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Questionnaires and acoustic measurements in summer season in Longyearbyen area

Dorota MŁYNARCZYK, Paweł MAŁECKI, Janusz PIECHOWICZ, Jerzy WICIAK
AGH University of Krakow, 30-059 Krakow, al. Mickiewicza 30

Corresponding author: Dorota MŁYNARCZYK, email: dorota.mlynarczyk@agh.edu.pl

Abstract Svalbard is a Norwegian province in the Arctic, encompassing the Svalbard archipelago located between 71°–81° N latitude and 10°–35° E longitude. Longyearbyen, the largest town in Svalbard, is the administrative centre with a population of approximately 2,100 residents. The objective of this paper is to present the results of acoustic measurements conducted in summer season at various selected sites in Longyearbyen and the surrounding area. These sites were chosen based on a survey that identified tourism activity preferences during the summer season in Longyearbyen. Based on the responses, three groups of tourist activities were identified: (1) Activities in Longyearbyen, (2) Trips using various modes of transport, and (3) Nature hikes. Acoustic measurements were conducted at locations corresponding to the mentioned categories. Acoustic analyses included the analysis of time courses of A-weighted equivalent continuous sound level, spectra, and spectrograms.

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 [1–3]. The Svalbard archipelago is a unique place in terms of scientific research. It is the world's northernmost science lab and is a place where climate change is occurring faster than in these mid-latitudes around the globe. The Arctic is currently experiencing twice the average temperature increases of about 1.7C than the rest of the globe. On 5 July 2020, the record temperature of 21.7 degrees Celsius was recorded in the Svalbard archipelago, which is also the highest temperature ever recorded in the European part of the Arctic. It is also worth noting that between 2005 and 2022 there was also a significant increase in water temperature in the Arctic Fuglebekken River on Svalbard of up to 6 degrees Celsius [4]. By raising the average temperature, numerous changes to Arctic ecosystems are observed. The duration of the warm period, and thus the growing season, is extended. Induced climate change may affect the abundance and occurrence of bird species and vegetation and thus change the acoustic environment found on Spitsbergen.
A significant part of scientific research, especially year-round research, is carried out in two permanent research centres operating in Svalbard: the Norwegian research station at Ny-Ålesund and the Polish polar station at Hornsund [5]. The most important scientific areas in Svalbard are climate change, glaciology, biodiversity, ocean currents and the Earth's magnetic field. [6]. Acoustic research has also been conducted. Most acoustic research in Arctic areas has been focused on underwater recordings of animal activity [7–10], infrasound measurements of glacier activity [11, 12]. The paper [13] summarizes research on ambient noise data collected during the summers of 2016 and 2017 using an autonomous Ambient Noise Measurement System (ANMS) deployed in Kongsfjorden, Arctic. The analysis of this data identified five distinct sources contributing to the soundscape. These include three geophysical sources—iceberg bubbling, glacier calving, and rain noise—as well as two anthropogenic sources—shipping noise and ice ramming noise.

In the paper [14], fixed-location recorders were used to characterize the soundscape and study the occurrence and phenology of marine mammals at two locations within Svalbard. Kongsfjorden (2017–2018), on the west coast, has already undergone significant environmental change, whereas (2019–2020), on the east coast, remains more typically Arctic. The study's results reveal notable differences in the soundscapes and species assemblages between the west and east. In the west, Arctic species were detected from winter to summer, and migrant marine mammal species were occasionally detected during the autumn. In contrast, in the east, Arctic species were detected almost year-round, with a few migrant species observed during the summer. Additionally, vessels were detected more frequently in the west than in the east.

The monograph [15] examines specific topics concerning the acoustic environment of Spitsbergen, including the analysis of sound levels over time and space, as well as the recording of the soundscape using ambisonic technology.

The acoustics and soundscape analysis of selected valleys is presented in articles [16, 17]. This analysis highlights the variability and distinctive features of the natural Arctic soundscape, while also identifying the local contamination caused by human activity

The paper [18] presents the results of spatial impulse response measurements conducted in four different glacier caves within the Svalbard archipelago near Longyearbyen. These results highlight the diversity of the acoustic environments inside the glacier caves, which are significantly influenced by the caves' morphology and dimensions. This suggests that the acoustic properties of glacier caves vary greatly depending on their specific physical characteristics. The design process of acoustic panels, inspired by the glacier caves in Spitsbergen and lava caves, is detailed in [19]. This work explores how the unique acoustic properties and structures of these natural formations can inform and enhance the development of innovative acoustic panel designs. The paper [20] presents the results of acoustic measurements carried out 'white winter' at selected popular tourist sites near Longyearbyen. The sites were selected based on an analysis of a survey to determine preferences for tourist activities in the Longyearbyen area.

This paper presents survey results related to the identification, perception and evaluation of sounds occurring in the centre of Longyearbyen and Nybyen. Also, in the paper are presented results of acoustic measurements of selected sites in Longyearbyen and further away from Longyearbyen. The sites for the acoustic study were also selected based on an analysis of results from a survey for the identification of tourism activity preferences in summer in the Longyerabyen, Spitsbergen.

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 [21–23]. 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.

The researchers aimed to conduct acoustic analyses of the soundscapes in popular tourist locations in Longyearbyen, the administrative capital region of Svalbard. They sought to identify preferences in tourism activities through a survey. This approach likely allowed them to gather valuable insights into how tourists perceive and interact with the acoustic environment during their visits to these locations.

The acoustics and soundscape analyses adjusted to the specificity of selected based on the survey sites are presented in the 4 chapter. Sound pressure level (SPL) measurements were conducted at the listed sites using the SVAN 971 Class 1 sound level meter. Measurements were taken in the broadband range, incorporating A, C and Z-weighted filters. The meter also determined octave and 1/3-octave spectra within the audio-acoustic bandwidth. For long-term monitoring of sound level changes in Longyearbyen, a SVAN SV 277 PRO monitoring station equipped with a Class 1 sound level meter SV977 was utilized. This measurement system was housed in an all-weather enclosure that included the sound level meter, power battery, 3G modem, and a control system.

Survey in the form of paper questionnaires was conducted in summer 2019 by participants of the AGH University research expedition. Similarly to the studies conducted during the white winter [20], the survey was carried out among randomly selected individuals, including tourists and temporary residents. The survey was conducted at the same locations as before: the museum entrance, the main hall of the university, and the entrance to the largest supermarket.

The questionnaire included, inter alia, the following 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. I can hear well the following types of sounds during my visit of the area like: traffic sources (general, cars, buses, trains, air planes, other), other mechanical sounds (general, construction noise, enterprises, machines, sirens other), human sounds (general, talking, laughing, children playing, footsteps, other), natural sounds (general, wind and leafs, water, birds, other). Responses were given on a 5-point scale: 1 – not at all, 2 – a little, 3- moderate, 4 – very, 5 extremely

4. I perceive the sounds from "the same sources as above" pleasant/unpleasant during my visit of the area. Responses were given on a 5-point scale: 1 – very unpleasant, 2 – unpleasant, 3 – neither unpleasant nor pleasant, 4 – pleasant, 5 very pleasant
5. List places you have visited during your stay in Svalbard, starting from the one which you like the best.

The survey was conducted among 29 people, mainly tourists. The distribution of answers to the individual questions are shown in Figures 1–3.

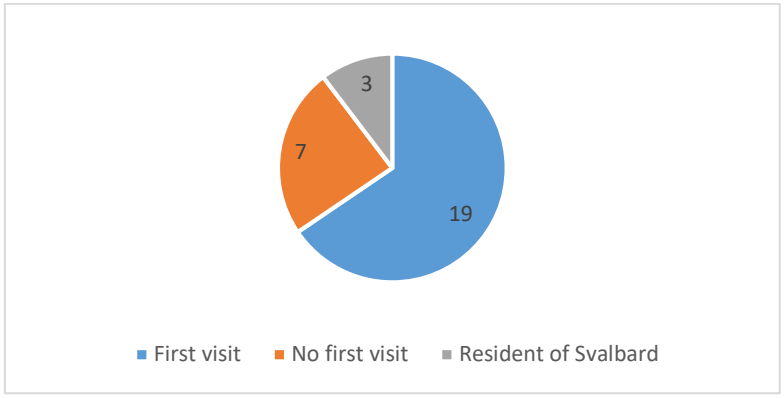

Figure 1. The distribution of answers (numbers of respondents) for question 1: Is it your first visit to Svalbard?

Based on the analysis of the answers to the first question (see Fig. 1), it can be concluded that 8% of the respondents were residents, 72% were visiting Svalbard for the first time, and 19% had visited several times (ranging from 2 to 3 times). A similar distribution of responses was obtained in studies conducted during the white winter [20].

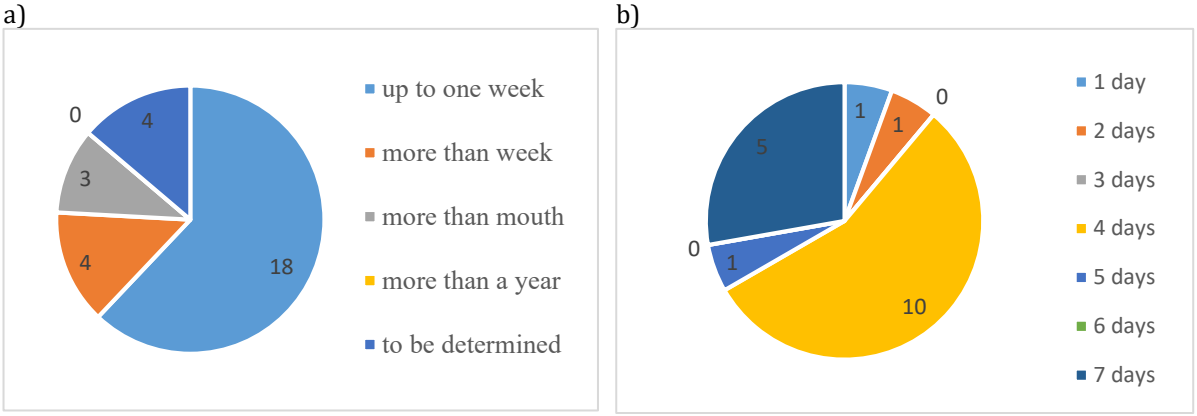

Figure 2. The distribution of answers (numbers of respondents) for question 2: How long are you going to a) stay in this area b) all answers;

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 the modal value of 4 days. However, there were also people who spent between one week and one month on the island.

3. Soundscape evaluation survey

Figures 3 to 10 below show an analysis of the question about the sounds that tourists identified in the places they visited in Longyearbyen: city centre – CITY (point IIIa) and periphery – NYBYEN (point IIIb). Respondents were asked what the intensity of the different groups of sounds in the place was, and how they rated their perception of them. The sounds that were asked about were:

- the traffic sources (general, cars, buses, trains, airplanes, other)
- other mechanical sounds (general, construction noise, enterprises, machines, sirens other),
- human sounds (general, talking, laughing, children playing, footsteps, other),
- natural sounds (general, wind and leafs, water, birds, other).

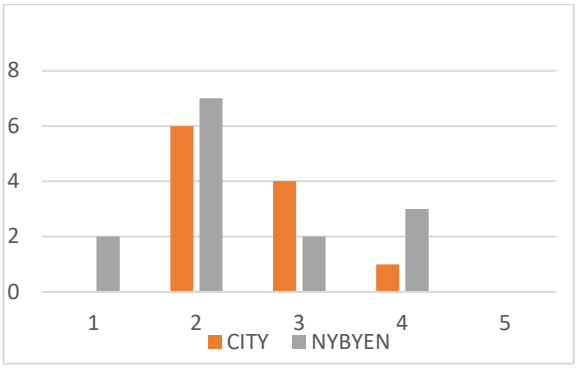

Figure 3. The distribution of answers (numbers of respondents) for question 4: I can hear well the traffic sources (general, cars, buses, trains, airplanes, other)

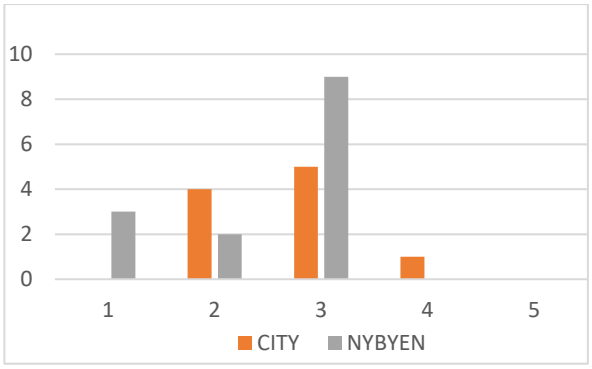

Figure 4. The distribution of answers (numbers of respondents) for question 5: I perceive the sounds from traffic sources (general, cars, buses, trains, airplanes, other) as pleasant/unpleasant during my visit of the area.

Analysing Figure 3, it could be stated that most respondents provided responses of 2 and 3. Additionally, four people noted "Traffic source" in Nybyen. This observation could be attributed to the notable contrast between the occurrence of silence in Nybyen and the increase in the sound pressure level when the traffic source appeared. Three people found this type of sound very unpleasant. It's noteworthy that many hikers are drawn to Nybyen to commence their onward journey.

In Figure 4, the majority of respondents perceive traffic sounds as moderate. This suggests that these sounds are familiar to them, likely occurring where they live.

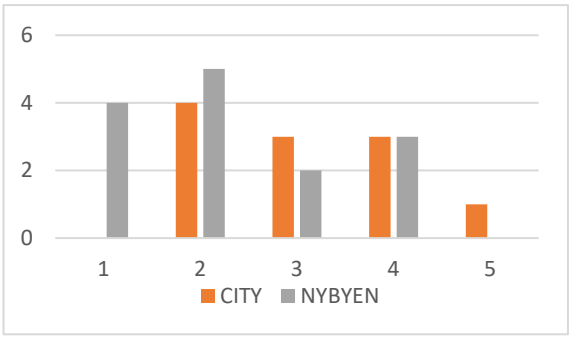

Figure 5. The distribution of answers (numbers of respondents) for question 4: I can hear well the other mechanical sounds (general, construction noise, enterprises, machines, sirens other).

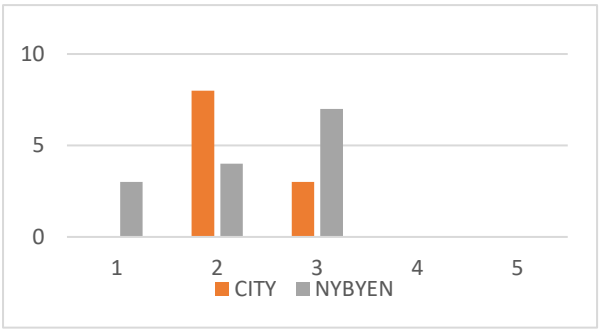

Figure 6. The distribution of answers (numbers of respondents) for question 5: I perceive the sounds from other mechanical sources as pleasant/ unpleasant during my visit of the area.

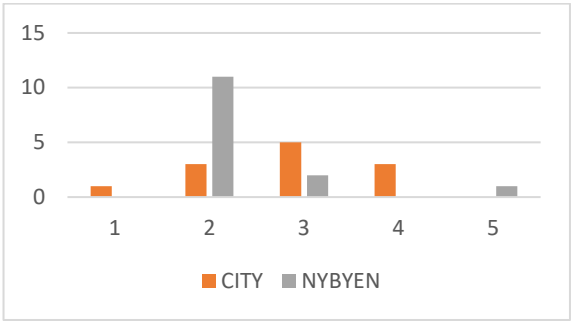

Figure 7. The distribution of answers (numbers of respondents) for question 4: I can hear well the human sounds (general, talking, laughing, children playing, footsteps, other).

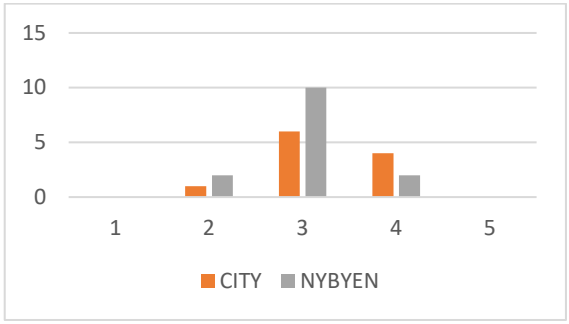

Figure 8. The distribution of answers (numbers of respondents) for question 5: I perceive the human sounds as pleasant/unpleasant during my visit of the area.

Analysing Figure 5, it can be concluded that respondents did not note or note a little other mechanical sound source in Nybyen. These sources were particularly audible in city centre. For most people, these sounds were unpleasant or covered independently of the place of assessment. As strongly unpleasant and unpleasant they were in Nybyen (Fig. 6).

Human sounds were more frequently perceived in Nybyen (Fig. 7), which is due to the low levels of the acoustic background in that area. For most of the people surveyed, these sounds like talking, laughing, children playing, footsteps and other were neutral. A few people found them unpleasant, while a similar number found them pleasant (Fig. 8).

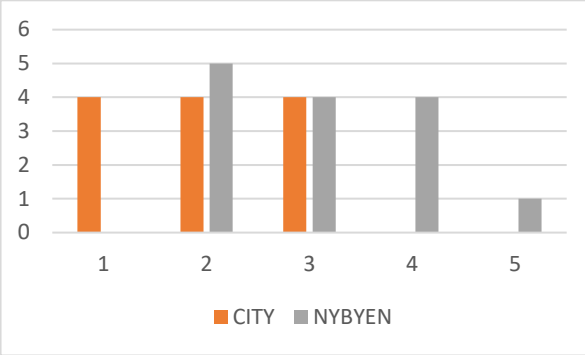

Figure 9. The distribution of answers (numbers of respondents) for question 4: I can hear well the natural sounds (general, wind and leafs, water, birds, other).

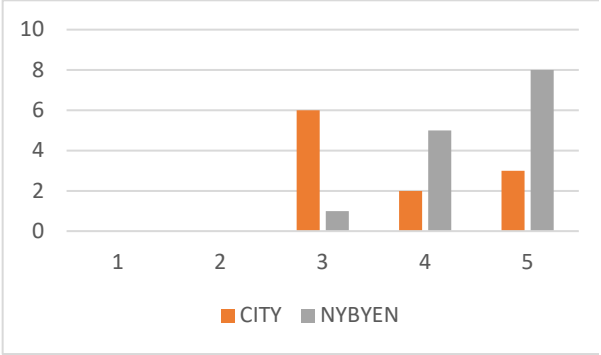

Figure 10. The distribution of answers (numbers of respondents) for question 5: I perceive the natural sounds as pleasant/unpleasant during my visit of the area.

Analysis of Figure 9 reveals major differences between the two analysed sites. The sounds of nature were less audible in the city centre compared to Nybyen. For most people surveyed, the sounds of nature were pleasant or very pleasant. This trend is particularly noticeable for Nybyen. In contrast, in the city centre, respondents generally found the sounds of nature to be indifferent (Fig. 10).

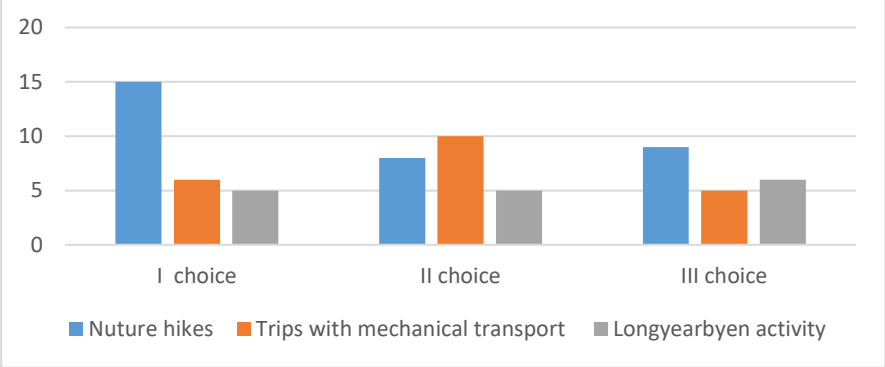

Figure 11. The distribution of answers [numbers of respondents] for question 3: List places you have visited during your stay in Svalbard, starting from the one which you like the best.

A detailed analysis of the answers to fifth 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:

- nature hikes: trips to the summits of the Sarkofagen, Trollsteinen, Platafjellet, Elveneset peaks, hiking on the Longyear Glacier, fossil hunting, trips to the valleys,
- trips using mechanical transport: boat or cars: Barentsburg, Pyramiden, Borebukta, Isfjord radio, Barentz camp, walrus safari, Ny-Alesund,
- Longyearbyen activities: a round trip to town, pubs and restaurants.

The respondents' answers were assigned weights as follows: First choice – 3, Second choice – 2, and Third choice – 1. Based on these weights, the locations that received the highest overall scores were calculated: nature hikes – 70, trips using mechanical transport – 43, and Longyearbyen activities – 31. The

subsequent section presents the results of acoustic studies conducted in sample destinations, which can be categorized into the respective groups.

The survey conducted in winter revealed different results [20]. The winter activities indicated by the respondents included nature hikes as a I choice, Longyearbyen activities as a II choice and snowmobile trips as a III choice. It is worth noting that activities in Longyearbyen are more popular in winter than in summer. Additionally, hiking excursions around the town remain highly popular in both seasons.

4. 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. 12 and 13):

- hike to glacier Lars (measurement point I),
- boat trip to Pyramiden (measurement point II)
- Longyearbyen activities: city centre (measurement point IIIa) and Nybyen area (measurement point IIIb).

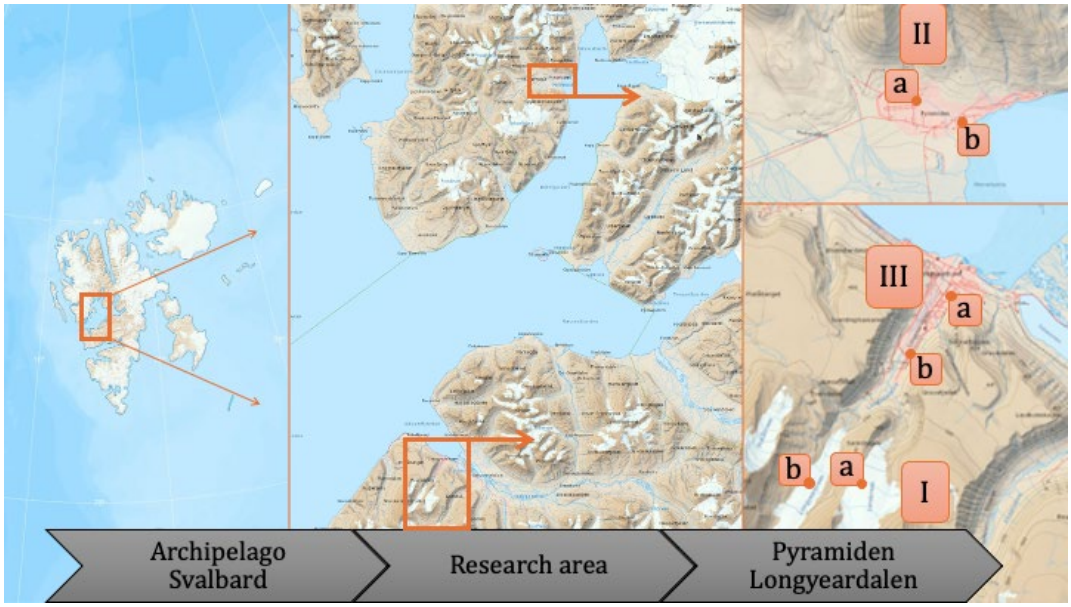

Figure 12. Localization of the acoustic measurement's points:
I – Nature hike to the Lars and Longyear Glacier, II – Pyramiden Hotel and Monument,
III – Longyearbyen activities: city centre and Nybyen (map prepared based on [23]).

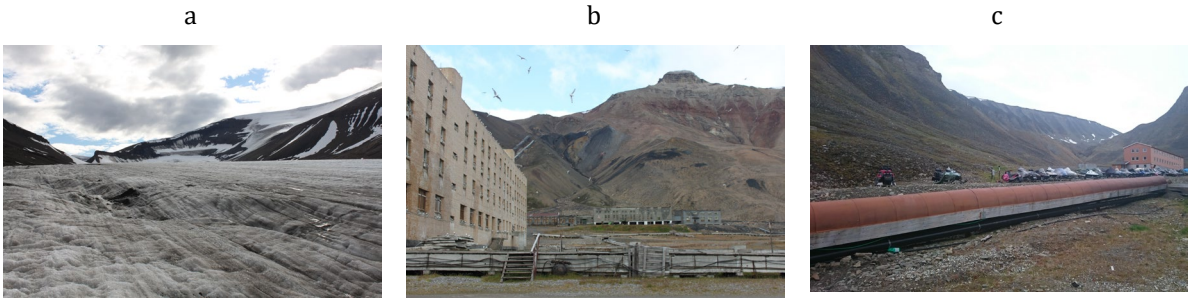

Figure 13. Photograph of landscape of the acoustic measurement's points:
a – Longyear Glacier, b – Pyramiden Hotel, c – Nybyen.

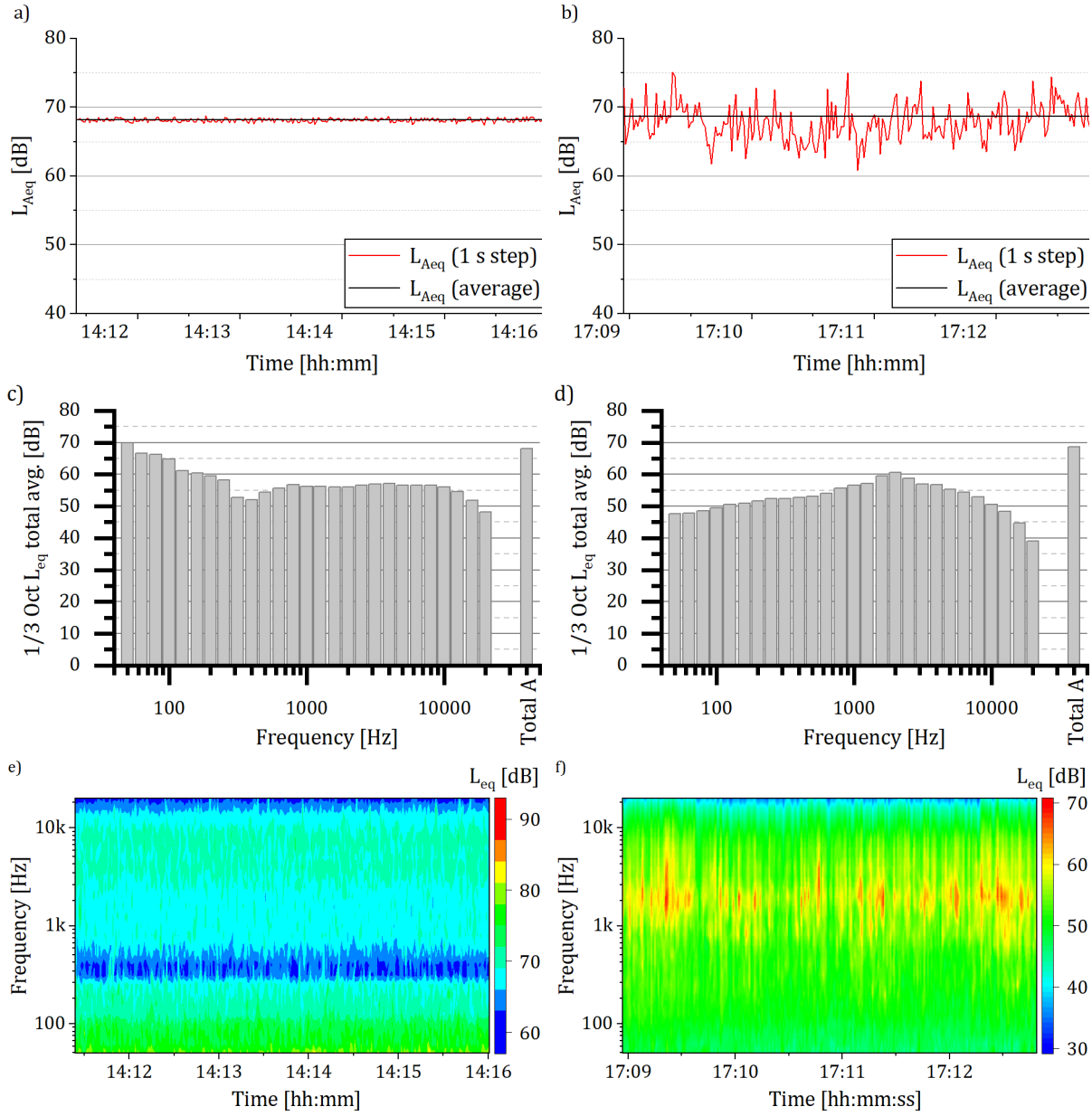

Figure 14. The Lars (a, c, e) and Longyear (b, d, f) Glacier acoustic environment: a) and b) the 1-second A-weighted equivalent continuous sound level; c) and d) average spectrum; e) and f) spectrogram.

4.1. Nature hike to the Lars and the Longyear Glacier

Almost 60% of Svalbard is covered by majestic blue glaciers. Several glaciers near Longyearbyen are worth exploring. Very popular are Larsbreen and Longyearbreen, which are also on the way to Sarkofagen. One of the highlights of the trek through the glacial moraine area is meeting many meltwater channels. Hiking in the glaciers, there is also the opportunity to explores the spectacular backyard of Longyearbyen and offers a stunning view over the city and surrounding mountains.

During the summer geophony dominates both in Longyearbreen [17] and Larsbreen. Four sources of sound were identified: glaciers streams, wind and occasional sounds of tourists including conversations and the creaking of footsteps and crampons on snow and ice. Crampon footsteps in particular can be disruptive and strongly affect the perception of glacier soundscape therefore Figure 14 presents the course and characteristics of these sounds.

The results of the SPL measurements taken at the glaciers using the SVAN 971 Class 1 sound level meter are shown in Figure 14. The figures show the time course, amplitude-frequency characteristics, and the amplitude-frequency-time characteristics of the melting ice noise and the squeaking of footsteps on the ice

4.2. The boat trip to Pyramiden

Pyramiden is an abandoned Russian mining town located in Mimerbukta Bay, which extends from Billefjorden. The town is named after the pyramid-shaped mountain that rises above the settlement, reminiscent of the pyramids of Egypt. Pyramiden was the only self-sufficient town on Svalbard. It had a school, sports hall, cultural centre, cinema, café, swimming pool, library. Pyramiden had functioning vegetable greenhouses and even raised livestock, contributing to the town's self-sufficiency by providing fresh produce and meat. Today, Pyramiden is a popular destination for day trips, attracting tourists with its unique history and the well-preserved remnants of its past. The results of the acoustic measurements are shown in Figure 15, (IIa and IIb points in fig. 12).

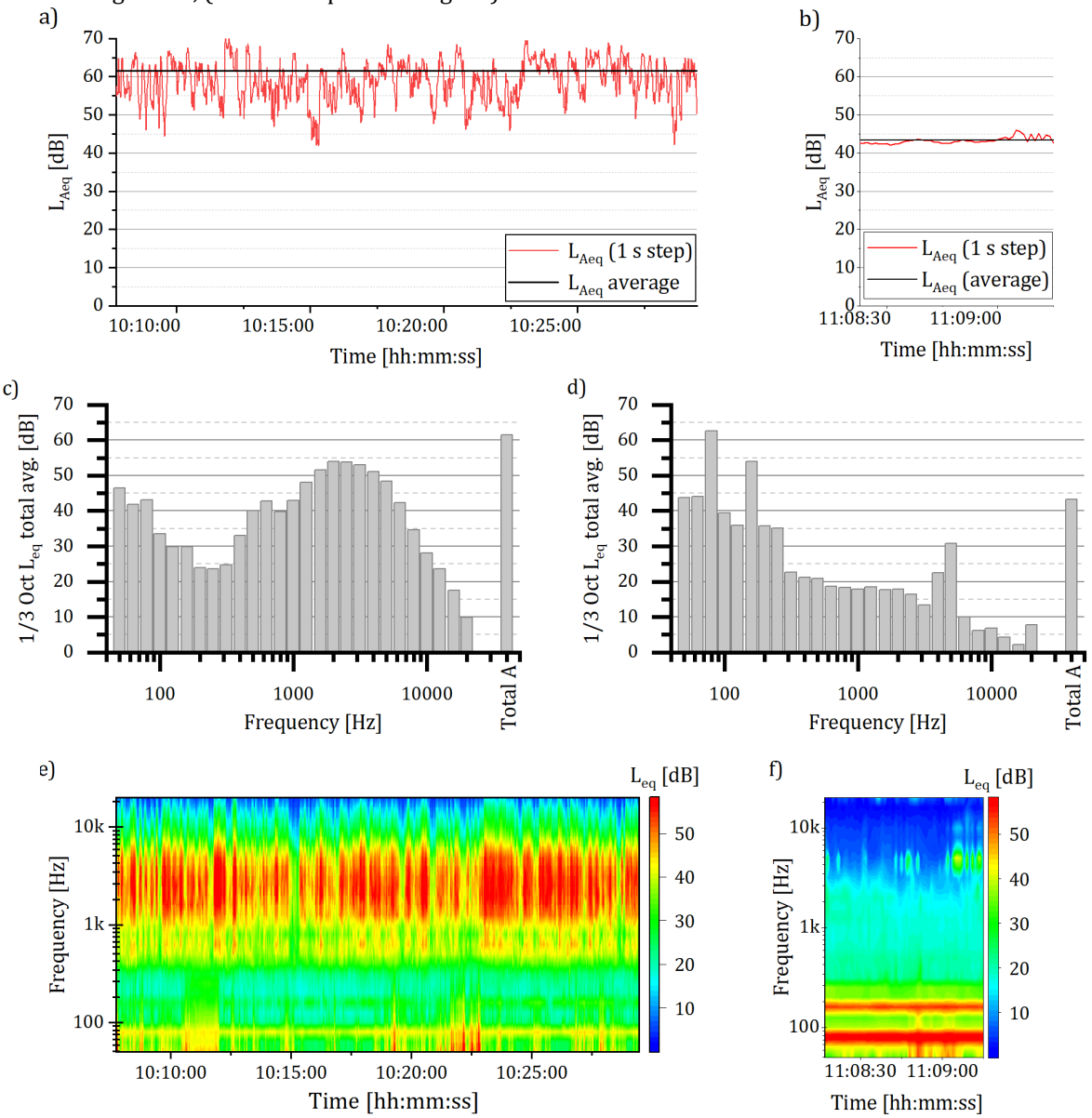

Figure 15. Pyramiden acoustic environment near hotel and main square (point IIa) and entrance monument (point IIb): a) and b) a 1-second A-weighted equivalent continuous sound level; c) and d) an average spectrum; e) and f) a spectrogram.

The soundscape of Pyramiden is mainly determined by the operating generator and bird activity. The generator, necessary to provide power to the remaining operational buildings and to support the occasional presence of tourists and researchers, creates a constant hum that defines the auditory environment. In summary, anthropogenic and biogenic sounds dominate in Pyramiden in summer, but geogenic sounds are also present. A total of ten sounds were identified. Eight man-made sound sources: electricity generator station, hotel equipment including fans, settlement staff cars and bus, noise from hotel guests, yachts and

boats in the harbour, occasional helicopter with supplies. One, but very intense especially in the centre, biogenic sound – seagull shrieks, and one geogenic sound – wind [15].

In the case of generator noise (Fig 15b, d and f), there are two main frequencies, 80 Hz and 160 Hz, at which sounds are radiated. The A-weighted equivalent sound pressure level was 43.3 dB. Complementing this mechanical background are the sounds of various bird species that have taken over the area, adding a natural layer to the town's soundscape. These bird sounds become more dominant as we move further away from the generators (point IIb – see Fig. 15 a, c and e). A major part of the acoustic energy is accumulated in the frequency band from 1.6 kHz to 4 kHz. The range of sound pressure variation was from 41.9 dB to 70.4 dB, with the average sound pressure level of 61.5 dB. With decreasing impact of industrial noise and the presence of nature reclaiming the area, the acoustic environment is dominated by the sounds of visitors exploring the town and the local birdlife. The tranquil, yet amazing atmosphere adds to the unique experience of visiting this distant and inaccessible location.

4.3. The Longyearbyen activities: city centre and Nybyen

Longyearbyen is a remarkable town that balances its rich mining heritage with modern advancements in tourism, research, and community life. At the beginning of 2019, the population of Longyearbyen was two thousand two hundred and fifteen, representing 84 per cent of Svalbard's total population. In the first half of 2021, this number has risen to two thousand four hundred and thirty inhabitants, which now represents 86 per cent of the population living on the island of Spitsbergen. The town of Longyearbyen consists of more than a dozen streets, most of which are numbered. The only street that has been given its own name is Hilmar Rekstens Vei. Within the city, the car is the main means of transport. Although the length of the roads is less than fifty kilometres and there is no connection to other settlements or towns, there are approximately one thousand five hundred registered vehicles in Longyearbyen [24]. In the centre of Longyerbyen there are, among others, a community centre with a cinema, a tourist centre, shops, galleries, hotels, restaurants, pubs.

In Longyearbyen, the soundscape contains all three main elements: geogenic, biogenic and anthropogenic sound sources with anthropogenic sounds dominating [15]. Anthropogenic sounds include road noise, airport and air traffic noise, port noise, noise generated by energy facilities (thermal power plant, transformer stations, heat exchangers), machinery and equipment on buildings (fans, pumps), the sound of people's footsteps and conversations, etc. Sounds from geogenic sources are: the sounds of the Longyearelva River flowing from the Longyearbeen and Larsbeen glaciers, located in the valleys above the city), the roar of a waterfall on the Longyearelva River and the sound of the wind. Sources of biogenic origin are mainly the sounds of birds and dogs. At Point IIIa in the city centre, there are eight sound sources: footsteps and people talking, road noise, fan noise from buildings, occasional air traffic noise, wind noise, dogs barking and birds singing. At Point IIIb in the Nybyen there are six sound sources: wind, birds, fan noise from buildings, occasional road noise and footsteps and people talking.

The long-term SPL measurements using a SVAN SV 277 PRO monitoring station were taken at two points: IIIa – in the downtown close to the shopping centre (see Fig. 12) and IIIb – in the Nybyen. Figure 16 shows the equivalent continuous sound level L_{Aeq} for the daytime and night-time.

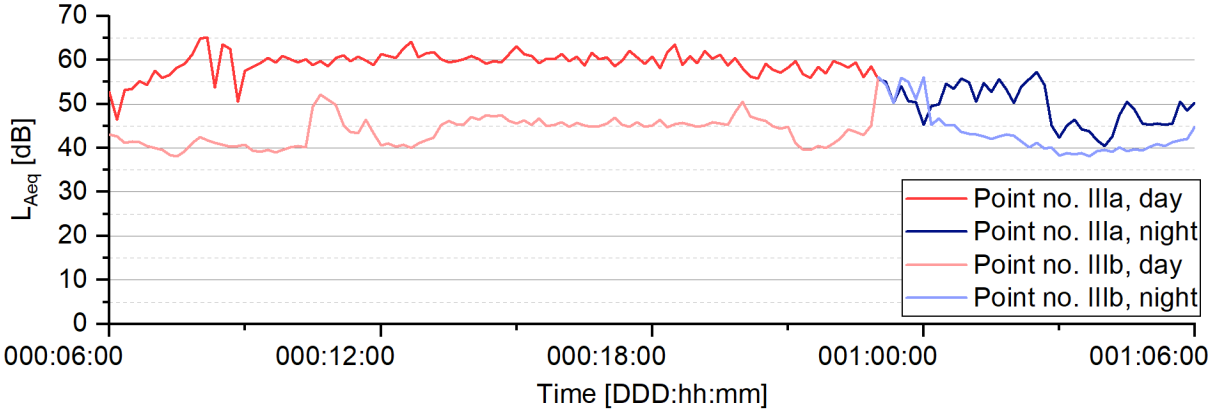

Figure 16. Longyearbyen 24-hour 1-second step A-weighted equivalent continuous sound level: points IIIa in city centre and point IIIb in Nybyen.

For point IIIa, the 1-second step A-weighted equivalent continuous sound level L_{Aeq} for the daytime (6:00-22:00 hours) was L_{A16h} = 60.3 dB and for the night-time (22:00-6:00 hours) was L_{A8h} = 48.2 dB (see

Fig. 16). The A-weighted equivalent continuous sound level difference for the daytime and night-time is not to large, about 12.1 dB, which is due to the high activity of tourists and residents during the late-night hours. It can be seen that there are slightly higher A-weighted equivalent continuous sound levels of about 1.6 dB and 1.5 dB for daytime and nighttime respectively, compared to the studies carried out during the white winter [20]. It is mainly related to tourist activity in the city centre.

For point IIIb, the equivalent continuous sound level L_{Aeq} for the daytime was L_{A16h} = 45.6 dB, and for the night-time it was L_{A8h} = 44.3 dB (see Fig. 16). Comparing the two measurement points, it can be seen that at point IIIa, the A-weighted equivalent continuous sound level is significantly higher during daytime (14.7 dB higher) and slightly higher during nighttime (3.9 dB higher). This increase during daytime is primarily caused by motor vehicle traffic on the nearby Vei 500 road.

5. Conclusions

Based on the survey, the most popular summer tourism activities on Spitsbergen and frequently visited sites were identified. These include: nature hikes (hiking on the glaciers, trips to the mountain summits, fossil hunting), trips using mechanical transport (boat or cars to Barentsburg, Pyramiden, Borebukta, Isfjord radio, Barentz camp, walrus safari) and Longyearbyen activities (city tours, pubs and restaurants). All sites are acoustically interesting and difficult to measure. Table 1 summarises the main results of the acoustic measurements, sondscape analysis and survey. Analysing the summary presented, it can be seen that the choice of popularity of a tourist site was more influenced by the small number of sound sources, especially anthropogenic sounds, and less by the total SPL level.

Table 1. Summary information on the six locations studied: measured SPL levels, number of sound sources present and subjective assessment of these sites. All values are for daytime measurements.

Localization	LAeq [dBA]	Number of sources occurred	Subjective assessment
Measurement point Ia	68.1	4	First choice
Measurement point Ib	68.6	4	First choice
Measurement point IIa	61.5	10	Second choice
Measurement point IIb	43.3	8	Second choice
Measurement point IIIa	60.3	8	Third choice
Measurement point IIIb	45.6	6	Third choice

The summer hikes on glaciers and near Longyearbyen are a great opportunity for contact with Arctic nature and natural sounds. As you walk on the glacier, you can hear the sounds of flowing water and see the hollowed-out channels full of twists and small waterfalls. The A-weighted equivalent sound pressure level close to water channels was 68.1 dB.

In Pyramiden the acoustic environment is dominated by the sounds of visitors exploring the town and the local birdlife, however the continuous hum of the running generator is audible in some areas

Long-term SPL measurements in the centre of Longyearbyen and Nybyen were recorded summer season. The recorded data are unique and will provide a baseline for future analysis. During summer, the midnight sun brings continuous daylight, and the town is livelier with increased human activity and tourism and natural sounds are often masked by the higher levels of urban noise. At night, city centre becomes significantly quieter as human activities decrease. At the Nybyen the overall sound environment is more tranquil, contributing to a peaceful atmosphere.

In conclusion, as highlighted in the current and previous article [20], seasonal variations play a significant role in shaping the soundscape, with distinct differences between the bustling, continuous daylight of summer and the serene, dark winter months. This diverse soundscape enhances the unique experience of living in or visiting Longyearbyen, showcasing both its natural beauty and the resilience of its community.

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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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