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Assessing the Effects of Noise on Sound Identities of Historical Landmarks

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Abstract: The degradation caused by environmental noise affects the sound identities of several areas, especially at a city level, so there is a need for immediate individual and collective action. This paper focuses on the environmental noise impacts towards the soundscapes of historical landmarks located in the city of Thessaloniki (Greece). Furthermore, it offers an insight regarding a new urban quiet area attribute, since it discovers whether elevation contributes to the formation of their sound identity. The first step of this research utilized the opinion of more than 500 residents of Thessaloniki with the aid of a questionnaire, in order to highlight areas of the city's historic center with unique soundscapes. The resulted soundscapes were studied and analyzed by gathering both quantitative and qualitative data. Finally, these soundscapes were assessed by sound experts in order to thoroughly describe their sound identities. The Roman and Byzantine landmarks studied, being at lower and higher elevation levels, respectively, presented differentiations regarding noise levels and other soundscape characteristics. This paper proposes a new protocol, according to which the factor of elevation is worth considering during the process of identifying and utilizing urban quiet areas.

Keywords: environmental noise; urban soundscape; sound identity; elevation; quiet areas

1. Introduction

The concept of sound identity is well known within the scientific community [1–4]. In recent years, the sound dimension of landscape or the soundscape, as referred by Schafer [5,6], concerns several scientists studying acoustic ecology. According to Truax [7], a soundscape is shaped by both the conscious and subliminal perceptions of the listener and soundscape analysis based on the perceptual and cognitive attributes such as foreground, background, contour, rhythm, silence, density, space, and volume. From these terms, more analytical concepts were derived, similar to keynotes, sound events, soundmarks, sound objects, and sound signals. Driven by this claim, Krause [8] and Gage [2] created the terms, i.e., anthropophony, biophony, and geophony, in order to categorize sounds.

Undoubtedly, man-made sounds dominate the biosphere [9]. Furthermore, the sound identity of our planet is continuously changing, due to the increasing rate of human population and the evolving technology [10–12]. Recently, a new discipline called ecoacoustics emerged [13,14].

Ecoacoustics investigates the relationship between natural and anthropogenic sounds with the environment [15] using new technologies regarding audio recording and signal analysis. The quantifiable information about the environment we can draw through sound is numerous and regarding ecosystem management [16–18].

According to Rossi [19], one of the first warning signs of an impending environmental crisis is the slightest change in the soundscape of the area in question, a view also shared by other scientists [20–23]. The environmental problem caused by noise is a wide-ranging issue expanding over multiple scales of time and space. The cause of the problem does not entirely refer to the increased sound volume generated by the violation of the thresholds set [24]. Noise also affects animal communication and the way that organisms produce and receive sound in the environment [25], leading to alterations in soundscape quality and ecosystemic health [26].

Due to the fact that the nature of this problem is multivariate, an interdisciplinary scientific approach is needed, involving ecology, biology, sociology, psychology [27], and even architecture design and urban planning [28]. Therefore, in the last twenty years, many collaborative efforts have been made between governments, organizations, and scientists in order to reduce the noise pollution observed in densely populated urban centers [29]. A sustainable solution to the problem, with multiple benefits for humans and the biosphere in general, is to highlight, maintain or even create quiet areas in the urban context.

In addition to the identification and protection of urban quiet areas, as defined in the European Directive 2002/49 (KSEE, 2002), the QUADMAP program and other similar additions [25] attempt to integrate quiet areas and areas that citizens may consider quiet (e.g., public recreation areas, parks, and historic buildings/structures) [30,31], but exceed noise limits [32]. Especially in cities with a long history, such as Thessaloniki, where old ruins and contemporary buildings coexist, it is necessary to preserve and protect their sound identities [29,33]. Thus, historic urban centers provide an opportunity to increase the number of quiet areas, accessible to all citizens [29,31,34,35].

Greece, which did not complete the action plans provided by the European legislation [28], established special legal frameworks related to urban noise issues. Indicatively, two of them are mentioned:

1. According to article 2 of P.D. 1180/1981, "On the regulation of issues related to the establishment and operation of industries, handicrafts of all kinds, mechanical installations and warehouses and therefore the protection of the environment in general" (*Government Gazette 293/A '6.10.1981*), the maximum permissible noise level in 'Areas where the urban element prevails' is 50 dB (A).
2. According to article 4 of Y.A. 211773/2012 on "Determination of assessment indicators and maximum permissible limits of environmental noise, produced by operation of transport projects, technical specifications of special acoustic studies of calculation and application (EAMYE) of noise-canceling devices (*Government Gazette 1367/B '27.4.2012*)", the maximum permissible limits of road, rail, and air noise indicators are set to 70 dB(A) for the L_{den} (day-evening-night noise indicator) index and those are set to 60 dB(A) for the L_{night} (night-time noise indicator) index.

The problem of having few quiet areas in agglomerations of Greece is a given [31]. Environmental noise levels in cities such as Athens and Thessaloniki exceed the limits provided by Greek and European legislation, and thus, many unique soundscapes of great historical and ecological importance are in danger of degradation and eventually extinction. These areas' sound identities must be preserved at all costs [29]. Nevertheless, studies in this direction have been already completed [25,28], which could be proven beneficial.

As pointed out by Maffei [35], finding or establishing quiet areas in urban complexes of Mediterranean countries such as Greece, where historical monuments and archeological sites occupy a large part of the city, is a real challenge. Recently, it has been shown that in several cases, sites such as historic courtyards, churches, and open-air archeological sites (e.g., ancient theaters) may be considered as quiet areas [29,35,36]. This approach preserves the city's cultural heritage and identity, with the co-benefit of reducing the adverse effects of environmental noise [37].

The main purpose of this research is to highlight and assess the sound identities of the Roman and Byzantine landmarks in the historic center of Thessaloniki. Furthermore, the environments under consideration were studied in relation to their elevation differences, and more specifically higher or lower than the street level. Finally, this research offers a new quiet area attribute to be added in the existing list, provided by previous research.

2. Materials and Methods

The development of this research derived tools used in the interdisciplinary field of acoustic ecology. More specifically, the methods used the definition and management of urban quiet areas obtained from the guidelines provided by the QUADMAP program [32], the descriptive model of the World Soundscape Project (WSP), and the phenomenological approach proposed by the CRESSON Institute and finally from previous research in small urban settings [31], utilizing knowledge provided by the field of ecoacoustics [13,14]. The four steps of the methodology followed, is presented as a flowchart in Figure 1.

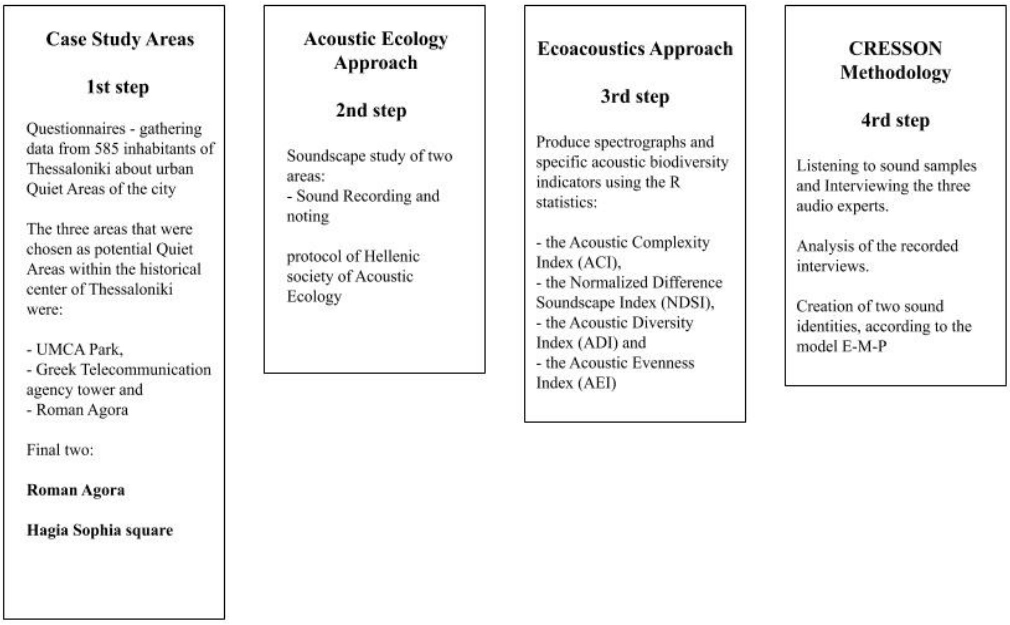

Figure 1. Proposed methodology of the study explained in a flowchart.

2.1. Case Study Areas

The study area was the historic center of Thessaloniki, the second most populated city of Greece and the largest in the northern part of the country. According to the latest census of 2011, the urban complex of Thessaloniki has a permanent population of 788,952 inhabitants, while the population of the metropolitan area amounts to about one million inhabitants. The historical center of Thessaloniki was defined as the area that extended from the port (old section) to the old beach (a pier to Lefko Pyrgos), to Pavlou Mela Street, where Byzantine Church in Hagia Sophia is located (Government Gazette 833/B/1994). The advantages of this choice consisted of being an accessible area that includes landmarks of different elevation. Currently, multiple efforts of environmental remediation take place by local authorities.

In order to highlight the study areas and reduce the location selection bias, the contribution of three local sound experts active in Thessaloniki was required. The three experts were an architect, a musician, and an environmental scientist. After discussing the study subject, it was decided to select four representative landmarks for each category having different elevation (at the street level and higher and lower level than the street level).

- Areas at the street level: Aristotle University of Thessaloniki Campus, UMCA park, Aristotelous Square, and Dikastirion Square
- Areas higher than the street level: White Tower Terrace, Roof Garden Electra Palace, Pedagogical School of Aristotle University of Thessaloniki (tower), and Greek Telecommunication agency tower
- Areas below the street level: Byzantine Church of Panagia ton Halkeon, Byzantine Church Panagia Achiropoietou, Navarinou Square (Roman ruins of Galerius Palace), and Roman Market

Using citizen science techniques, 585 inhabitants of the city participated in this research. Thus, it was necessary to create a similar questionnaire, which in addition led to the gathering of information regarding the way citizens perceive urban quiet areas.

The three areas that were chosen as potential quiet areas within the historical center of Thessaloniki were the UMCA Park, the Greek Telecommunication agency tower, and the Roman Agora.

Many of the respondents answered the questionnaire referring to quiet areas placed outside the boundaries set for this survey, including urban groves and other less urbanized areas. Nevertheless, these areas were not assessed, as they fell out of the scopes of this paper. Due to the COVID-19 crisis, Greek Telecommunication agency tower was out of order, and so as to keep the proposed protocol, it was decided, with the consent of the aforementioned experts, to record sound on a roof with the same height close to the Greek Telecommunication agency tower. Thus, the roof of an eight-floor building, Byzantine Church, in Hagia Sophia Square was chosen. The UMCA Park sound levels are not presented in this paper due to the fact that the historical landmarks of the city are the main scope of this paper.

2.2. Field Sampling Protocol

Along with sound recordings, noise levels were collected using the A-weighting equivalent Continuous Sound Pressure Level (L_{eq}) indicator, during the day period using a rapid assessment technique. Prior to the noise measurements, a sound level meter PRO-DX of Castle Group was calibrated using the standard 94 dB calibrator, as is required for all the class 1 measurement instruments according to the EN 61326-1:1997 + A1:1998 specifications. Furthermore, a Tascam DR-2d Portable digital high-resolution recorder was used in order to obtain soundscape recordings. Each measurement station was located in the open field far from high walls or urban structures. The notion was to minimize phenomena like sound reflection, refraction, and diffraction.

2.3. The Acoustic Ecology Approach

The protocol used for the field recordings was based on the framework developed by the Hellenic Society for Acoustic Ecology [38]. The recording crew consisted of two people: a person in charge of noting the area's sounds in the special registration form (subjective observation recording) and a person in charge of the digital sound recordings and noise level measurements (objective observation recording). In addition to the recording crew, a coordinator was present. The coordinator was standing within the crew's field of vision, but not less than 10 m away from the sound recording station. She raised her hand (so as not to affect the procedure in any way) at the beginning and end of each recording, using 15-s intervals. The rest of the group completed the form by scoring on a 3-level scale of the perceptual approach regarding intensity for each individual sound heard, anthropogenic, biological, or geological (with 1 indicating sounds of low intensity and 3 indicating sounds of high intensity).

The whole process lasted 10 min for each study area. All the collected data were organized and then processed. Uncompressed audio formats (wav files) were used as the perfect representation of the recorded audio, and Audacity software was employed to import these files and test whether any failures occurred during the sampling.

2.4. The Ecoacoustics Approach

Two 10-min long audio files were collected from each study area. The audio files were processed using Audacity software, in order to extract four-minute long audio segments that included the most useful information.

These files were imported into the R 'Stats' software, in order to produce spectrographs and specific acoustic biodiversity indicators for the soundscapes under study. Specifically, the collected sound files were processed in order to determine the acoustic complexity index (ACI), the normalized difference soundscape index (NDSI), the acoustic diversity index (ADI), and the acoustic evenness index (AEI) using the R statistics v. 3.1.3 software [39] and the associate packages Seewave, TuneR, Ineq, and Soundecology [40–42].

2.5. Interviews with the CRESSON Methodology

In the third stage of this study, the method proposed by the CRESSON Institute was used, involving the interviews of three audio experts so as to analyze and evaluate the sound identities of the selected study areas [43]. After listening to the selected sound recordings, the interviewees commented by answering a semi-structured questionnaire. The next step was the analysis of the recorded interviews by the writers of the article. More specifically, the interviewees commented that the various data obtained at the time and place of each soundscape recording and the detailed descriptions regarding each audio sample were taken under consideration.

Finally, after the analysis of the audio experts' answers describing the atmosphere of the quiet areas, their sound identities were formed, according to the model E-M-P proposed by Amphoux [43] combining both the qualitative and quantitative characteristics of the sound environment.

3. Results

3.1. Sound Identity of the Roman Agora

3.1.1. Site

The Ancient Roman Agora is considered to be one of the largest landmarks in Thessaloniki's historical center; it emerged as the most representative site according to the expert's judgment. As presented in Figure 2, it is located between Egnatia and Agiou Dimitriou Streets, north of Aristotelous Square, an unexpected open space in the heart of the city without loud noises.

Figure 2. The Ancient Roman Agora presented in the map. The pictures of the area were taken by the authors at the same time as the sampling protocol was followed.

3.1.2. Quantitative Data Assessment of a Sound Recording

According to the protocol created, a sound recording was conducted at 12:08 p.m. on 12 March, 2020. The temperature at the time was 17 °C. The recording lasted 10 min, but a 4-min and 12-s extract was selected in order to conduct the interviews and analyze the data (Table 1). The value of the NDSI in this audio sample complied with the respective form, in which anthropophonic sounds prevailed. This is obvious, as the NDSI had a negative sign (Table 2). The Roman Agora could be characterized as a quiet area based on the average sound levels measured in decibels (dBs) (Figure 3). The noise levels in this part of the city were lower than other urban areas, with the lowest noise levels reaching 43 dBs and the highest reaching 49 dBs. The spectrogram analysis (Figure 4) revealed that low-frequency sounds were heard during the audio recordings.

Table 1. The Roman Agora soundscape characteristics as highlighted by the researchers.

	Roman Agora																
Time	Minute	1′				2′				3′				4′			
	Second	15″	30″	45″	60″	15″	30″	45″	60″	15″	30″	45″	60″	15″	30″	45″	60″
Background	Cars	1	2	1	1	2	1	2	1	1	1	1	2	2	2	1	1
	Birds	2	2	2	2	2	2	2	1	1	2	1	2	3	1	2	3
Foreground	Voices		1		2		1	1	2		1	2		1	1		
	Car horns		3														
	Music			3													
	Dog barking									3							
	dB(A)	43	44	63	43	42	43	43	44	45	43	44	45	42	47	42	43

Table 2. The indicators resulted from the Roman Agora sound recording. The negative sign in the NDSI highlighted the fact that anthropophonic sounds prevailed.

Roman Agora				
Qualitative data				
Background sounds	Biophony	22	volume	52
	Anthropophony	30		
Foreground sounds	Biophony	18	volume	21
	Anthropophony	3		
Quantitative data				
dB(A)	minimum	42	average	44.8
	maximum	63		
Acoustic complexity	Left channel	7609.19	average	7593.12
	Right channel	7577.05		
NDSI	Left channel	−0.49	average	−0.47
	Right channel	−0.46		
Acoustic diversity	Left channel	0.04	average	0.05
	Right channel	0.05		
Acoustic evenness	Left channel	0.74	average	0.89
	Right channel	0.72		

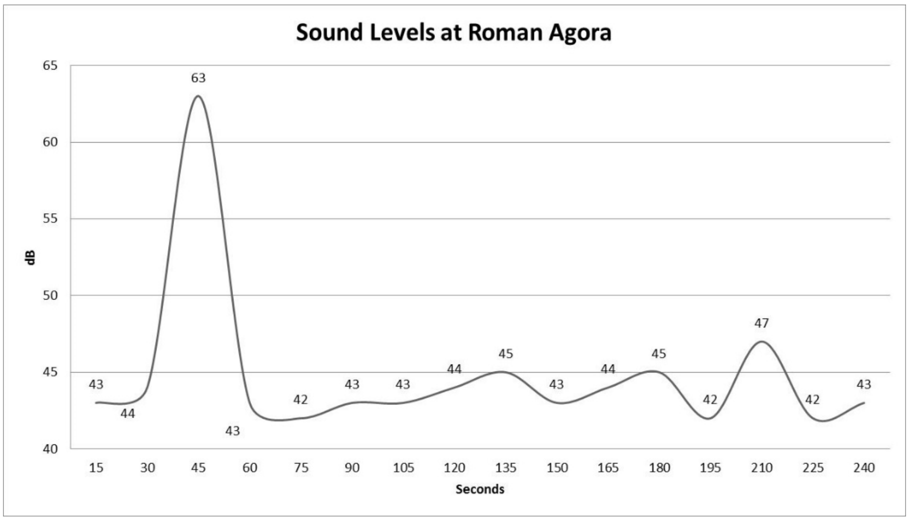

Figure 3. A graph showing levels of noise (dB) in the Roman Agora.

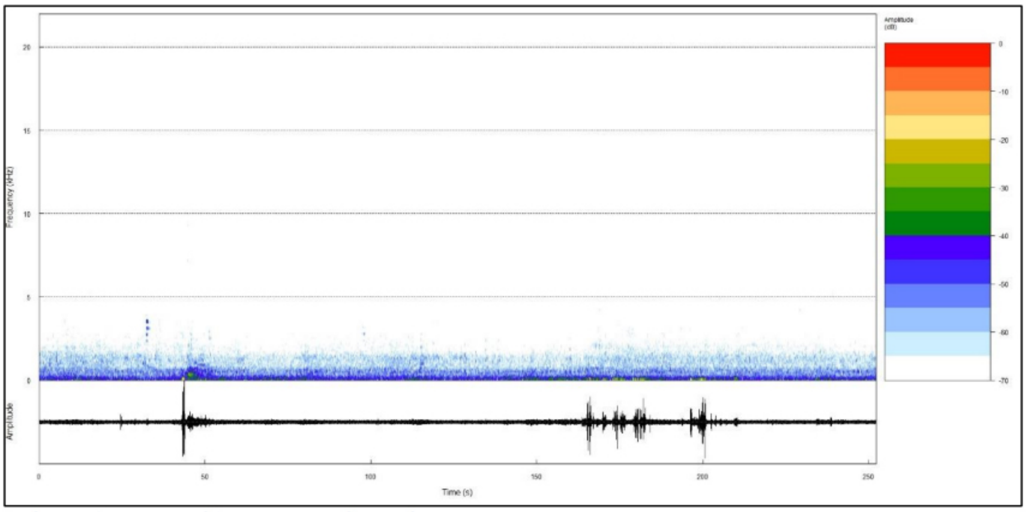

Figure 4. The spectrogram analysis of the Roman Agora sound recording. The low-frequency sounds were visible.

3.1.3. Qualitative Data

Sound Recording Identification

A participant, after listening to the first audio sample, recognized that the sound recording took place at a lower elevation from the street level in the city center and that the traffic was heard from a higher level, maybe in the Roman Agora or a nearby Street. Another participant recognized that she heard sounds from an area in the center of Thessaloniki, near some trees, but at a higher elevation from the street level. In addition, the third one was reminded of a narrow bus lane in the city with no heavy traffic, maybe an apartment in a second or third floor of a tall building. She identified the different altitude but attributed it to higher elevation from the street level and not lower one.

Verbal Description of the Sound Recording

Regarding the soundscape, the background sounds were louder than the sounds in the foreground and mainly man-made. The most complex sound events were recorded in the first minute, apart from human talks that did not cease during the entire sound recording. Furthermore, a sudden car honking was recorded along with brief but loud music from a passing vehicle. Finally, in the third minute, a dog barking was heard.

The quality of the recording was unanimously described as good. The first participant recognized the identity of the area, where the sound recording took place, as a "buried" area close to a road and a place, where the sounds floated "above you". The second participant was certain that the sound recording took place in an area having little vegetation in the city center, noticed that the sound recording did not take place at the level of the street but at a higher elevation and erroneously stated that the place being recorded was a balcony, but not in the city center. In fact, it characterized this particular soundtrack "ordinary to a habitat of Thessaloniki". All the participants agreed that the recording was definitely made during the springtime and more precise during the morning hours. The sound effects described were drone, mask (music from a passing vehicle), and repetition (bird singing).

3.1.4. Environment, Milieu, and Paysage

The space was perceived as open, public and green, next to major highways. One participant indicated correctly that the recording took place in the Roman Agora, which was below the street level and had a unique sound identity regarding the city of Thessaloniki. Moreover, the space was perceived as a large-scale open field, with an obvious lack of the built environment constructing a particularly complex soundscape. The sound sources were clearly identified at the time of the recording, i.e., a spring morning.

The soundscape was a mix of an equal number of biological and anthropogenic sounds. Interesting elements were identified in this sound recording. There was a strong presence of birds singing and other sounds made by animals, while all the three participants highlighted that the recorded space was located in the center of Thessaloniki. The sound recording showed a unique soundscape for the city of Thessaloniki, a place with sound comfort and quality, where one can easily distinguish the sound sources.

3.2. Sound Identity of Byzantine Church in Hagia Sophia Square

3.2.1. Site

In Hagia Sophia Square, building facades of high-rise old structures can be found, and most of them are without any balconies, which favor sound phenomena like standing waves and low-frequency resonances. In addition, at the street level, there is one of the largest sidewalks in Thessaloniki, frequented by many street musicians composing a rather characteristic soundscape. The apartment, in which the sound recording was made, has eight floors. Therefore, as it can be seen in Figure 5, the recording point is located about 27 m above the street level.

Figure 5. The Hagia Sophia Square presented in the map. The pictures of the area were taken by the authors at the same time as the sampling protocol was followed.

3.2.2. Quantitative Data Assessment of a Sound Recording

A recording was conducted at 11:39 a.m. on 12 March, 2020. The weather was, as mentioned above, sunny, with the temperature at the time being 16 °C. The initial sound recording lasted 10 min, but a 4-min clip was selected to conduct interviews and analyze results. The soundscape characteristics are shown in Table 3. The value of the NDSI in this audio sample (Table 4) complied with the respective form, due to the negative sign, in which anthropophonic sounded prevailed. According to the sound measurement results, the specific area could be included in Thessaloniki's quiet areas (Figure 6). The noise levels in the specific part of the city (Figure 6) were lower than other urban areas, with the lowest value reaching 43 dBs and the highest reaching 49dBs. Finally, the spectrogram analysis (Figure 7) revealed that low frequencies prevail in the spectrum while an advanced complexity is noticeable in the high-frequency range, indicating that some sounds of biophonic origin were present.

Table 3. The soundscape characteristics of Byzantine Church in Hagia Sophia Square as highlighted by the researchers.

Byzantine Church in Hagia Sophia (Square)																	
Time	Minute	1′				2′				3′				4′			
	Second	15″	30″	45″	60″	15″	30″	45″	60″	15″	30″	45″	60″	15″	30″	45″	60″
Backg	Cars	2	1	2	2	2	2	3	1	2	1	1	2	2	3	1	2
	Birds	1	2	1	1	2	1	2	1	1	1	2	2	3	1	2	2
Foreground	Voices		1					1							1	2	1
	Car Brakes		1		2		2										
	Dog Barking									1	1						
	Music											3		2	2	2	2
	Balcony Tent/Awning												3				
	dB(A)	48	47	49	47	47	46	47	46	44	46	47	45	47	45	43	44

Table 4. The indicators resulted from the Hagia Sophia Square sound recordings. The negative sign in the NDSI highlighted the fact that anthropophonic sounds prevailed.

Byzantine Church in Hagia Sophia (Square)				
Qualitative data				
Background sounds	Biophony	29	volume	54
	Anthropophony	25		
Foreground sounds	Biophony	25	volume	27
	Anthropophony	2		
Quantitative data				
dB(A)	minimum	43	average	46.1
	maximum	49		
Acoustic complexity	Left channel	7421.69	average	7401.08
	Right channel	7380.47		
NDSI	Left channel	−0.47	average	−0.48
	Right channel	−0.50		
Acoustic diversity	Left channel	0.09	average	0.09
	Right channel	0.09		
Acoustic evenness	Left channel	0.74	average	0.73
	Right channel	0.72		

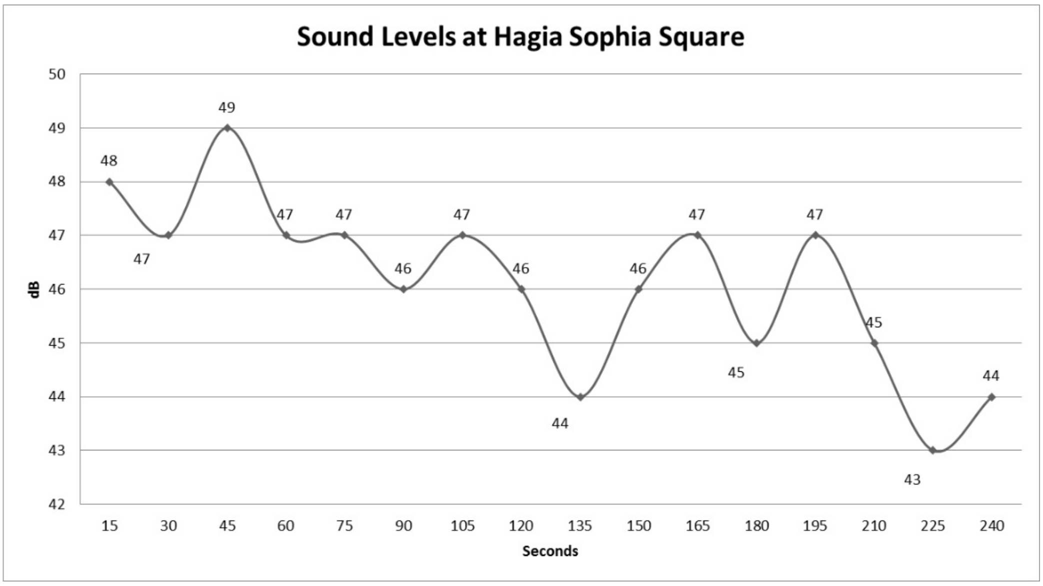

Figure 6. A graph showing levels of noise (dB) in Hagia Sophia Square.

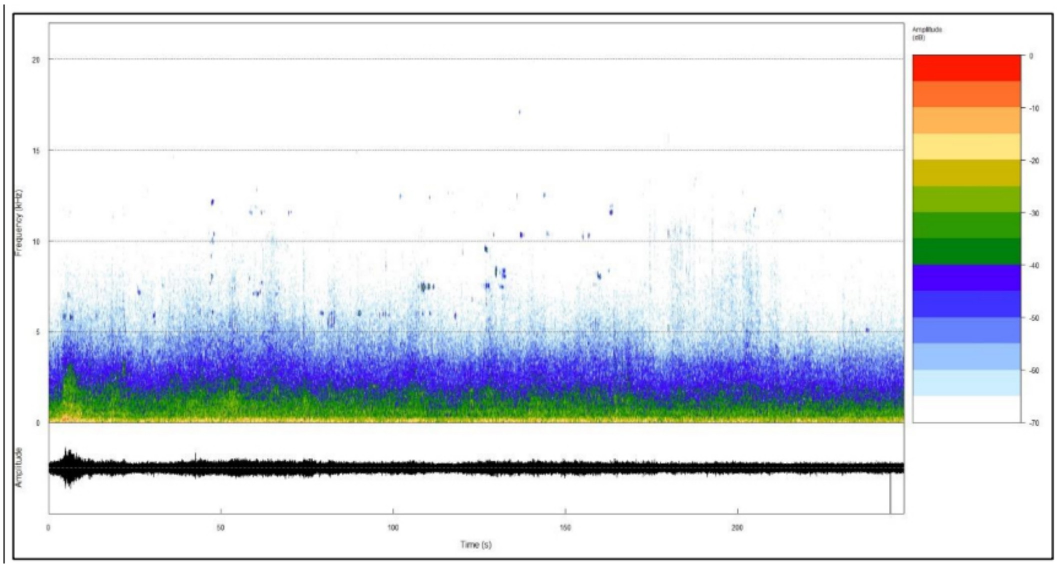

Figure 7. The spectrogram analysis of the Hagia Sophia Square sound recording. Despite the fact that low frequencies prevailed in the spectrum, an advanced complexity was noticeable in the high-frequency range.

3.2.3. Qualitative Data

Sound Recording Identification

One of the participants, after listening to the second audio sample, realized that the soundscape was of low intensity, pointing out that the sound recording took place at a building terrace in an apartment in the city center (Agia Sofia, Egnatia). While the other two participants pointed out that the city noise was heard from far away and attributed it to the fact that the sound recording probably took place in the middle of the COVID-19 quarantine. One of the participants was uncertain whether the sound recording took place on a high floor of a building, because the street sound sources were not loud enough.

Verbal Description of a Sound Recording

Regarding the soundscape, the background sounds were louder than the sounds in the foreground, with anthropophony prevailing in the acoustic scene. After listening to the sound recording, all three participants perceived human talks by passers-by. Furthermore, participants highlighted that they heard sounds originating from vehicles' brakes, dog barkings, and the lowering of a tent. The third minute of the sound recording was indicated by the presence of a street musician. It is worth mentioning that the traffic in this part of the city was reduced due to the COVID-19 quarantine, which is usually heavier.

The quality of the recording was described by every participant as adequate; however, the views regarding the quality of the sound environment were not in agreement. One of the participants found it worse than the other sound recording, because the soundscape was loud in relation to the Roman Agora. The second participant found it better, and the third one liked it because she considered that all man-made sounds in an urban environment were completely disarmed. All agreed that it was a spring morning in an open field. The sound effects described were drone, mask (tent), synecdoche (street musician), and repetition (bird singing).

3.2.4. Environment, Milieu, and Paysage

The sound recording took place in a small open space. The sound sample did not have any strong time elements except for sounds from heavy road traffic that indicated a morning time. The sounds of the street musician were distinctive and reminiscent of a city center pedestrian street. One of the participants talked about the sound recording taking place during spring or summer time, because she heard a crowded space with a lot of action.

The sounds produced by the street musician advocated that the weather was good, ruling out wintertime. One of the participants talked about the sound recording taking place during a relaxed lunch or breakfast when the market was closed, because any sounds of human activity were not heard, maybe due to the COVID-19 quarantine. However, she distinguished sounds of trucks and engines that repeatedly stopped and started again. The combination of these sounds and their intensities led another participant to a different realization that the sound recording took place during the wintertime. The participants agreed that the soundscape was urban and unknown and that the area had no special sound comfort. The squeaking sound of a tent and the music played from a street musician stood out. The soundscape was typical for the city of Thessaloniki but acquired a strong character due to the music.

4. Discussion

4.1. Roman Agora Soundscape

The area of the Roman Agora had a unique soundscape with significant sound comfort, special acoustic quality and sound complexity. It was perceived as an open, public, large-scale area, within the urban fabric, lacking built environment indicators (within a walking distance). However, the observed noise levels corresponded to the sound recording on the terrace of the apartment in Hagia Sophia. As a result, the impression created was that the sound recording took place at a different altitude of the road.

4.2. Hagia Sophia Soundscape

The terrace of the apartment in Hagia Sophia Square was identified as a small open space with some sound interest because of the street musician. The human presence was particularly noticeable, not only because of the continuous movement of citizens, but also as a result of typical domestic practices (such as lowering a tent). In fact, the combination of the sounds of human presence (on the foreground), the sounds of birds, and the drone of vehicles (on the background) clearly indicated that the sound recording took place at a building in an urban center of high altitude, as the volumes of the various sound sources were clearly low compared to what was heard at the street level.

The environmental noise levels (L_{eq}) of the two study areas are conjunctively presented in Figure 8. It is obvious that the Roman Agora had lower noise levels (44, 8 dB (A)) than the terrace in Hagia Sophia Square (46, 1 dB (A)). However, even if slightly deviated, the Roman Agora presented higher Acoustic Complexity Levels (ACI: 7593.12), in relation to the Hagia Sophia square (ACI: 7401.08).

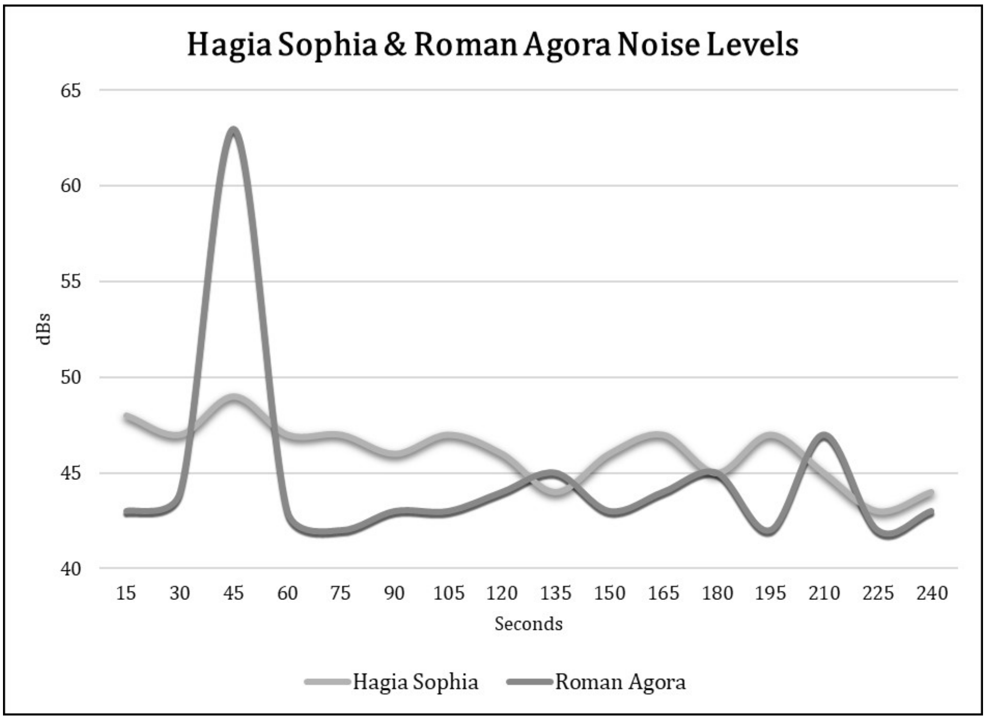

Figure 8. A graph showing levels of noise (dB) in the Roman Agora and Hagia Sophia Square. The Roman Agora had lower noise levels than the terrace in Hagia Sophia Square.

4.3. Restrictions of the Research

The presented study attempted to investigate opinions of inhabitants of Thessaloniki, so as to highlight areas in the historic center of the city that meet the definition criteria of quiet areas. In addition, the knowledge of three sound experts, an architect, a musician and, an environmental scientist, was used in order to achieve two objectives:

- to identify the sound identities of the study areas through selectively listening to sound recordings and semi-structured interviews;
- to assess whether altitude plays a role in the identification of quiet areas in the urban context.

The implementation of the measures, imposed by the Greek Government to limit the spread and protect citizens from the COVID-19, affected the formation of the overall soundscape of the city. Thus, the two studied soundscapes do not fully reflect the reality, although the experts unanimously decided that the sound recordings represented the areas being studied. Furthermore, the replacement of the study area "Greek Telecommunication agency tower", which citizens identified as more representative of the category "Areas higher than road level", was crucial.

4.4. Future Studies

Despite its restrictions, this study contributes substantially to the soundscape studies. The original protocol, combining tools of different scientific disciplines such as acoustic ecology, ecoacoustics, citizen science, architectural, and urban planning, is open to be modified or supplemented appropriately by experts of each field. Finding new and preserving already known quiet areas in the urban fabric with and without unique sound identities is of utmost importance in order to limit the many negative effects of environmental noise.

5. Conclusions

The historic center of Thessaloniki, due to its many layers, was ideal so as to evaluate the altitude factor. However, the altitude difference between lower and higher levels in the city of Thessaloniki and any other cities in Greece is not large. It is a fact that the highest building in Greece is the Tower of Athens (103 m) while the highest building in Europe is located in St. Petersburg (462 m). Therefore, there is a lack of opportunities to listen to high-altitude urban soundscapes. The differences regarding the acoustic quality in natural environments of different heights have been assessed, and the study revealed the differentiation regarding acoustic complexity at different altitudes. Therefore, the need for studies regarding elevation in the urban fabric is necessary, due to the fact that it could offer new solutions by providing acoustic comfort to urban residents.

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