INTER-NOISE 2007
28-31 AUGUST 2007
ISTANBUL, TURKEY

Soundscape quality in urban open spaces

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ABSTRACT

Guideline values for traffic-noise exposure in urban outdoor spaces are missing, mainly due to the lack of knowledge on the effect of noise on perceived soundscape quality. For this reason, questionnaire studies were conducted in several urban open spaces in the Stockholm area. The areas included a wide range of soundscapes, from highly traffic-noise exposed city parks to quiet suburban open spaces. Consistent relationships were found between measured overall sound levels and perceived soundscape quality. However, sound source identification was found to be a stronger predictor of soundscape quality than measured sound levels. Soundscape quality was negatively related to presence of technological sounds (e.g., road-traffic noise) and positively related to presence of nature sounds. These relationships remained also after controlling for overall measured sound level. Taken together, the results suggest, as a rule of thumb, that good soundscape quality in urban open spaces would require day-time traffic-noise exposure below 50 dBA. In situations with exposures between 50 and 55 dBA, soundscape design that promotes positive sounds from nature may be efficient in improving soundscape. At higher levels, soundscape design has to be complemented with traditional noise control measures in order to achieve good soundscape quality.

1 INTRODUCTION

Outdoor open spaces provide opportunities for relaxation and stress recovery. In urban areas, noise pollution is a threat to these health-promoting functions of outdoor spaces. Therefore, the EC-directive on environmental noise points out the need to preserve existing quiet urban areas [1]. Unfortunately, guideline values for quiet urban areas are typically missing, mainly due to the lack of knowledge of the effect of noise on perceived soundscape quality in outdoor areas.

This paper presents research on soundscape perception in city parks and suburban green areas, conducted in the Swedish multidisciplinary research program “Soundscape Support to Health”. The primary goal was to determine how perceived soundscape quality is related to combination of adverse and positive sounds in the environment. Such knowledge is needed for defining guideline values grounded in soundscape perception and for guiding soundscape design that promotes positive sounds [2-5].

Two questionnaire studies in city parks and suburban green areas were conducted in the research program. The first study (Field Study I), was carried out in the summer of 2004 in cooperation with the Swedish Environmental Protection Agency and the City of Stockholm. The main purpose of the study was to compare perceived soundscape quality in suburban

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Figure 1. Data collection in the field. Photographs from Field Study I, left (photo: Östen Axelsson), and Field Study II, right (photo: Nader Faharani).

green areas and city parks, and to relate perceived quality of soundscapes to measured overall sound levels. Detailed description of this study is found in Nilsson & Berglund [3, 6].

The second study, conducted in the summer of 2006, was carried out in cooperation with the City of Stockholm. The study was an extension of Field Study I, including a larger set of areas, a larger number of visitors, and more detailed sound measurements. The goal was to obtain a great variation in perceived soundscape quality across areas.

2 METHODOLOGY

In both studies, visitors in city parks and suburban green areas filled in questionnaires including detailed questions on soundscape perception. Personnel from Stockholm University was stationed at specific pre-selected places in the investigated areas, and everyone that passed this place was approached and asked to participate in the study in exchange of a small gift. Sound levels were measured during data collection at a place close to where the respondents filled in the questionnaire. In Field Study I, 286 visitors completed the questionnaire; 30-40 in each area. In Field study II, 1116 visitors completed the questionnaire, 65-73 in each area. Figure 1 shows photographs from data collection in Study I (left) and II (right).

2.1 Areas

In Field Study I, four suburban green-areas and four city parks in the greater area of Stockholm were investigated. The four suburban areas were located at great distances from major roads, railways and airways. The city parks were close to major roads, but not to major railway or airway lines.

In Field Study II, 16 areas in Stockholm were investigated, four of which were also included in Field Study I. Three of the areas in Field Study II were located outside the city, and were at great distances from major roads, railways and airways. The remaining 13 areas were city parks located close to major roads, but not to major railway or airway lines.

According to noise maps produced by the city of Stockholm, the city park's exposure in both Field Study I and II were between 45 and 65 dB L_{day}.

2.2 Questionnaires

The questionnaire used in Field Study I contained 29 questions, which were answered in approximately 15 min. Perceived soundscape quality was assessed with a single question "How would you describe the area with respect to its sound environment, as you experienced it during today's visit?" Answers were to be given on a five-point bipolar category scale with the response alternatives "very good", "good", "neither good, nor bad", "bad" and "very bad". The questionnaire also contained detailed questions on the identification and the evaluation of specific sound sources. Source identification was assessed on a three-point

category scale with the response alternatives “never”, “sometimes”, and “often”. Sounds heard during the visit in the area were evaluated on a three-point bipolar category scale with the response alternatives: “pleasant”, “neutral”, and “annoying”.

The questionnaire used in Field Study II contained 19 questions, which were answered in approximately 10 min. The overall soundscape quality was assessed on the same scale that was used in Study I. The questionnaire also included questions on perception of sound sources. Unlike the questionnaire in Study I, which asked *how often* specific sounds were heard, the questionnaire in Study II asked to which *degree* sounds *dominated* the soundscape. Three sound-source categories were assessed on a five-point category scale with the response alternatives “not heard”, “heard a little”, “heard moderately”, “heard a lot” and “completely dominating”. The categories were (i) sounds from humans, e.g., people talking and children at play, (ii) sounds from nature, e.g., bird song and wind in the leaves, and (iii) technological sounds, e.g., road-traffic noise and ventilation noise.

2.3 Sound level measurements

In Field Study I, 15-min sound level measurements were conducted close to the place where the respondents filled in the questionnaire. Measured equivalent sound levels ranged from 44 to 47 dB in the suburban green areas, and from 51 to 58 dB in the city parks ($L_{Aeq,15min}$). More detailed measurements were conducted in Field Study II. One-third octave-band sound levels were measured continuously, each 0.1 s, at a place close to where the respondents filled in the questionnaire. Measured equivalent sound levels during data collection ranged from 43 to 62 dB ($L_{Aeq,4h}$). For each participant, the 10-min time period during which the questionnaire was filled in was identified. For each such 10-min period, a number of acoustic indicators were calculated from the measured 1/3-octave-band sound levels [7].

3 MAIN RESULTS AND DISCUSSION

The following presentation focuses on perceived soundscape quality and its relationship to the perception of sound sources and measured sound levels. The presentation below is restricted to the area level. That is, individual responses within an area are summarized in one value, for example, the proportion of respondents who assessed the soundscape as good or very good. Individual differences in soundscape perception were found to be related to person factors, such as age of visitors and the purpose of their visit. However, between-area differences in person factors did only explain a small part of the between-area variation in soundscape quality [3].

Table 1 gives measured sound levels and proportions of visitors considering the soundscape to be good or very good for the four areas common to Field Study I (year 2004) and II (year 2006). The agreement between the two studies was found to be high, suggesting that both acoustic and perceptual properties of the soundscape were stable over time in these areas.

3.1 Criteria of good soundscape quality

In Sweden, national agencies have suggested a perceptual definition of good soundscape quality in outdoor areas, namely, that at least 80 % of visitors should consider the soundscape to be of good quality [8]. In order to evaluate this criterion, Nilsson and Berglund [3] defined good soundscape quality in terms of the proportion of participants that found the soundscape to be “good” or “very good” (five-point bipolar category scale, see Section 3.2). The stipulated goal of 80 % was fulfilled in four areas in Field Study I, and in three areas in Field Study II. All these areas were located outside the city, at large distances from major roads. In the city parks, the proportion of satisfied visitors was always below 80 %; between 65 and

Table 1. Comparison of results from Field Study I (2004) and Field Study II (2006).

	Sound level[a]		Soundscape quality [b]	
Area No.	Study I	Study II	Study I	Study II
3.	46 dB	49 dB	84 %	88 %
4.	53 dB	53 dB	65 %	77 %
8.	51 dB	51 dB	58 %	64 %
11.	58 dB	57 dB	53 %	47 %

[a]Study I: LAeq,15min. Average of five to seven 15-min measurements; Study II: LAeq,4h. Average of two 4-h measurements

[b]Percent of visitors assessing the soundscape as "good" or "very good".

53 % in Field Study I and between 77 and 9 % in Field Study II. Thus, city park soundscapes were generally inferior to soundscapes in recreational areas outside the city.

3.2 Soundscape quality and sound source perception

In both studies, perceived soundscape quality was found to be strongly related to sound source perception. In Field Study I, soundscape quality was found to be considerably better in the suburban areas than in the city parks. More than 70 % of the respondents in the city parks reported that they often had heard technological sounds, compared to 40 % in the suburban green areas. Interestingly, there was no corresponding difference in how often nature sounds were heard. For instance, more than 80 % of the visitors in both suburban green areas and city parks had often heard bird song during their visit in the area. Thus, technological sounds did not mask sounds from nature, and the presence of nature sounds in the city parks did not compensate for the presence of technological sounds.

In Field Study II, the question on source perception was rephrased in order to measure the *degree of dominance* of sound sources within the soundscape. Each of the three categories (i) nature sounds, (ii) sounds from human activity, and (iii) technological sounds was assessed with respect to the degree to which they were dominating the soundscape. Figure 2 shows the proportion of respondents who reported that sounds from a given source category was "heard a lot" or "dominated completely". The 16 areas are numbered with respect to the proportion of visitors that considered the soundscape to be "good" or "very good", from Area 1 (97 %) to Area 16 (9 %).

As expected, nature sounds (green bars) were the most dominating sounds in areas with good soundscape quality, whereas technological sounds (red bars) were the most dominating sounds in areas with low soundscape quality. Sounds from human activity (yellow bars) were not strongly related to soundscape quality. This agrees with results from Field Study I, in which sounds from humans were evaluated as "neutral", whereas sounds from nature and technological sounds were evaluated as "pleasant" and "annoying", respectively [3]. Correlation analyses confirmed that soundscape quality was negatively related to dominance of technological sounds and positively related to dominance of nature sounds. These relationships remained also after controlling for overall measured sound level. In fact, dominance of technological sounds was found to be a better predictor of soundscape quality than measured sound level [7]. This agrees with previous research which has shown that sound-source perceptions is the main determinant of perceived soundscape quality [2, 4, 5].

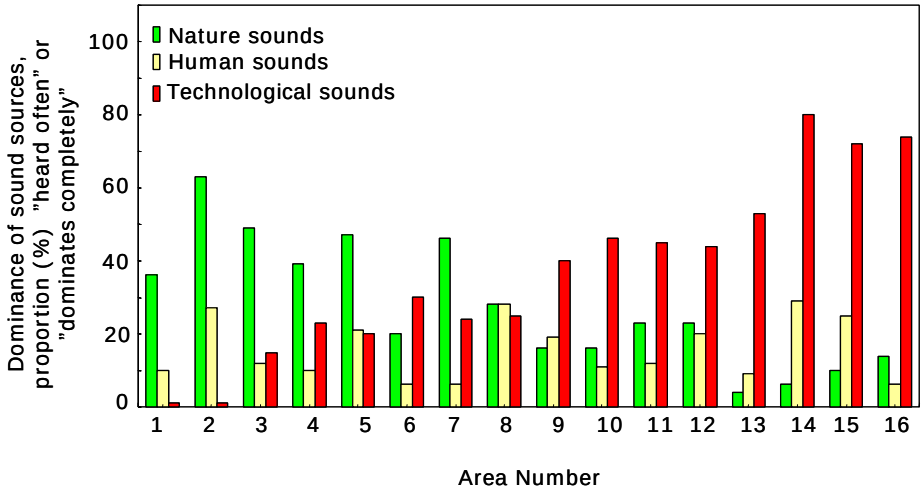

Figure 2. Proportion of visitors perceiving sound-source categories to be "heard often" or to "dominate completely". Data from Field Study II. The 16 areas are numbered with respect to the proportion of visitors that considered the soundscape to be "good" or "very good", from Area 1 (97 %) to Area 16 (9 %).

3.3 Perceived soundscape quality and measured sound level

In Field Study I, measured equivalent sound levels ($L_{Aeq,15min}$) were below 50 dB in the suburban areas, and above 50 dB in the city parks. Road-traffic noise was the main reason for the higher levels in the city parks, and it was also the most annoying source. Based on these findings it was suggested, as a rule-of-thumb, that road-traffic noise in outdoor areas should be below 50 dB in order to assure good soundscape quality [3]. Of course, this has to be interpreted with caution. Positive sounds from nature will also contribute to the measured overall sound level, along with adverse sounds such as traffic noise. Consequently, overall sound level is not an indicator of soundscape quality. The 50 dB rule-of-thumb suggested above should therefore be understood as referring to *adverse* sounds only, such as traffic noise. It should also be observed that this rule refers to day time levels, and it is in agreement with our research program's definition of quiet sides in residential areas, based on 24-h equivalent sound level ($\leq$45 dB $L_{Aeq,24h}$).

A main goal of Field Study II was to determine the relationship between perceived soundscape quality and measured sound level, for a larger set of areas and a greater variation of noise exposures than included in Field Study I. Furthermore, sound levels were measured continuously during data collection in Field Study II, whereas only selected 15-min periods were measured in Field Study I.

Figure 3 shows the relationship between measured sound level ($L_{Aeq,4h}$) and the percentage of respondents perceiving the soundscape as "good" or "very good". The line shows the best fitting logistic function. According to this function, 80 % satisfied visitors correspond to 49 dB. These findings agree with the conclusion of Field Study I, namely that the overall sound level should be below 50 dB in order to assure good soundscape quality. A great variation in soundscape quality was found for areas in the interval 50-55 dB. For example, 77 % of the visitors to Area 4 (53 dB) assessed the soundscape as good or very good, whereas the corresponding proportion was only 40 % for Area 13 (53 dB). One difference between these areas was the dominance of nature sounds, which was considerably

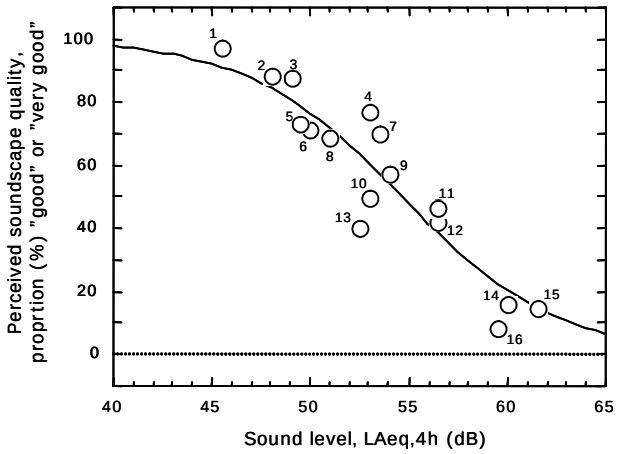

Figure 3. Proportion of visitors perceiving the soundscape quality as “good” or “very good”, as a function of measured sound level (LAeq,4h). Data from Field Study II. Numbers refer to area number (cf. Fig. 2).

higher in Area 4 compared to Area 13 (see Figure 2). This suggests that soundscape design based on promotion of positive sounds from nature may be efficient. At levels above 55 dB, less than 50 % of the visitors assessed the soundscape as good or very good.

4 CONCLUSIONS

(1) Areas with good soundscape quality (more than 80 % of visitors considering the soundscape to be “good” or “very good”), were only found in areas outside the city, at great distances from major roads.

(2) Perception of sound sources within the soundscape was found to be a better predictor of soundscape quality than measured sound levels. Soundscape quality was negatively related to dominance of technological sounds (e.g., road-traffic noise) and positively related to dominance of nature sounds. These relationships remained also after controlling for overall measured sound level.

(3) Taken together, the results suggest, as a rule of thumb, that good soundscape quality in urban open spaces would require day-time traffic-noise exposure below 50 dBA. [This rule refers to day time levels, and it is in agreement with our research program’s definition of quiets sides in residential areas, based on 24-h equivalent sound level, ≤ 45 dB $L_{Aeq,24h}$]. In situations with exposures between 50 and 55 dBA, soundscape design based on promotion of positive sounds from nature may be efficient. At higher levels, soundscape design has to be complemented with traditional noise control measures in order to achieve good soundscape quality.

5 ACKNOWLEDGEMENTS

This research was conducted in the research programme “Soundscape Support to Health”, sponsored by the Swedish Foundation for Strategic Environmental Research (MISTRA), the Swedish Agency for Innovation Systems (Vinnova) and the Swedish National Road Administration (VV). The field studies were also sponsored by the Swedish Environmental Protection Agency and the City of Stockholm. Thanks go to Kyriakos Zachariadis, Swedish Environmental Protection Agency, and Magnus Lindqvist, the City of Stockholm, for their valuable contribution to the design of the studies. Thanks also goes to Östen Axelsson, Erika Gyllensvärd Wentzel, Owe Gustavsson and Nader Farahani for valuable assistance in collecting and analyzing research data.

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