave: the Lars Glacier, and VII – Glacier cave: the Longyear Glacier (map from [28]).

3.1. The Longyear Valley: UNIS area and shopping centre

The Longyear Valley is around 30-40 km long. On one side it reaches the Advent Bay, on the other side it ends with the summit of Sarkofagen, which divides it into two parts with glaciers: the Longyear Glacier and the Lars Glacier. On the slopes of the valley, there are entrances to the historic coal mines. The long-term SPL measurements using a SVAN SV 277 PRO monitoring station were taken at two points: I – near UNIS and II – in the downtown close to the shopping centre (see Fig. 5). Figure 5 shows the equivalent continuous sound level L_{Aeq} for the daytime and night-time.

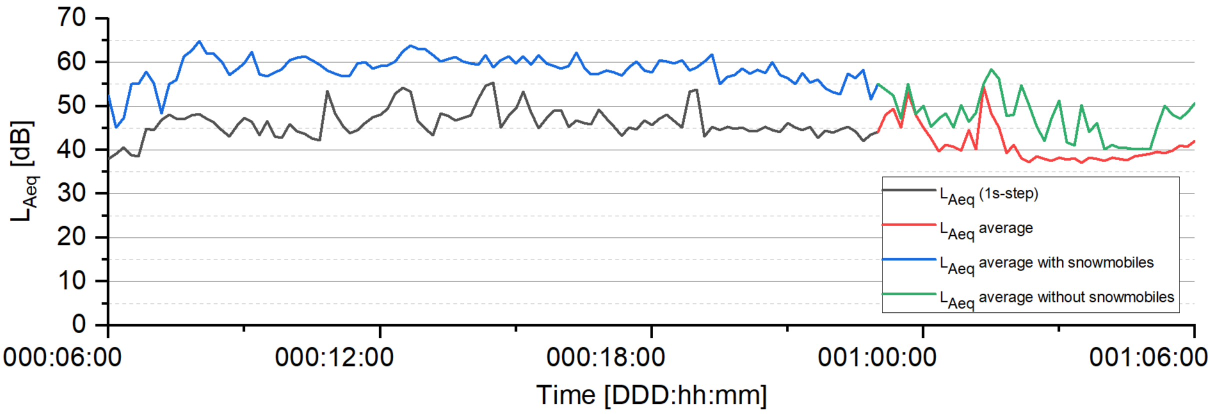

Figure 5. 24-hour 1-second step A-weighted equivalent continuous sound level – points I and II.

For point I, the 1-second step A-weighted equivalent continuous sound level L_{Aeq} for the daytime (6:00-22:00 hours) was L_{A16h} = 47.3 dB and for the night-time (22:00-6:00 hours) was L_{A8h} = 42.8 dB (see Fig. 5). The noise level difference for the daytime and night-time is not large, about 4.5 dB, which is due to the high activity of tourists and residents during the late-night hours (snowmobile crossings, traffic on parallel streets, the sound of footsteps, etc.).

For point II, the equivalent continuous sound level L_{Aeq} for the daytime was L_{A16h} = 59.5 dB, and for the night-time it was L_{A8h} = 52.4 dB (see Fig. 5). Comparing the two measurement points, a significant influence of anthropogenic noise can be observed, the increase in value is for the daytime and night-time is 12 dB and 10 dB, respectively. This increase is mainly related to motor vehicle traffic on the nearby Vei 500 road.

3.2. Nature hike to Sarkofagen

Hike to Sarkofagen is one of the most popular hiking trips that explores the spectacular backyard of Longyearbyen and offers a stunning view over the city and surrounding mountains. Another popular trail is the route to the Trollsteinen, 850 m above sea level. The results of the SPL measurements taken at the top of the mountain using the SVAN 977 Class 1 sound level meter are shown in Fig. 6. A time window around 12 minutes is shown to highlight single events involving a group of tourists on scooters crossing the valley and glacier. The figures show the time course, amplitude-frequency characteristics, and the amplitude-frequency-time characteristics when a group of snowmobiles pass through the Longyear Valley and glacier.

Figure 6a shows a sample SPL time history measured on Sarkofagen in winter from around 13:02:00 to 13:14:00. During windless weather, there is a 'deathly' silence on Sarkofagen, the SPL value is around 23.4 dB. In winter sounds of nature are often interrupted by the noise of snowmobiles. There is an increase in SPL of 9.7 dB to a value of 33.1 dB when snowmobiles pass through the valley (see Fig. 6a). Also, analysis of the spectrogram shows (see Fig. 6d) that low frequencies dominate when snowmobiles pass through the valley.

3.3. Sound measurements of dog sleds and snowmobile rides

It is a very large valley stretching 30 km southeast and east of Longyearbyen and is a very popular area for dog sleds and snowmobile rides. The valley originates from the mountains Slottet and Tronfjellet, under the glaciers Hellefonna and Drøn, and the end of the valley is close to the University Centre in Svalbard, Longyearbyen. At the entrance to the valley are the port of Longyearbyen and kennels (places where sled dogs are). Further on, there is Lake Isdammen, about 2.5 km long, whose name means "ice pond". Figure 7 shows the spectrum of a single dog howling and the passage of a single snowmobile with an average speed of 40 km/h.

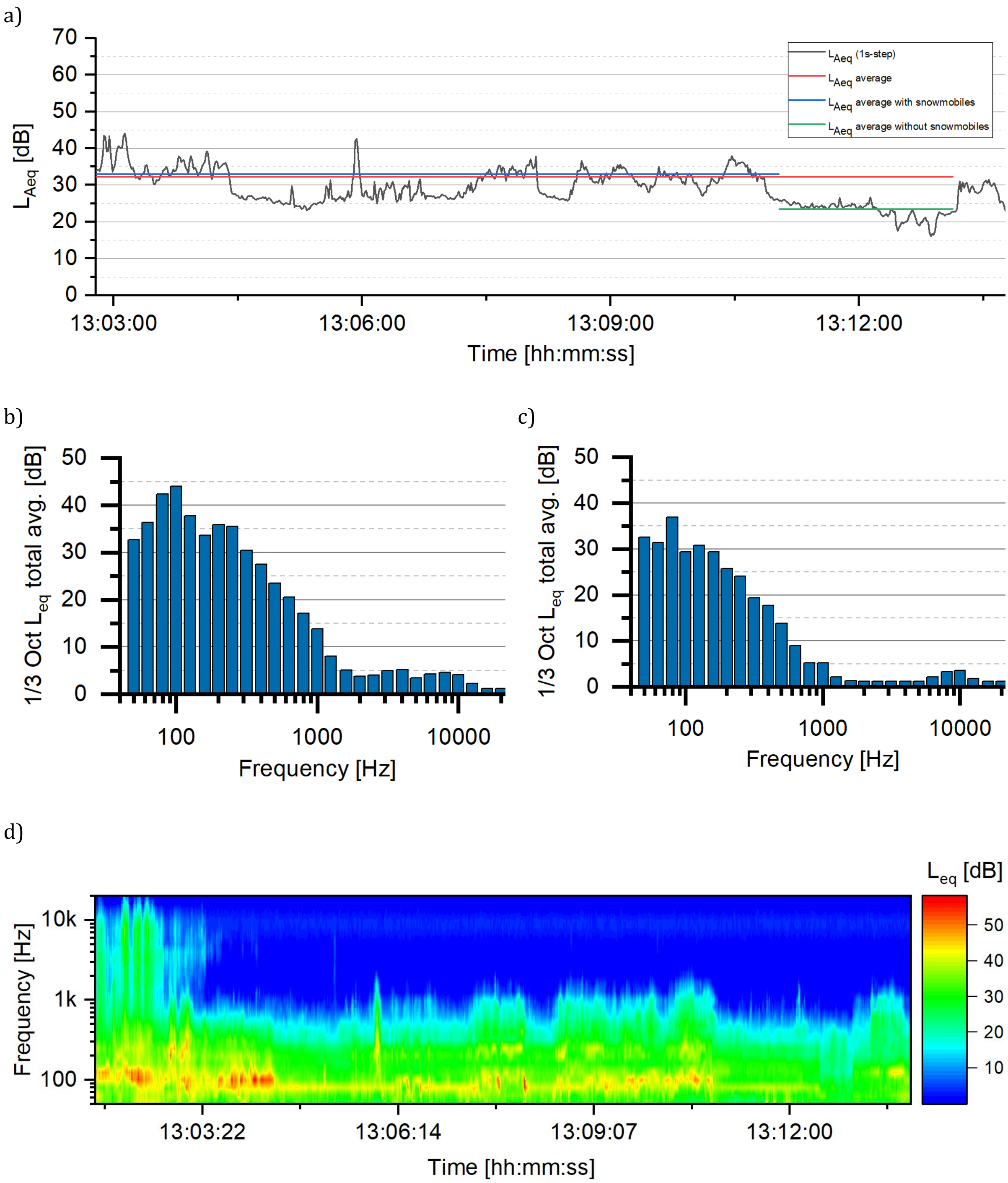

Figure 6. The Sarkofagen's acoustic environment:
a) the 1-second A-weighted equivalent continuous sound level; b) average spectrum of the period with snowmobiles (until around 13:11:00) c) average spectrum of the period without snowmobiles (from around 13:11:00 to 13:13:00); d) spectrogram.

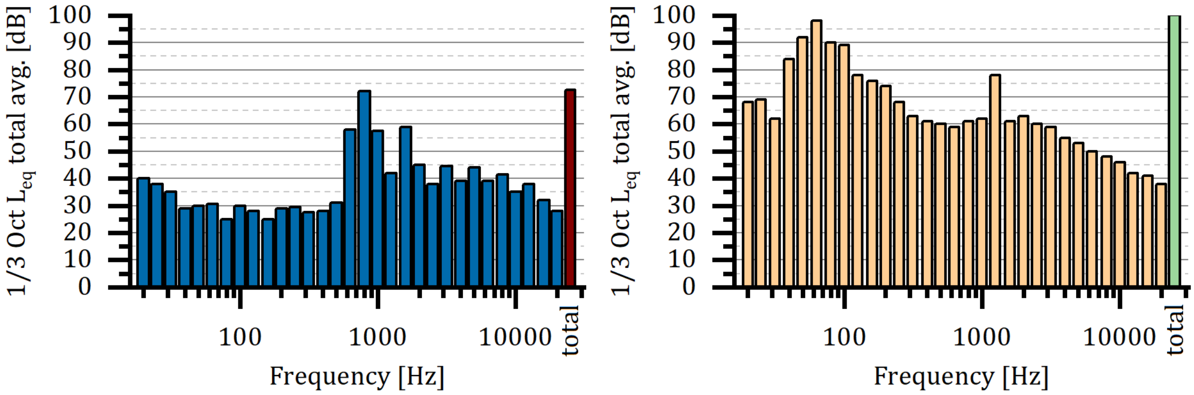

Figure 7. Frequency characteristics: a) howling dog, b) snowmobile.

An analysis of the amplitude-frequency characteristics shows that the total sound pressure level of a single dog's howl is approximately 72 dB and is a tonal noise (see Fig. 7a.). The fundamental frequency of such barking is approximately 800 Hz. Snowmobile emitted the total sound pressure level as high as 100.1 dB from a distance of 10 m (see Fig. 7b). This is a broadband noise with a slight dominance of low frequencies.

Figure 8 shows spectrograms of the howling of a single dog and a group of dogs. Figure 8a shows a time extension of the high noise values around 81–82 dB. The 12 dB increase in SPL value of the dog group (see Fig. 8b) is related to the synchronisation of the howling phase by the dog group.

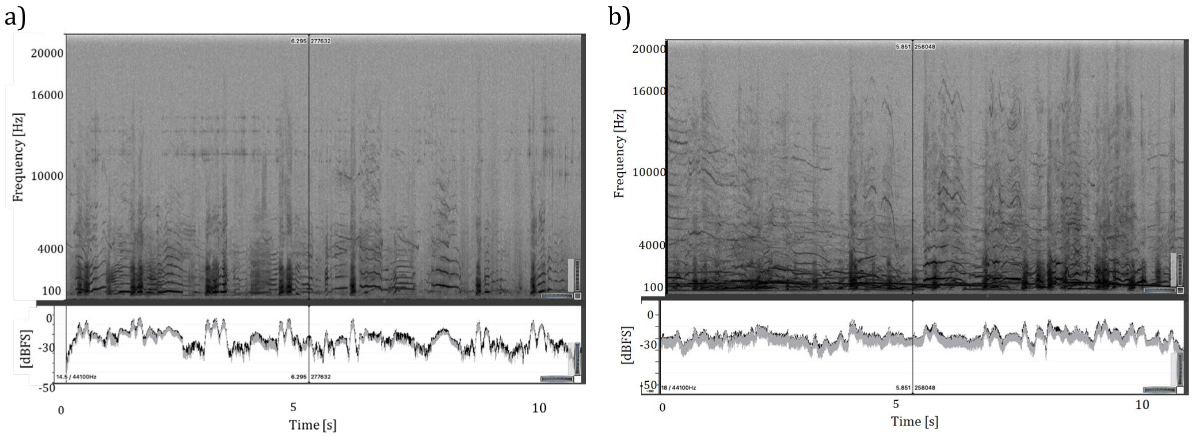

Figure 8. Amplitude-time characteristics and spectrogram of:
a) a single dog, b) a group of dogs.

Analysis of the time course of dog sleds and snowmobile rides confirmed the conclusions of the observations made during the study. To highlight the difference in the impressions perceived by the rider, the average noise levels during the different phases of dog sleds and snowmobile rides are summarised in Table 1. The table shows a comparison of the measured A-weighted equivalent continuous sound levels at different phases of a single snowmobile and a dog sled ride. A snowmobile ride is significantly noisier by about 30 dB than a dog sled ride. A person riding a snowmobile, depending on the speed and direction of travel (uphill or downhill), is exposed to noise levels ranging from 70 dB to 80 dB. A person riding a dog sled can perceive the natural sounds of the surroundings. The sound pressure level in the quiet valleys of Spitsbergen maintains a value of around 40 dB.

Table 1. Measured A-weighted equivalent continuous sound levels at different phases of a single snowmobile and dog sled ride.

	Driving phases L_{Aeq} (dB)				
	Preparation	Start of the ride	Downward run	Upward run	Stop/rest
Snowmobile	35.6	81.4	72.3	80.7	35.6
Dog sled	83.1	41.2	41.1	41.2	35.7

3.4. Ice caves in the Lars Glacier and the Longyear Glacier

The Lars Glacier and the Longyear Glacier are two small glaciers located near Longyearbyen. These glaciers contain beautiful ice caves. The Longyear Glacier (78°11′ N, 15°30′ E) is a 4.8 km long, northeast-oriented valley glacier located in central Spitsbergen, Svalbard. It has an altitude range of 210–850 m a.s.l. and the equilibrium-line altitude (ELA) is at ~615 m a.s.l. Its average thickness is 53 m, and the velocity at the ELA is ~2–4 m a^{-1} [29]. The Lars Glacier is a small glacier about 3.5 km long, extending from Trollsteinen (850 m) and Lars Hiertafjellet (876 m) in the south and flowing northwest to the Longyear Valley. The glacier moraine contains many blocks containing fossils of deciduous trees from the Cretaceous period. The name of the glacier comes from the Swedish publisher and politician Lars Johan Hierta (1801–1872) [30].

The explored caves had the form of long narrow corridors with many ice shelves, sometimes with a few larger empty volumes – chambers. Two acoustic states of the caves were recorded during the visit: silence - without the presence of people - and brief acoustic events in the form of footsteps and shouts (see Fig. 9). In the first situation, the A-weighted equivalent continuous was equal to 13.2 dB and was related to the self-noise of the measuring instrument.

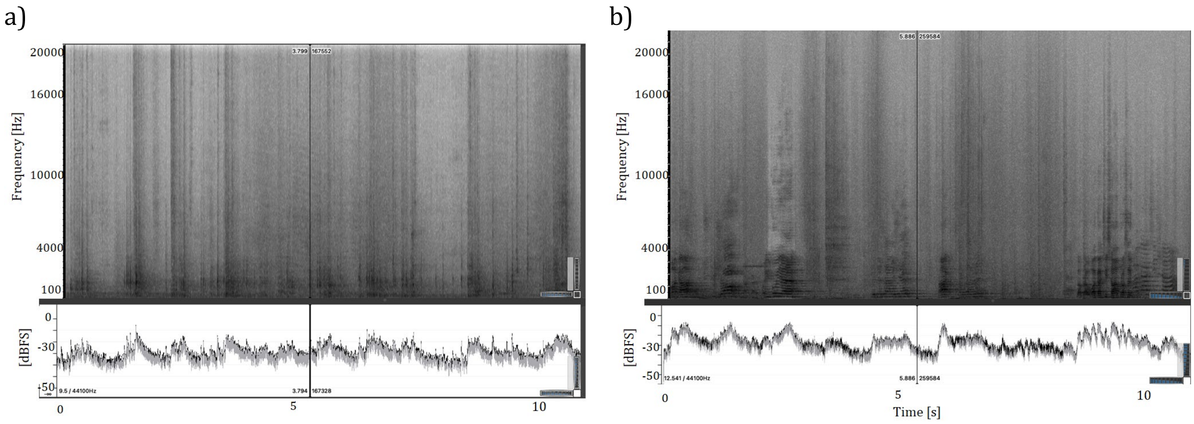

Figure 9. Amplitude-time characteristics and spectrogram of:
a) steps in the ice cave corridor, b) short shouts in the Longyear Glacier cave.

In subsequent time periods related to the step frequency and shout frequency, there are similar values of SPL amplitudes (see Fig. 9). The reverberation time in the caves is long from 0.4 to 2s due to the highly reflective surfaces in the caves. The differences are mainly due to the different structure of the bounding surfaces made up of ice, snow, and rocks.

4. Conclusions

Based on the survey, the most popular winter tourism activities on Spitsbergen and frequently visited sites were identified. These include snowshoeing, dog sledding, glacier hiking, and visiting ice caves. Acoustic studies have been carried out by the authors of this paper at the sites mentioned. Sites that are acoustically interesting and very difficult to measure include glacier caves.

Long-term SPL measurements in the centre of Longyearbyen were recorded. The recorded data are unique and will provide a baseline for future analysis. The winter hike near Longyearbyen is a great opportunity for contact with Arctic nature and natural silent. Unfortunately, the mountains hiking near the town is not free from the influence of civilisation. Longyearbyen is surrounded by many snowmobile routes. Therefore, on the peaks overlooking the Longyear Valley, the perception of nature is often disturbed by the noise of snowmobiles, which was the subject of environmental studies.

Comparing the two very popular Arctic modes of transport, it can be said that the silence that accompanies a dog-sled ride contrasts with the noise of the dogs being prepared and harnessed to the sleigh. A dog-sled ride allows you to contemplate the landscape and the sounds of nature.

A snowmobile ride is significantly noisier by about 30 dB than a dog sled ride. A person riding a snowmobile, depending on the speed and direction of travel is exposed to noise levels ranging from 70 dB to 80 dB.

The caves form a specific acoustic system. It is an enclosed area bounded by walls of widely varying geometry and structure. One can expect different acoustic field parameters in a narrow, low, twisted corridor, others in a high uplifted part of the cave, and still others in a wide chamber. The characteristics of sound propagation in caves are its multiple reflections from the walls, isolation from the external environment, and mostly low background noise levels. Caves have very different resonant frequencies: the sound in some parts of the caves is amplified and the decay time is a few seconds.

Due to the specific nature of the ice caves and the technical possibilities, it is not possible to carry out acoustic studies using standard measuring equipment. Sound pressure levels were recorded, and recordings were made of acoustic signals of relatively low amplitude and energy at low frequencies.

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Additional information

The authors declare: no competing financial interests and that all material taken from other sources (including their own published works) is clearly cited and that appropriate permits are obtained.

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