environments

Article

Approaching Quietness as an Urban Sustainability Opportunity

Aggelos Tsaligopoulos * and Yiannis G. Matsinos

Acoustic Ecology Laboratory, Department of Environment, University of the Aegean, 81100 Mytilene, Greece; matsinos@aegean.gr
* Correspondence: tsaligopoulos@env.aegean.gr

Abstract: Quietness in an urban environment is vital for the well-being of city residents. Nevertheless, the ambiguity in the conceptualization of the terms noise and quietness as urban acoustic planning and design objectives, has resulted in two different approaches: the soundscape approach and the noise control approach. The main purpose of this research is to supplement the existing approaches by proposing a new ecological acoustics approach in order to identify quiet areas in the city of Mytilene (Lesbos Island, North Aegean, Greece). The use of the soundscape approach involved the participation of Mytilene's residents and the collection of subjective and objective eligibility criteria. By means of Multi-Criteria Decision Making two urban green areas were highlighted as potential quiet areas. For the noise control approach, road noise maps have been created through a commercial noise mapping software, validated by trough measurements. As a result, two areas located in the outskirts of the city were highlighted. Finally, the novel ecological acoustics approach involved acoustic recordings and the extraction of the Composite Urban Quietness Index (CUQI). The outcome of this approach converged with the soundscape approach results. Quietness, as an urban acoustic planning and design goal, could be viewed as an opportunity for ecologically sustainable urban environments.

Keywords: quiet areas; noise; soundscape approach; noise control; noise mapping; quietness; urban sustainability

check for updates

Citation: Tsaligopoulos, A.; Matsinos, Y.G. Approaching Quietness as an Urban Sustainability Opportunity. *Environments* **2022**, *9*, 12. https://doi.org/10.3390/environments9020012

Academic Editor: Paul C. Sutton

Received: 11 December 2021
Accepted: 15 January 2022
Published: 18 January 2022

1. Introduction

The immediacy of sound could serve as an indicator of urban sustainability which is the main focus of ecological urban planning and design [1]. Changes in the urban environment produce an acoustic impact highlighting sound as an indicator of environmental alteration associated even with climate change [2]. Therefore, an increasing number of urban planners and designers have turned their attention towards soundscaping [3]. Nevertheless, the lack of ecological knowledge in order to deal with the material and immaterial qualities of the urban environment has created the need for transdisciplinary research collaborations [4] between urban planners and acoustic ecologists.

Efforts aiming towards noise pollution reduction are determined by the way in which the concepts of noise and quietness are interpreted as objectives of urban acoustic planning and design. The polysemy of the concept of noise and the variety of characterizations attributed to this term [5] has determined the interpretation of the concept of quietness in an analogous manner as a counterpoint. The version of noise as an unwanted sound renders quietness as a desirable acoustic condition and thus a positive or pleasant soundscape [6,7]. Concurrently, if noise is interpreted as a sound of high intensity [8] characterized by a high decibel value [9], then quietness is the opposite. A vital urban acoustic planning and design objective is the creation of quiet areas, along with the noise reduction efforts in a noise polluted area. The approaches dealing with the two differentiating objectives are the soundscape approach [10] and noise control approach [11]. These two different approaches and the general ambiguity in the conceptualization of the relevant terms has caused the creation of different urban acoustic design methodologies with different results, which often overlook ecological co-benefits.

The main goal of this article is to assess these approaches using an example of urban quiet area identification project in the city of Mytilene, located on the island of Lesbos (North Aegean, Greece). Furthermore, a new approach will be introduced entitled the *ecological acoustics approach*.

2. Scientific Background: The Different Approaches of Quietness

The Environmental Noise Directive (END) addressed the need for the creation of quiet areas in agglomerations. Urban quiet areas are defined as "areas delimited by the competent authority, for instance which is not exposed to a value of L_{den} or of another appropriate noise indicator greater than a certain value set by the Member State, from any noise source" [8]. The concept of quietness as portrayed through this definition was questioned on several occasions [12,13].

Quietness in a noisy urban environment is of vital importance and should be viewed as a public good [14]. Transportation is the cause of high intensity intrusive sounds deriving from multiple sources, impacting the well-being of urban citizens [15,16]. More specifically, transportation noise that can be segregated into road traffic noise from a variety of street vehicles [17,18], railway traffic [19,20] and aviation noise affecting both populated areas and natural areas. Apart from transportation, other noise sources similar to recreational noise [21,22] and industrial noise [23,24] can deteriorate the acoustic environment of a city and intensify the need for quietness.

So far, urban quietness regards the citizen's well-being [25] in terms of relaxation and restoration, while rural quietness is associated with the natural environment, biodiversity and the Natura 2000 protected areas network [26]. Human's disconnection from the natural environment and the notion that nature is a recourse to be exploited [27] could lead towards the threat of biocultural homogenization [28] resulting in social and environmental injustices. Cities are socio-ecological systems [1] and biocultural complexity is an important element of its heritage [29] and of its environmental sustainability. Nevertheless, the association of quietness and biodiversity [30] and the linking of quiet areas with green areas [31–33] have provided a new view regarding the characteristics of this particular type of soundscape.

The introduction of quietness and quiet areas in an urban environment could be the result of two major approaches: the soundscape approach and the noise control approach. The soundscape approach similar to the Swedish Soundscape-Quality Protocol (SSQP) sorts of acoustic environments according to the way that people perceive them [6,28] and deals with sound as a source, rather than a waste. The noise control approach considers noise as a pollutant that needs to be mitigated leading to several urban planning and design outcomes [34,35].

The International Organization for Standardization (ISO) defined the term soundscape as "the acoustic environment as perceived or experienced and/or understood by a person or people, in context" [36]. The soundscape being the perceptual construct of the acoustic environment [9] is justifiably investigated through subjectiveness. Numerous paradigms that have used human perception as the main driver [37] towards designing are mostly case specific [9,38]. The perception of tranquility has been used as an indicator of quiet area identification. By means of socio-acoustic surveys, the auditory-visual factors contributing towards the perception of quietness can be assessed [39]. Through the soundscape approach, the positive aspects of an acoustic environment are being promoted in order to improve the quality of life. Several soundscape descriptors have been proposed, amongst which are vibrancy, pleasantness, the perceived affective quality, restorativeness, soundscape quality, appropriateness and, finally, quietness [40]. According to the soundscape approach, quietness is associated with tranquility, and thus the terms tranquil area and calm area are derived [30]. Quiet areas are therefore described as a particular type of soundscape that can be described and designed [41–44].

The noise control approach aims at reducing noise levels from various sources that can be measured, predicted and addressed [45–47]. According to the END provisions, strategic noise mapping [48,49] must be implemented for all heavily dense urbanized areas in order to manage the abatement of environmental noise and for action plans to be shaped [50,51]. Through the noise control approach, quiet areas are perceived as acoustic environments with low noise dB(A) levels. Therefore, a range of 50–55 dB(A) regarding the L_{den} indicator is suggested, coming into an alignment with the World Health Organization prompt of road traffic noise limitation at 53 dB(A) of the same indicator [52,53]. Implementations similar to noise barriers could support the noise control approach. According to simulations and actual implementations, the use of a noise barrier can affect sound attenuation due to diffraction that is highly dependent on the barrier's height [54,55].

Ecological principles [56] can be applied in urban planning and design through ecosystem services [57,58] provisioning in order to achieve both the sustainable and desirable in regard to quality of life [59]. In an urban environment different sounds are transmitted by a variety of biological, geophysical and man-made sources [60–63] reflecting the landscape. Noise in a city, apart from the annoyance and direct health implications in humans [53] also disrupt communication between species inhabiting the urban environment [64]. Man-made noise occupies a layer of the of the city's acoustic palimpsest, causing auditory masking and forcing city birds to sing in a higher pitch [65,66], leading to numerous implications [67] that eventually harm the ecosystem's integrity. High levels of acoustic complexity in an acoustic environment are a result of biotic sounds such as bird songs [68]. It is well understood that man-made noise is the reason for complexity deterioration [69], leading to diversity and ecosystem resilience decline [70].

Conceptual limitations of the terms "noise" and "quiet" and their interpretation as a contradiction have initiated design tactics with reduced ecological co-benefits, promoting short-term benefits of pleasant soundscapes. The main idea in the ecological acoustics approach is to break the association between these concepts and assign quietness a value in order for it to become an autonomous quantity. The association of quietness with biodiversity [30] and the fact that nature sounds are enjoyed by humans [71] present an opportunity for long-term ecological urban planning and design. In this manner quietness can become the means towards a truly sustainable city with high levels of both biological and cultural complexity [72].

3. Materials and Methods

The city of Mytilene (39.1067° N, 26.5573° E) was chosen as a case study area for this research. Mytilene is the capital city of the island of Lesbos, located in the North Aegean Region in Greece. Islands are notable for their biological endemism and encapsulate within their borders various biological and anthropological processes, such as species migration and human demographic concentration. Amongst the most valuable resources associated with islands are their acoustic environments, which are part of their cultural heritage and reflect important ecosystem services [73].

3.1. Soundscape Approach Methodology

The soundscape approach involved the active participation of Mytilene's residents through a small-scale citizen science program [74,75]. As can be seen in Figure 1, four major steps were implemented for this approach.

Citizen input regarding the assessment of soundscapes and acoustic environments is a promising field and new citizen science tools such as applications on smartphones are emerging [25]. For this research a total of 55 inhabitants participated in acoustic ecology themed seminars, workshops, discussions and educational soundwalks. The participants' age class was 18–26 years (45.25% male, 54.75% female). All of them were members of the academic community of the city's local university and permanent residents of Mytilene. The participants were asked to observe their daily routine, including weekdays and weekends, mainly by focusing on their acoustic environment. The next step was a follow-up interview, the purpose of which was to identify the acoustic environments chosen by the participants as the most acoustically interesting. Furthermore, several related issues were discussed regarding sounds liked and disliked and also the feeling of safety that the participants had in these areas as users. The resulted areas were categorized as (a) urban green areas, (b) public spaces, (c) archaeological sites and (d) areas of designated use and were handled as case study areas. These areas were incorporated in the data collection procedure in order to set the list of quiet area selection criteria.

Due to the fact that noise levels were one of the criteria chosen, a sound level meter was used in order to conduct measurements and collect the L_{den} values for each area. The device was calibrated prior of this research using a calibrator as required for all Class 1 measuring instruments and in accordance with the specifications of EN61326-1:(1997 + A1):1998.

The complete list of criteria, apart from the noise levels, included the area's health restoration and recreation opportunities, its size and distance from the city's center and also the presence of green infrastructure. These criteria were incorporated in a multi-criteria decision making (MCDM) tool in order to prioritize the case study areas. The MCDM method chosen was the Analytical Hierarchy Process (AHP) [76].

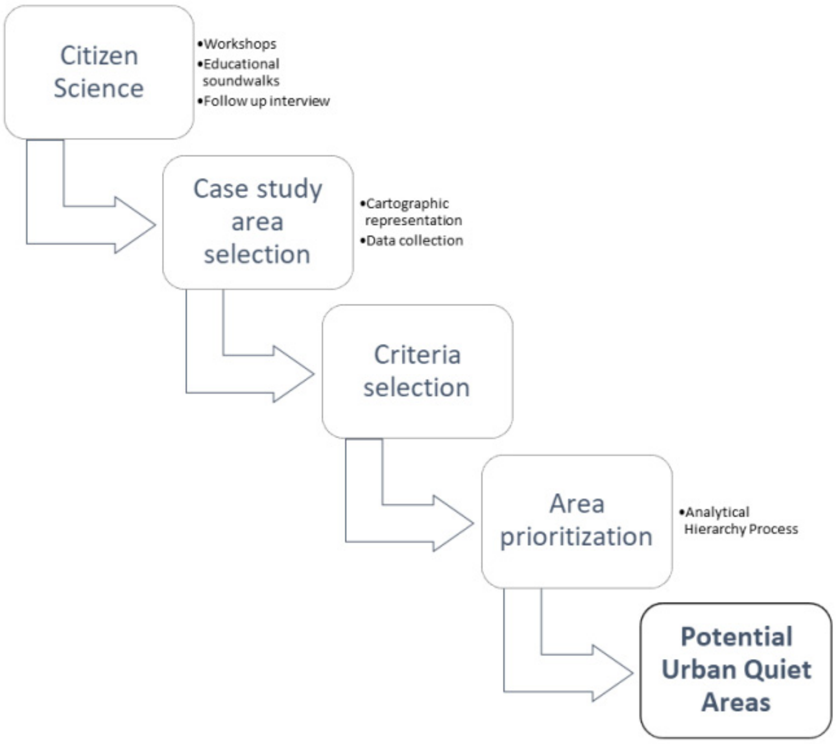

Figure 1. The soundscape approach flow chart.

3.2. Noise Control Methodology

A noise map in order to assess the effects of road traffic noise was created using the CadnaA (Computer Aided Noise Abatement) software [77]. The L_{eq} (dBA) levels deriving from 13 roads crossing the case study areas were collected using the same noise level meter described above. As can be seen in Figure 2, for each road three check spots were chosen in which the noise measurements were conducted.

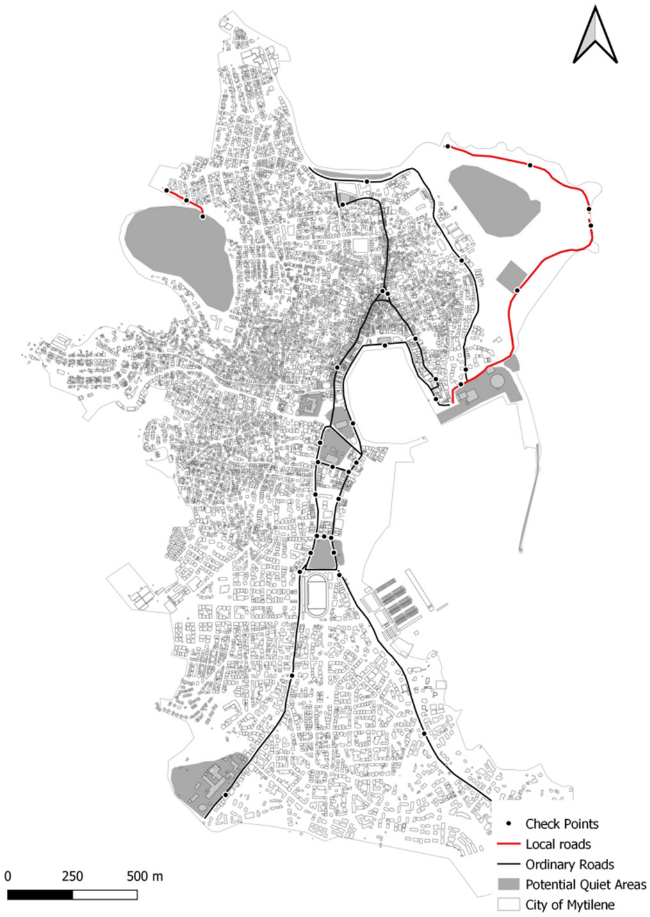

Figure 2. The local and ordinary roads crossing the case study areas and the 39 check points.

The noise level measurement results were imported into the noise mapping software (CadnaA MR1) and the case study areas were assessed as receivers. Each potential quiet area was assessed as a receiver of road traffic noise propagating from the nearby road(s). The simulated noise levels of each area were used in order to rank the areas from the quietest to the noisiest.

On each of the 13 roads, three noise measurements were conducted at the beginning, middle and last point of each selected part of the road network. The calibrated Class 1 sound level meter was mounted on a tripod at 1.5 m above ground and pointed towards the source (0° reference direction). All measurements were conducted at morning hours (8.00 am–11.00 am) and lasted 5 min each. The A-weighted equivalent continuous sound level (L_{eq}) was extracted for all 39 points checked.

Of the 13 roads checked, three of them were rough textured local roads and ten smooth asphalt ordinary roads. The width of each road was measured and imported as a feature in order to obtain realistic results. Furthermore, all traffic lights that were active during the measurement hours were incorporated in the modeling procedure. A dry road surface and a constant vehicle speed at 50 km/h were used for all types of vehicles. Most of the data required for successful traffic noise prediction have three-dimensional spatial characteristics. The management and visualization of these three-dimensional spatial data is important for urban planners and engineers as it offers them the ability to interactively modify their plans for ideal results [78].

Structural morphology data were collected and imported to the noise mapping software along with the noise measurement data. More specifically, a detailed cartographic representation of the area under consideration that included the building and foliage height and exact location [79] were incorporated.

At this point it is important to mention that the noise map created for this research does not represent the holistic noise climate of the city of Mytilene from multiple sources. Nevertheless, the scope of this procedure was to assess the effects of the dominant road traffic noise on the potential quiet areas of the city.

3.3. Ecological Acoustics Approach Methodology

The analysis of digital sound recordings and the extraction of the Acoustic Indices (AI) [80] have been used for Rapid Biodiversity Assessment (RBA) [81] in an increasing rate for a variety of environments [82–84]. Furthermore, the scientific field of ecoacoustics [85,86] has offered a new approach regarding the investigation of the ecological role of sound [87–90]. The use of several AI for biodiversity monitoring in urban environments face challenges due to the auditory masking effect caused by anthropogenic noise [91]. The proposed ecological acoustics approach embrace's these challenges and utilizes two of the available AI's, placing them out of their original context regarding RBA.

The R Statistics software (v. 3.6.1) [92] was used in order to extract AIs. More specifically, the R computational packages seewave [93], tuneR package [94], soundecology [95] and ineq [96] were used. For this research, the Acoustic Complexity Index (ACI) [69] that highlights the degree of complexity by processing the intensities recorded in an audio-file and the Normalized Difference Soundscape Index (NDSI) [97] were extracted.

As can be seen in Figure 3, sound recordings were conducted in eight check points on the perimeter of a case study area (edges) and one on the area's center (core). The AI's ACI and NDSI were extracted and used as sub-indicators in a novel composite index entitled Composite Urban Quietness Index (CUQI) [14]. The CUQI index was calculated for all case study areas and the results were ranked in order to highlight the potential urban quiet areas of Mytilene.

The CUQI (1) index is calculated according to the following formula:

$$CUQI = AD \times (RG_{ACI} \times CB) \quad (1)$$

where:

AD = anthropogenic disturbance calculated as a ratio of the resulted NDSI values;
RG_{ACI} = range of the acoustic complexity values;
CB = ratio of the acoustic complexity values.

Figure 3. Example of sampling check points for CUQI extraction.

4. Results

The soundscape approach, the noise control approach and the ecological acoustics approach were tested in the city of Mytilene. The previous studies conducted, regarding the soundscape approach [74,75] and the ecological acoustics approach [14,72], were supplemented by the noise mapping in order to holistically investigate the potential quiet areas of Mytilene.

4.1. Soundscape Approach Results

The soundscape approach practically involved city residents in order to define the case study areas and highlight soundscapes perceived as interesting. As can be seen in Figure 4, in total 18 areas were derived. Amongst the areas, 6 were urban green areas, 3 were public spaces, 3 were archaeological sites and 6 were areas of designated use.

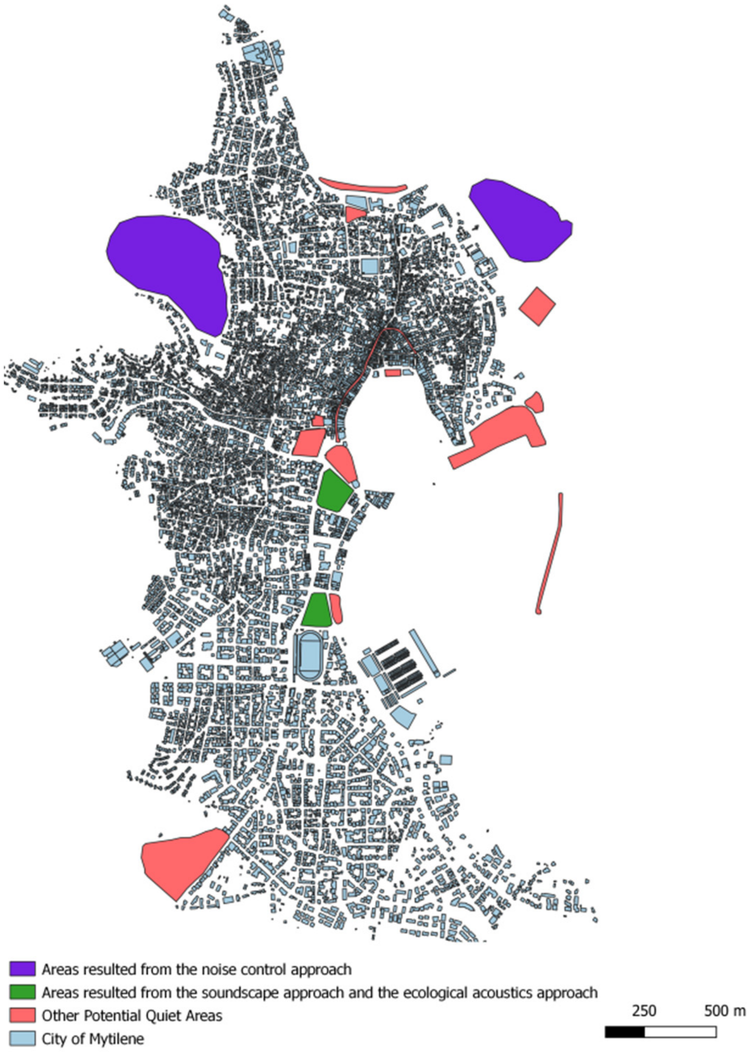

Figure 4. The resulted potential quiet areas.

In Figure 5, the ranking resulted from the AHP is presented. Two urban green areas located in the city's center gave the highest scores in the paired evaluation conducted (the Agias Eirinis park and the Karapanagiotis park, the two areas colored green in Figure 2). For the AHP, higher weights were attributed to the restoration and recreation criteria and lower to the noise level thresholds of the areas. Finally, in the follow up interviews that were conducted, most of the participants conveyed the fact that they do not feel safe in the areas that they selected, especially during the night period. Furthermore, they highlighted the positive sounds present. Most of these sounds were natural, including biological (bird singing) and geophysical (sea waves) sounds, followed by several anthopogenic recreational sounds, similar to music and the vocal expression of enjoyment of children playing.

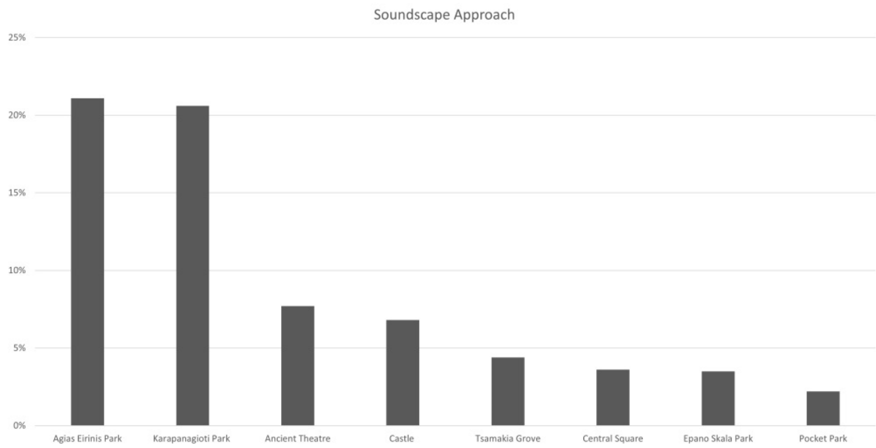

Figure 5. Potential quiet areas ranked using the soundscape approach.

4.2. Noise Control Results

The measured noise levels (L_{eq} dBA) for each checkpoint on each road are presented in Table 1. As expected, the local roads measured where quieter due to the lesser amount of road traffic.

Table 1. Noise level measurement results and descriptive statistics for the 13 roads crossing the potential quiet areas.

Road Code	Check Point 1	Check Point 2	Check Point 3	Measured Mean
1 [1]	71.3	60.4	65.4	65.7
2 [1]	70.2	72.3	73.5	72
3 [1]	64.5	64.9	63.9	64.4
4 [1]	66.3	65.4	62.3	64.6
5 [1]	69.8	65.2	62.3	65.7
6 [1]	69.3	65.2	66.7	67
7 [1]	73.6	68.8	70.9	71.1
8 [1]	70.8	69.8	65.4	68.6
9 [2]	65.3	60.1	61.1	62.1
10 [2]	58.5	57.9	60.9	59.1
11 [2]	50	56.3	51.2	52.5
12 [1]	63.1	64.2	61.7	63
13 [1]	61.2	66.8	66.9	64.9

[1] Ordinary road; [2] Local road.

In Table 2, the simulated noise levels, along with the measured, are presented. Due to the fact that several areas were affected by more than one road, the total measured mean was calculated in order for a comparison between the noise measured and the noise simulated to take place.

Table 2. Measured noise levels and simulated noise levels for each potential quiet area.

Potential Quiet Area	Road Code	Measured Mean	Total Measured	Simulated Noise Levels	Difference
Ancient Theater	10	59.1	59.1	44.7	14.4
Castle	11	52.5	52.5	47	5.5
Tsamakia	12	63	63.95	55.4	8.55
	13	64.9			
Agias Eirinis Park	3	64.4	64.9	61.8	3.1
	1	65.7			
	4	64.6			
	6	67			
Karapanagioti Park	2	72	67.01	62.7	4.31
	5	65.76			
	1	65.7			
	4	64.6			
Epano Skala	12	63	63	64.4	−1.4
Square	7	71.1	71.1	74.8	−3.7
Walkway	8	68.6	65.35	80	−16.65
	9	62.1			

As can be seen in Figure 6, two archeological sites located on the outskirts of the city and near local roads were the quietest and therefore can be described as Mytilene's quiet areas.

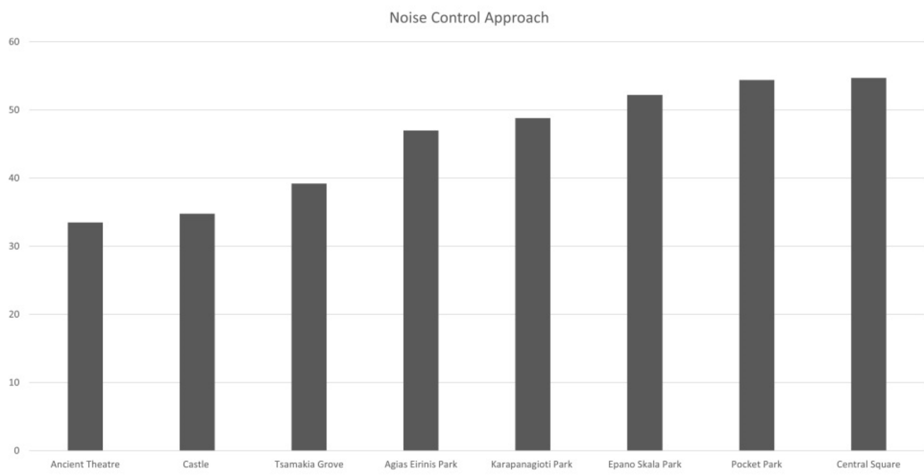

Figure 6. Potential quiet areas ranked using the noise control approach.

Finally, the noise map that was created using the cadnaA software is presented in Figure 7.

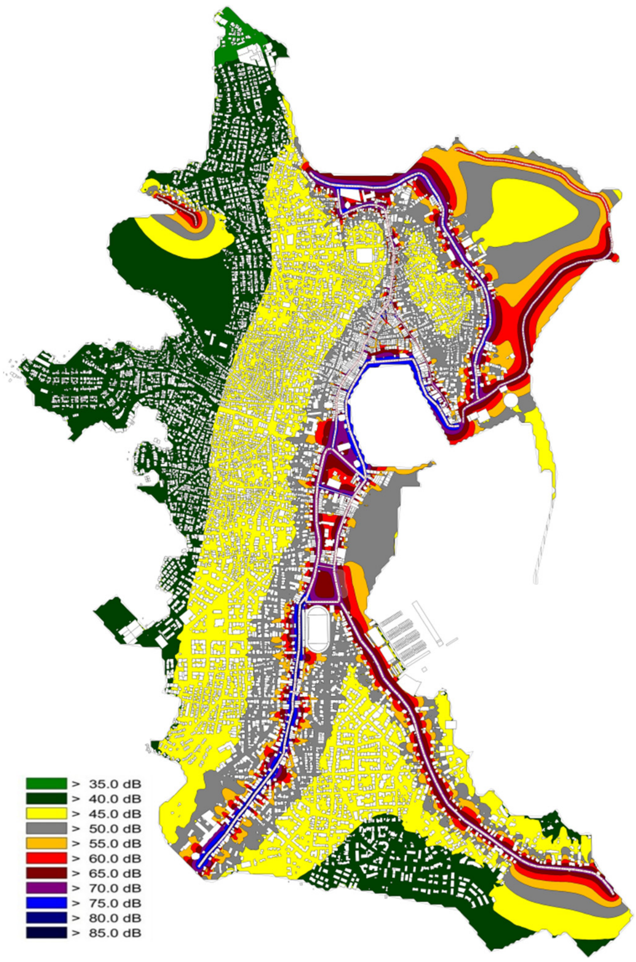

Figure 7. The city's noise map from the 13 selected roads.

4.3. Ecological Acoustics Approach Results

The results provided by the CUQI calculations (Figure 8) appear to give similar outcomes to the soundscape protocol used to identify urban quiet areas (Agias Eirinis park and Karapanagioti park, Mytilene, Lesbos Island, North Aegean, Greece). The CUQI appears to comply with research requirements that balance the multi-factor perspectives of environmental complexity as an easy-to-use decision-making tool.

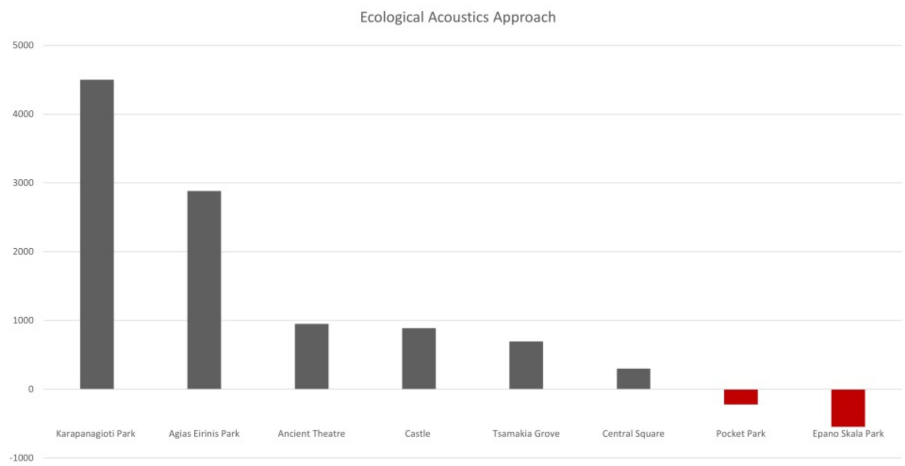

Figure 8. Potential quiet areas ranked using the Ecological acoustics approach. The negative values of CUQI (red bars) derived due to the use of NDSI that indicates anthropophony with a negative sign.

5. Conclusions

Quietness can be interpreted subjectively in terms of pleasantness and tranquility, or objectively in terms of low intensity levels. Depending on how the term is understood, a different approach can be used in order to identify quiet areas in an urban environment. Though interrelated, the two major approaches are the soundscape approach and the noise control approach. The authors of this research argue that the issue of urban quiet areas presents an opportunity for urban sustainable development. Therefore, a third supporting approach is proposed in an effort to introduce ecological acoustic concerns in future urban acoustic planning and design.

For this research the soundscape approach conducted in order to identify the quiet areas of Mytilene utilized quantitative data from measurements and qualitative data from a citizen science scheme. The results highlighted two urban green areas located in the city's center. For the noise control approach a road traffic noise map was created by conducting noise level measurements. The assessment of the results highlighted areas with lower sound pressure levels, which were two areas located in the outskirts of the city. Finally, for the ecological acoustics approach, the Composite Urban Quiet Index (CUQI) was applied, resulting in the same areas as the ones with the soundscape approach. This similarity is due to the fact that the qualitative criteria used in a similar way to the restorative and recreational value were the ones responsible for the increased levels of biological and cultural complexity.

The views and preferences of local residents, as well as the needs of a community, are valuable tools for sustainable urban planning. However, a risk of bias emerges, which concerns the lack of, or the coincidental presence of, ecological co-benefits, particularly in soundscape design efforts that include the preferable natural sounds.

Future research involves the theoretical and practical advancement of the ecological acoustics approach. Planners and designers in collaboration with ecologists need to plan ahead in small scale, "safe to fail" projects in order to "learn by doing" [98]. Quietness and the creation of quiet areas present an opportunity for a truly sustainable urban planning and design, following three main principles: planning for resilience, planning for biodiversity and planning for connectivity [1,99] that can be summarized as "planning for quietness". The green infrastructure, including ecological networks, patches, corridors, green roofs and walls can be the means to both abate excessive amounts of noise levels and increase biodiversity [100], thus creating urban quiet areas that are able to recover from disturbances and adapt to change while maintaining their fundamental structure and function.

Author Contributions: Conceptualization, A.T. and Y.G.M.; methodology, A.T. and Y.G.M.; writing—original draft preparation, A.T.; writing—review and editing, Y.G.M.; supervision, Y.G.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data sharing is not applicable to this article.

Acknowledgments: We would like to express our gratitude to the anonymous reviewers for their valuable comments and insights.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Heymans, A.; Breadsell, J.; Morrison, G.M.; Byrne, J.J.; Eon, C. Ecological Urban Planning and Design: A Systematic Literature Review. *Sustainability* **2019**, *11*, 3723. [CrossRef]
2. Krause, B.; Farina, A. Using Ecoacoustic Methods to Survey the Impacts of Climate Change on Biodiversity. *Biol. Conserv.* **2016**, *195*, 245–254. [CrossRef]
3. Kang, J.; Aletta, F.; Gjestland, T.T.; Brown, L.A.; Botteldooren, D.; Schulte-Fortkamp, B.; Lercher, P.; van Kamp, I.; Genuit, K.; Fiebig, A.; et al. Ten Questions on the Soundscapes of the Built Environment. *Build. Environ.* **2016**, *108*, 284–294. [CrossRef]
4. Radicchi, A.; Yelmi, P.C.; Chung, A.; Jordan, P.; Stewart, S.; Tsaligopoulos, A.; McCunn, L.; Grant, M. Sound and the Healthy City. *Cities Health* **2020**, 5. [CrossRef]

5. Schafer, R.M. *The Soundscape: Our Sonic Environment and the Tuning of the World*; Simon and Schuster: New York, NY, USA, 1993; ISBN 978-1-59477-668-7.
6. Axelsson, Ö.; Nilsson, M.E.; Berglund, B. A Principal Components Model of Soundscape Perception. *J. Acoust. Soc. Am.* **2010**, *128*, 2836–2846. [CrossRef]
7. Aletta, F.; Kang, J. Towards an Urban Vibrancy Model: A Soundscape Approach. *Int. J. Environ. Res. Public. Health* **2018**, *15*, 1712. [CrossRef]
8. END. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32002L0049&from=EN (accessed on 7 May 2021).
9. KANG, J. From DBA to Soundscape Indices: Managing Our Sound Environment. *Front. Eng. Manag.* **2017**, *4*, 184–192. [CrossRef]
10. Xiao, J.; Aletta, F. A Soundscape Approach to Exploring Design Strategies for Acoustic Comfort in Modern Public Libraries: A Case Study of the Library of Birmingham. *Noise Mapp.* **2016**, *3*, 264–273. [CrossRef]
11. Salomons, E.M.; Bakri, T. Fluctuating Traffic Noise Levels Calculated from Time-Dependent Traffic Data: An Engineering Approach. *Noise Control Eng. J.* **2018**, *66*, 432–445. [CrossRef]
12. Aletta, F.; Van Renterghem, T.; Botteldooren, D. Influence of Personal Factors on Sound Perception and Overall Experience in Urban Green Areas. A Case Study of a Cycling Path Highly Exposed to Road Traffic Noise. *Int. J. Environ. Res. Public. Health* **2018**, *15*, 1118. [CrossRef]
13. Aletta, F.; Kang, J. Promoting Healthy and Supportive Acoustic Environments: Going beyond the Quietness. *Int. J. Environ. Res. Public. Health* **2019**, *16*, 4988. [CrossRef]
14. Tsaligopoulos, A.; Kyvelou, S.; Votsi, N.-E.; Karapostoli, A.; Economou, C.; Matsinos, Y.G. Revisiting the Concept of Quietness in the Urban Environment—Towards Ecosystems' Health and Human Well-Being. *Int. J. Environ. Res. Public. Health* **2021**, *18*, 3151. [CrossRef]
15. Korkontzila, A.; Karapostoli, A.; Tsaligopoulos, A.; Matsinos, Y.G. Assessing the Effects of Noise on Sound Identities of Historical Landmarks. *Acoustics* **2020**, *2*, 719–734. [CrossRef]
16. Licitra, G.; Gallo, P.; Rossi, E.; Brambilla, G. A Novel Method to Determine Multiexposure Priority Indices Tested for Pisa Action Plan. *Appl. Acoust.* **2011**, *72*, 505–510. [CrossRef]
17. Cueto, J.L.; Petrovici, A.M.; Hernández, R.; Fernández, F. Analysis of the Impact of Bus Signal Priority on Urban Noise. *Acta Acust. United Acust.* **2017**, *103*, 561–573. [CrossRef]
18. Bianco, F.; Fredianelli, L.; Lo Castro, F.; Gagliardi, P.; Fidecaro, F.; Licitra, G. Stabilization of a P-u Sensor Mounted on a Vehicle for Measuring the Acoustic Impedance of Road Surfaces. *Sensors* **2020**, *20*, 1239. [CrossRef] [PubMed]
19. Licitra, G.; Fredianelli, L.; Petri, D.; Vigotti, M.A. Annoyance Evaluation Due to Overall Railway Noise and Vibration in Pisa Urban Areas. *Sci. Total Environ.* **2016**, *568*, 1315–1325. [CrossRef] [PubMed]
20. Bunn, F.; Zannin, P.H.T. Assessment of Railway Noise in an Urban Setting. *Appl. Acoust.* **2016**, *104*, 16–23. [CrossRef]
21. Keppler, H.; Dhooge, I.; Vinck, B. Hearing in Young Adults. Part II: The Effects of Recreational Noise Exposure. *Noise Health* **2015**, *17*, 245–252. [CrossRef]
22. Petri, D.; Licitra, G.; Vigotti, M.A.; Fredianelli, L. Effects of Exposure to Road, Railway, Airport and Recreational Noise on Blood Pressure and Hypertension. *Int. J. Environ. Res. Public. Health* **2021**, *18*, 9145. [CrossRef] [PubMed]
23. Eleftheriou, P.C. Industrial Noise and Its Effects on Human Hearing. *Appl. Acoust.* **2002**, *63*, 35–42. [CrossRef]
24. Morel, J.; Marquis-Favre, C.; Gille, L.-A. Noise Annoyance Assessment of Various Urban Road Vehicle Pass-by Noises in Isolation and Combined with Industrial Noise: A Laboratory Study. *Appl. Acoust.* **2016**, *101*, 47–57. [CrossRef]
25. Radicchi, A.; Henckel, D.; Memmel, M. Citizens as Smart, Active Sensors for a Quiet and Just City. The Case of the "Open Source Soundscapes" Approach to Identify, Assess and Plan "Everyday Quiet Areas" in Cities. *Noise Mapp.* **2016**, *5*, 1–20. [CrossRef]
26. Votsi, N.-E.P.; Kallimanis, A.S.; Mazaris, A.D.; Pantis, J.D. Integrating Environmental Policies towards a Network of Protected and Quiet Areas. *Environ. Conserv.* **2014**, *41*, 321–329. [CrossRef]
27. Lomas, T. The Elements of Eco-Connection: A Cross-Cultural Lexical Enquiry. *Int. J. Environ. Res. Public. Health* **2019**, *16*, 5120. [CrossRef] [PubMed]
28. *From Biocultural Homogenization to Biocultural Conservation*; Rozzi, R.; May, R.H.; Chapin III, F.S.; Massardo, F.; Gavin, M.C.; Klaver, I.J.; Pauchard, A.; Nuñez, M.A.; Simberloff, D. (Eds.) Ecology and Ethics; Springer International Publishing: Cham, Switzerland, 2018; Volume 3; ISBN 978-3-319-99512-0.
29. Kyvelou, S.S.; Bobolos, N.; Tsaligopoulos, A. Exploring the Effects of "Smart City" in the Inner-City Fabric of the Mediterranean Metropolis: Towards a Bio-Cultural Sonic Diversity? *Heritage* **2021**, *4*, 690–709. [CrossRef]
30. EEA Technical Report No 4/2014. Available online: http://acm.eionet.europa.eu/reports/EEA_TR_4_2014_practice_guide_quiet_areas (accessed on 29 June 2017).
31. Chiesura, A. The Role of Urban Parks for the Sustainable City. *Landsc. Urban Plan.* **2004**, *68*, 129–138. [CrossRef]
32. Payne, S.R. The Production of a Perceived Restorativeness Soundscape Scale. *Appl. Acoust.* **2013**, *74*, 255–263. [CrossRef]
33. Dzhambov, A.M.; Markevych, I.; Tilov, B.; Arabadzhiev, Z.; Stoyanov, D.; Gatseva, P.; Dimitrova, D.D. Lower Noise Annoyance Associated with GIS-Derived Greenspace: Pathways through Perceived Greenspace and Residential Noise. *Int. J. Environ. Res. Public. Health* **2018**, *15*, 1533. [CrossRef]
34. Axelsson, Ã.; Nilsson, M.E.; Berglund, B. The Swedish Soundscape-Quality Protocol. *J. Acoust. Soc. Am.* **2012**, *131*, 3476. [CrossRef]

35. Riedel, N.; Köckler, H.; Scheiner, J.; van Kamp, I.; Erbel, R.; Loerbroks, A.; Claßen, T.; Bolte, G. Urban Road Traffic Noise and Noise Annoyance—A Study on Perceived Noise Control and Its Value among the Elderly. *Eur. J. Public Health* **2019**, *29*, 377–379. [CrossRef]
36. Jacobsen, F.; Poulsen, T.; Rindel, J.H.; Gade, A.C.; Ohlrich, M. *Fundamentals of Acoustics And Noise Control*; Technical University of Denmark: Lyngby, Denmark, 2011; p. 181.
37. Technical Committee: ISO/TC 43/SC 1 Noise ISO 12913-1:2014. Available online: https://www.iso.org/cms/render/live/en/sites/isoorg/contents/data/standard/05/21/52161.html (accessed on 5 December 2021).
38. Schulte-Fortkamp, B.; Fiebig, A. Going beyond Noise in Urban Planning—Human Perception Will Be the Trusted Guide. *J. Acoust. Soc. Am.* **2017**, *142*, 2672. [CrossRef]
39. Schulte-Fortkamp, B.; Volz, R.; Jakob, A. Using the Soundscape Approach to Develop a Public Space in Berlin—Perception and Evaluation. *J. Acoust. Soc. Am.* **2008**, *123*, 3808. [CrossRef]
40. Cassina, L.; Fredianelli, L.; Menichini, I.; Chiari, C.; Licitra, G. Audio-Visual Preferences and Tranquillity Ratings in Urban Areas. *Environments* **2018**, *5*, 1. [CrossRef]
41. Aletta, F.; Kang, J.; Axelsson, Ö. Soundscape Descriptors and a Conceptual Framework for Developing Predictive Soundscape Models. *Landsc. Urban Plan.* **2016**, *149*, 65–74. [CrossRef]
42. Kang, J. From Understanding to Designing Soundscapes. *Front. Archit. Civ. Eng. China* **2010**, *4*, 403–417. [CrossRef]
43. Volz, R.; Jakob, A.; Schulte-Fortkamp, B. Using the Soundscape Approach to Develop a Public Space in Berlin—Measurement and Calculation. *J. Acoust. Soc. Am.* **2008**, *123*, 3808. [CrossRef]
44. Schulte-Fortkamp, B. The Daily Rhythm of the Soundscape "Nauener Platz" in Berlin. *J. Acoust. Soc. Am.* **2010**, *127*, 1774. [CrossRef]
45. Schulte-Fortkamp, B. Lessons Learning from Successful Projects in Soundscapes of Outdoor Spaces. *J. Acoust. Soc. Am.* **2017**, *141*, 3563. [CrossRef]
46. Khan, J.; Ketzel, M.; Jensen, S.S.; Gulliver, J.; Thysell, E.; Hertel, O. Comparison of Road Traffic Noise Prediction Models: CNOSSOS-EU, Nord2000 and TRANEX. *Environ. Pollut.* **2021**, *270*, 116240. [CrossRef]
47. Paviotti, M.; Vogiatzis, K. On the Outdoor Annoyance from Scooter and Motorbike Noise in the Urban Environment. *Sci. Total Environ.* **2012**, *430*, 223–230. [CrossRef]
48. Seidler, A.; Hegewald, J.; Seidler, A.L.; Schubert, M.; Wagner, M.; Dröge, P.; Haufe, E.; Schmitt, J.; Swart, E.; Zeeb, H. Association between Aircraft, Road and Railway Traffic Noise and Depression in a Large Case-Control Study Based on Secondary Data. *Environ. Res.* **2017**, *152*, 263–271. [CrossRef] [PubMed]
49. Vogiatzis, K.; Remy, N. From Environmental Noise Abatement to Soundscape Creation through Strategic Noise Mapping in Medium Urban Agglomerations in South Europe. *Sci. Total Environ.* **2014**, *482–483*, 420–431. [CrossRef] [PubMed]
50. Benocci, R.; Molteni, A.; Cambiaghi, M.; Angelini, F.; Roman, H.E.; Zambon, G. Reliability of Dynamap Traffic Noise Prediction. *Appl. Acoust.* **2019**, *156*, 142–150. [CrossRef]
51. Öhrström, E.; Skånberg, A.; Svensson, H.; Gidlöf-Gunnarsson, A. Effects of Road Traffic Noise and the Benefit of Access to Quietness. *J. Sound Vib.* **2006**, *295*, 40–59. [CrossRef]
52. De Kluizenaar, Y.; Janssen, S.A.; Vos, H.; Salomons, E.M.; Zhou, H.; Van den Berg, F. Road Traffic Noise and Annoyance: A Quantification of the Effect of Quiet Side Exposure at Dwellings. *Int. J. Environ. Res. Public. Health* **2013**, *10*, 2258–2270. [CrossRef] [PubMed]
53. Quiet Areas in Europe—The Environment Unaffected by Noise Pollution—European Environment Agency. Available online: https://www.eea.europa.eu/publications/quiet-areas-in-europe (accessed on 6 December 2021).
54. Environmental Noise Guidelines for the European Region. 2018. Available online: https://www.euro.who.int/en/publications/abstracts/environmental-noise-guidelines-for-the-european-region-2018 (accessed on 6 December 2021).
55. Amarilla, R.S.D.; Scoczynski Ribeiro, R.; Henrique de Avelar Gomes, M.; Pereira Sousa, R.; Henrique Sant'Ana, L.; Eduardo Catai, R. Acoustic Barrier Simulation of Construction and Demolition Waste: A Sustainable Approach to the Control of Environmental Noise. *Appl. Acoust.* **2021**, *182*, 108201. [CrossRef]
56. Hong, J.Y.; Jeon, J.Y. The Effects of Audio–Visual Factors on Perceptions of Environmental Noise Barrier Performance. *Landsc. Urban Plan.* **2014**, *125*, 28–37. [CrossRef]
57. Li, F.; Wang, R.; Paulussen, J.; Liu, X. Comprehensive Concept Planning of Urban Greening Based on Ecological Principles: A Case Study in Beijing, China. *Landsc. Urban Plan.* **2005**, *72*, 325–336. [CrossRef]
58. Costanza, R.; d'Arge, R.; de Groot, R.; Faber, S.; Grasso, M.; Hannon, B.; Limburg, K.; Naeem, S.; O'Neill, R.V.; Paruelo, J.; et al. The value of the world's ecosystem services and natural capital. *Nature* **1997**, *387*, 253–260. [CrossRef]
59. Costanza, R.; de Groot, R.; Braat, L.; Kubiszewski, I.; Fioramonti, L.; Sutton, P.; Farber, S.; Grasso, M. Twenty Years of Ecosystem Services: How Far Have We Come and How Far Do We Still Need to Go? *Ecosyst. Serv.* **2017**, *28*, 1–16. [CrossRef]
60. Farley, J. Ecosystem Services: The Economics Debate. *Ecosyst. Serv.* **2012**, *1*, 40–49. [CrossRef]
61. Pijanowski, B.C.; Farina, A. Introduction to the Special Issue on Soundscape Ecology. *Landsc. Ecol.* **2011**, *26*, 1209. [CrossRef]
62. Pijanowski, B.C.; Farina, A.; Gage, S.H.; Dumyahn, S.L.; Krause, B.L. What Is Soundscape Ecology? An Introduction and Overview of an Emerging New Science. *Landsc. Ecol.* **2011**, *26*, 1213–1232. [CrossRef]
63. Pijanowski, B.C.; Villanueva-Rivera, L.J.; Dumyahn, S.L.; Farina, A.; Krause, B.L.; Napoletano, B.M.; Gage, S.H.; Pieretti, N. Soundscape Ecology: The Science of Sound in the Landscape. *BioScience* **2011**, *61*, 203–216. [CrossRef]

64. Farina, A. Soundscape and Landscape Ecology. In *Soundscape Ecology: Principles, Patterns, Methods and Applications*; Farina, A., Ed.; Springer: Dordrecht, The Netherlands, 2014; pp. 1–28, ISBN 978-94-007-7374-5.64.
65. Slabbekoorn, H.; Peet, M. Ecology: Birds Sing at a Higher Pitch in Urban Noise. *Nature* **2003**, *424*, 267. [CrossRef]
66. Slabbekoorn, H.; den Boer-Visser, A. Cities Change the Songs of Birds. *Curr. Biol.* **2006**, *16*, 2326–2331. [CrossRef]
67. Brumm, H.; Zollinger, S.A. The Evolution of the Lombard Effect: 100 Years of Psychoacoustic Research. *Behaviour* **2011**, *148*, 1173–1198. [CrossRef]
68. Pieretti, N.; Farina, A.; Morri, D. A New Methodology to Infer the Singing Activity of an Avian Community: The Acoustic Complexity Index (ACI). *Ecol. Indic.* **2011**, *11*, 868–873. [CrossRef]
69. Pieretti, N.; Farina, A. Application of a Recently Introduced Index for Acoustic Complexity to an Avian Soundscape with Traffic Noise. *J. Acoust. Soc. Am.* **2013**, *134*, 891–900. [CrossRef]
70. Parrott, L. Measuring Ecological Complexity. *Ecol. Indic.* **2010**, *10*, 1069–1076. [CrossRef]
71. Kogan, P.; Arenas, J.P.; Bermejo, F.; Hinalaf, M.; Turra, B. A Green Soundscape Index (GSI): The Potential of Assessing the Perceived Balance between Natural Sound and Traffic Noise. *Sci. Total Environ.* **2018**, *642*, 463–472. [CrossRef]
72. Tsaligopoulos, A.; Kyvelou, S.; Votsi, N.E.; Karapostoli, A.; Economou, C.; Matsinos, Y. Towards a New Understanding of the Concept of Quietness. *J. Acoust. Soc. Am.* **2021**, *149*, A72. [CrossRef]
73. Farina, A.; Pieretti, N. The Soundscape Ecology: A New Frontier of Landscape Research and Its Application to Islands and Coastal Systems. *J. Mar. Isl. Cult.* **2012**, *1*, 21–26. [CrossRef]
74. Matsinos, Y.G.; Tsaligopoulos, A.; Economou, C. Identifying the Quiet Areas of a Small Urban Setting: The Case of Mytilene. *Glob. Nest J.* **2017**, *19*, 674–681. [CrossRef]
75. Tsaligopoulos, A.; Economou, C.; Matsinos, Y.G. Identification, Prioritization, and Assessment of Urban Quiet Areas. Available online: www.igi-global.com/chapter/identification-prioritization-and-assessment-of-urban-quiet-areas/198160 (accessed on 25 February 2021).
76. Saaty, T.L. Decision Making—the Analytic Hierarchy and Network Processes (AHP/ANP). *J. Syst. Sci. Syst. Eng.* **2004**, *13*, 1–35. [CrossRef]
77. Cadna—State-of-the-Art Noise Prediction Software | DataKustik GmbH. Available online: https://www.datakustik.com/products/cadnaa/cadnaa/ (accessed on 22 March 2021).
78. Li, B.; Tao, S.; Dawson, R.W.; Cao, J.; Lam, K. A GIS Based Road Traffic Noise Prediction Model. *Appl. Acoust.* **2002**, *63*, 679–691. [CrossRef]
79. Ow, L.F.; Ghosh, S. Urban Cities and Road Traffic Noise: Reduction through Vegetation. *Appl. Acoust.* **2017**, *120*, 15–20. [CrossRef]
80. Sueur, J.; Farina, A.; Gasc, A.; Pieretti, N.; Pavoine, S. Acoustic Indices for Biodiversity Assessment and Landscape Investigation. *Acta Acust. United Acust.* **2014**, *100*, 772–781. [CrossRef]
81. Depraetere, M.; Pavoine, S.; Jiguet, F.; Gasc, A.; Duvail, S.; Sueur, J. Monitoring Animal Diversity Using Acoustic Indices: Implementation in a Temperate Woodland. *Ecol. Indic.* **2012**, *13*, 46–54. [CrossRef]
82. Sharif, M.Z.; Wario, F.; Di, N.; Xue, R.; Liu, F. Soundscape Indices: New Features for Classifying Beehive Audio Samples. *Sociobiology* **2020**, *67*, 566–571. [CrossRef]
83. Chen, Y.-F.; Luo, Y.; Mammides, C.; Cao, K.-F.; Zhu, S.; Goodale, E. The Relationship between Acoustic Indices, Elevation, and Vegetation, in a Forest Plot Network of Southern China. *Ecol. Indic.* **2021**, *129*, 107942. [CrossRef]
84. Benocci, R.; Roman, H.E.; Bisceglie, A.; Angelini, F.; Brambilla, G.; Zambon, G. Eco-Acoustic Assessment of an Urban Park by Statistical Analysis. *Sustainability* **2021**, *13*, 7857. [CrossRef]
85. Ecoacoustics | Wiley Online Books. Available online: https://onlinelibrary.wiley.com/doi/book/10.1002/9781119230724 (accessed on 9 December 2021).
86. Sueur, J.; Farina, A. Ecoacoustics: The Ecological Investigation and Interpretation of Environmental Sound. *Biosemiotics* **2015**, *8*, 493–502. [CrossRef]
87. Sueur, J.; Krause, B.; Farina, A. Climate Change Is Breaking Earth's Beat. *Trends Ecol. Evol.* **2019**, *34*, 971–973. [CrossRef] [PubMed]
88. Farina, A.; Reid, V. The Ecological Role of Sound in Terrestrial and Aquatic Landscape: Theories, Methods and Applications of Ecoacoustics. *Biodiversity* **2020**, *21*, 1–3. [CrossRef]
89. Farina, A.; Righini, R.; Fuller, S.; Li, P.; Pavan, G. Acoustic Complexity Indices Reveal the Acoustic Communities of the Old-Growth Mediterranean Forest of Sasso Fratino Integral Natural Reserve (Central Italy). *Ecol. Indic.* **2021**, *120*, 106927. [CrossRef]
90. Farina, A.; Eldridge, A.; Li, P. Ecoacoustics and Multispecies Semiosis: Naming, Semantics, Semiotic Characteristics, and Competencies. *Biosemiotics* **2021**, *14*, 141–165. [CrossRef]
91. Fairbrass, A.J.; Rennert, P.; Williams, C.; Titheridge, H.; Jones, K.E. Biases of Acoustic Indices Measuring Biodiversity in Urban Areas. *Ecol. Indic.* **2017**, *83*, 169–177. [CrossRef]
92. R: The R Project for Statistical Computing. Available online: https://www.r-project.org/ (accessed on 29 June 2017).
93. SUEUR, J.; AUBIN, T.; SIMONIS, C. Seewave, a Free Modular Tool for Sound Analysis and Synthesis. *Bioacoustics* **2008**, *18*, 213–226. [CrossRef]
94. Ligges, U. R-Forge: Wave (Music, Speech, . . .) Analyses in R: Project Home. Available online: https://r-forge.r-project.org/projects/tuner/ (accessed on 16 January 2022).
95. Villanueva-Rivera, L.J.; Pijanowski, B.C.; Doucette, J.; Pekin, B. A Primer of Acoustic Analysis for Landscape Ecologists. *Landsc. Ecol.* **2011**, *26*, 1233. [CrossRef]

96. Zeileis, A.; Kleiber, C. Ineq: Measuring Inequality, Concentration, and Poverty, CRAN—Package Ineq. Available online: https://cran.r-project.org/web/packages/ineq/index.html (accessed on 17 March 2021).
97. Fuller, S.; Axel, A.C.; Tucker, D.; Gage, S.H. Connecting Soundscape to Landscape: Which Acoustic Index Best Describes Landscape Configuration? *Ecol. Indic.* **2015**, *58*, 207–215. [CrossRef]
98. Ahern, J. Urban Landscape Sustainability and Resilience: The Promise and Challenges of Integrating Ecology with Urban Planning and Design. *Landsc. Ecol.* **2013**, *28*, 1203–1212. [CrossRef]
99. Tsaligopoulos, A.; Karapostoli, A.; Radicchi, A.; Economou, C.; Kyvelou, S.; Matsinos, Y.G. Ecological Connectivity of Urban Quiet Areas: The Case of Mytilene, Greece. *Cities Health* **2019**, *5*, 20–32. [CrossRef]
100. Kyvelou, S. The Urban Question in the Context of the "Double World". *Homo Virtualis* **2019**, *2*, 108–112. [CrossRef]