Pilot study on acceptable sound levels in scenic areas

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Abstract: The intrusion of road traffic noise in scenic areas is one of the key issues in managing acoustic quality. Several studies focused on acceptable sound levels for road traffic noise in such areas; however, most of them estimated acceptable sound levels from the dose-response relationship between sound levels and annoyance or evaluation of acoustic comfort, and few studies investigated acceptable sound levels directly. We directly investigated the acceptable sound levels for road traffic noise in scenic areas in Japan by conducting psycho-acoustic experiments involving a group of participants. Two simulated road traffic noises were used as target sounds, and four audio and video recordings were used as background conditions. By a method of adjustment, the participants were required to adjust the playback level of each target to a maximum acceptable level while comparing the background sound levels. The results showed that the acceptable sound levels cannot be explained by a simple value or a simple signal-to-noise ratio (SNR). There is a clear tendency that a higher SNR, which means that road traffic noise can be heard more clearly, is acceptable in a quieter area. The acceptable sound levels of scenic areas are largely dependent on the evaluators and features of the areas.

Keywords: Acceptable sound levels, Acoustic quality, Scenic areas, Signal-to-noise ratio

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1. INTRODUCTION

Scenic areas, whether natural or historic, are areas where people visit to enjoy not only the scenery but also the ambience, including sounds. Therefore, these areas must be managed as areas of high acoustic quality [1].

In this sense, the National Park Service (NPS) in the US, which manages not only natural parks but also cultural and historical parks, has soundscape management policies [2], and has been developing methods of managing park soundscapes [3]. Similarly, the Department of Conservation (DOC) in New Zealand, which manages protected natural and historic areas, also manages recreational noise issues at those areas [4]. Furthermore, one of the aims of the EU Directive 2002/49/EC (END) [5] is preserving “quiet areas,” including natural and rural areas where the acoustic quality is good. These facts clearly show that the preservation of areas of high acoustic quality is a common issue in many countries.

Various studies within regions and countries have revealed that the intrusion of traffic sounds into areas where high acoustic quality is required is a key issue to address in managing acoustic quality [1–4,6–9]. Scenic areas in Japan also have the same difficulty. In particular, Japanese environmental quality standards for noise were established only to regulate disturbances in daily life [10], and there are also no other standards or guidelines for the preservation of tranquility. Therefore, the Tokyo District Court stated in a judgement that it is legally impossible to preserve tranquility [11]. In this background, discussions on the standards or guidelines of acceptable sound levels in areas of high acoustic quality are needed in Japan. Furthermore, the European Environmental Agency Expert Panel on Noise (EPoN) [12] reviewed the state of the art concerning approaches to quiet areas and proposed that more research studies on the dose-response relationship of perceived acoustic quality/appreciation and sound-pressure levels in quiet areas are required. In this way, more discussion on acceptable sound levels in areas where high acoustic quality is required is needed. To discuss the acceptable sound levels in such areas, we need scientific data on acceptable sound levels for traffic noise in such areas.
The acceptable sound levels in areas of high acoustic quality have mainly been discussed on the basis of dose-response relationships, and those discussions are divided roughly into two types: annoyance-based discussions and satisfaction-based discussions. The annoyance-based discussions originate from the assessment of the effects of transportation noise on communities in residential settings, which underlies the community noise policies of many countries [13]. In those discussions, the relationship between noise exposure and the percentage of visitors who report annoyance and/or interference with the natural quiet is focused on. For example, Krog and Engdahl examined the relationship between aircraft noise exposure and annoyance in local recreational areas [14,15], and Anderson et al. analyzed the relationship in natural parks [16]. Although there is no doubt that an acceptable sound level in a certain place has a strong relationship with the percentage of annoyed visitors at that place, whether a certain sound level is acceptable or not is not the same as whether the level is annoying or not. Therefore, the acceptable sound level cannot be determined directly on the percentage of annoyed visitors. Fidell pointed out that the definition of any particular value of noise exposure as a significant noise impact from this kind of dose-response relationship is inescapably arbitrary [13].

The satisfaction-based discussions emerged from soundscape studies. Yang and Kang analyzed the relationships between the measured sound levels and the subjective evaluation of the sound levels and the measured sound levels and the acoustic comfort evaluation in urban open public spaces across Europe, and revealed that people tended to show more tolerance in terms of acoustic comfort evaluation [17]. Nilsson and Berglund [7] investigated the soundscape quality in suburban green areas and city parks, and concluded that good soundscape quality in those areas would require traffic noise exposure to be below 50 dB ($L_{Aeq}$) during daytime. De Coensel and Botteldooren studied quiet rural soundscapes and proposed less than 35 dB ($L_{A50}$) as one of the important limit values in rural areas [18]. Meanwhile, Brambilla et al. [9] pointed out that there exist city parks where the acoustic quality is good even though the sound levels at these parks exceed 50 dB ($L_{Aeq}$), and advocated that the use of A-weighted equivalent sound pressure levels is insufficient to describe the quality of a sound environment. Here, whether a certain sound level is acceptable is not the same as whether the level is comfortable. Therefore, although it can be rational to think that a good or comfortable acoustic environment is also an acceptable one, the acceptable sound levels of a certain place cannot be derived directly from discussions of acoustic comfort.

In addition, it is considered that the acceptable sound levels in areas of high acoustic quality depend on the landscape quality of the areas. There are several studies that emphasize this point of view. For example, Tse et al. pointed out that an individual’s acceptability of the environment is affected more by the visual comfort evaluation of the landscape than by acoustic comfort [8]. Pheasant et al. investigated the effects of audio-visual interaction on the perception of tranquility in urban and rural environments, and proposed a method of calculating the Tranquility Rating using the sound level and the percentage of natural features present within a scene [19]. Furthermore, Watts and co-workers developed and proposed the provisional guidelines of the acceptable levels of tranquility using their Tranquility Rating [20,21], but the grounds of their guidelines were unclear.

In this way, previous mainstream studies related to the acceptable sound levels in areas of high acoustic quality did not directly examine the acceptable sound levels. This is why we think that the acceptable sound levels in areas of high acoustic quality should be directly analyzed.

Furthermore, considering the viewpoint of soundscape studies [22], it is possible that the acceptable sound levels in areas of high acoustic quality are affected by cultural and social contexts. Therefore, to discuss the acceptable levels for Japan, we also need local scientific data. Thus, in this study, we investigated the acceptable sound levels for road traffic noise in scenic areas by conducting psycho-acoustic experiments involving a group of participants.

2. TARGET SITES

The acceptable sound levels of parks vary depending on the characteristics of the respective areas, e.g., the main purpose of the visitors [3,6,23]. Thus, it is reasonable to assume that the acceptable sound levels in areas of high acoustic quality also vary depending on area characteristics. Therefore, the target sites in this pilot study were limited to scenic areas where people visit to enjoy not only the scenery but also the sounds heard in those areas. Three different scenic sites described below were selected for this study.

The first site was the observation deck at Mt. Takao, a quasi-national park located just outside Tokyo. This mountain site has been considered sacred and has been a place for training of Buddhist mountain ascetics. Therefore, the nature of the mountain surroundings has been well preserved for a long time. The observation deck is located halfway up the calm approach to Yakuo-in Temple (established in the 8th century). From this site, visitors can enjoy a distant view of metropolitan Tokyo beyond the mountain.

The second site was Ouchi-juku, a historical post-station town with a canal in Fukushima Prefecture. The landscape of the Edo period (from the 17th to 19th centuries) is well-preserved in this post-station town. This
town is also famous for the water sound from the canal, and therefore, was selected by the Environmental Agency in 1996 as one of the "100 Soundscapes of Japan: Preserving Our Heritage" [24]. No vehicles are allowed in this post-station town.

The third site was a seashore in Noto Peninsula in Ishikawa Prefecture. It has been said that the sound of the sea is one of the favorite sounds of Japanese folk. Indeed, at the public offering of "100 Soundscapes of Japan: Preserving Our Heritage," almost one-tenth of the recommendations of the natural soundscapes were those of the sea around Japan, and ultimately, nine sea soundscapes were selected for "100 Soundscapes of Japan: Preserving Our Heritage" [24]. The seashore selected for this study is a typical sandy beach facing the Japan Sea. Few vehicles pass through the nearest road from this site, and their sounds are masked by the wave sounds.

In each site, the environmental sounds were recorded using a digital PCM audio recorder (TASCAM, Japan, DR-100) with a Head and Torso Simulator (HATS: Brüel and Kjær, Denmark, Type 4100), and landscape scenes were recorded simultaneously with a high-definition video camera (Cannon, Japan, iVIS HF M31) to provide visual background stimuli for the psycho-acoustic experiments. For all recordings, the camera and HATS were directed at the scene toward which visitors would turn their heads to enjoy. Figure 1 shows the sceneries of those locations captured from the video recordings. Before taking sound recordings at each site, a calibrated signal was recorded using a sound calibrator (Brüel and Kjær, Denmark, Type 4231).

3. METHODS

In this study, the acceptable sound levels of road traffic noise in scenic areas were estimated by the method of adjustment using sound and video recordings of the scenic areas as background stimuli and sound recordings of road traffic noises as target stimuli. The experimental method is described below.

3.1. Background Stimuli

Background stimuli were made from the audio and video recordings described above. Approximately two continuous minutes of recordings were selected. The selection criterion for these recordings was for more natural sounds (such as birds chirping) with low-level background noise (such as wind noise). With regard to the recordings taken on the observation deck at Mt. Takao, acoustic environments varied depending on whether parties of visitors were passing through the approach behind the recording point. Therefore, two recordings were offered as background stimuli for Mt. Takao. The sounds of visitors, such as voices and footsteps, were recorded in the two stimuli for Mt. Takao (MT1 and MT2) and the stimulus for Ouchi-juku (PST), whereas no man-made sounds were recorded in the stimulus for the seashore (SEA). In all four stimuli, no vehicle sounds were recorded. The sound levels of the four background stimuli are listed in Table 1. The averages of A-weighted equivalent sound pressure levels ($L_{Aeq}$) of both channels in the respective stimuli given in Table 1 were calculated from the antilog of decibel values from each channel, and the logarithms of these values were used in the following analyses [25]. The power spectra of background stimuli are shown in Fig. 2.
3.2. Target Stimuli

The target stimuli were two simulated highway noises with the sound originating from behind the visitor; one specification for these noises was that the highway had to run parallel (Target 1) or at a $\pi/4$ radian angle (Target 2) to both ears of the visitor. To obtain these stimuli, highway noises were recorded at the roadside of the Tohoku expressway under the two conditions, using a digital audio recorder with HATS. The stimuli were generated with noise from a solitary standard-sized car and a heavy truck, selected from the recordings. In both stimuli, the sound of the car appeared 20 times and that of the truck appeared 10 times in 105 s, and the car and the truck appeared in the same order and the same timing of a 105 s exception from our recording at the roadside. This condition approximately corresponded to an average road condition of the recording site: that is, the total traffic volume is 1,000 vehicles per hour, with a truck percentage of 33%. The maximum sound pressure levels from the cars in both stimuli were the same, as they were also for the trucks. Table 2 lists the relative sound levels of target stimuli subject to the condition that the maximum levels of both sounds established the reference level (0 dB). The power spectra of target stimuli are shown in Fig. 3.

3.3. Participants

Thirty-seven participants (17 males and 20 females, aged between 15 and 57 with average age of 22.8 and S.D. of 7.9) took part in the experiments. According to participant questionnaires, no participants had ever been diagnosed with hearing loss.

3.4. Procedure

In the experiment, first, one of the background stimuli (environmental sounds and video images) was played through headphones (Senheiser, Germany, HD-650) and a 40-inch high-definition TV (Sony, Japan, KDL-40EX500) approximately 1.5 m in front of the participant. The sound levels of the background stimuli were set to the recorded values. Then, about 10 s later, using a sound mixer (Mackie, US, 802-VLZ3), one of the target sounds (the Table 1 A-weighted sound levels of background stimuli (environmental sounds).

| Recording point          | Channel | $L_{Aeq}$ [dB] | $L_{A_{max}}$ [dB] | $L_{A5}$ [dB] | $L_{A05}$ [dB] | $L_{A5} - L_{A05}$ [dB] | Average [dB] |
|-------------------------|---------|----------------|--------------------|---------------|----------------|--------------------------|---------------|
| MT1 (Mt. Takao with many visitors) | L       | 72.0           | 87.3               | 77.0          | 62.8           | 14.2                     | 71.4          |
|                         | R       | 70.8           | 83.9               | 76.5          | 58.0           | 18.5                     |
| MT2 (Mt. Takao with few visitors) | L       | 45.3           | 57.1               | 49.4          | 40.3           | 9.1                      |
|                         | R       | 46.3           | 60.9               | 50.4          | 40.3           | 10.1                     |
| PST (Post-station town) | L       | 57.8           | 67.2               | 60.3          | 55.4           | 4.9                      |
|                         | R       | 55.0           | 63.5               | 57.9          | 52.2           | 5.7                      |
| SEA (Seashore in Noto)  | L       | 66.3           | 69.2               | 67.7          | 64.8           | 2.9                      |
|                         | R       | 64.9           | 68.4               | 66.4          | 63.5           | 2.9                      |

Table 2 A-weighted relative sound levels of the target stimuli (road traffic sounds).

| Road traffic condition | Left channel | Right channel | Average $L_{Aeq}$ [dB] |
|------------------------|--------------|---------------|-------------------------|
| Target 1               | $L_{A_{eq}}$ [dB] | $L_{A_{max}}$ [dB] | $L_{A_{eq}}$ [dB] | $L_{A_{max}}$ [dB] | $L_{A_{eq}}$ [dB] | $L_{A_{max}}$ [dB] | $L_{A_{eq}}$ [dB] |
| The highway parallel to both ears of the visitor | $-8.5$ | $0.0$ | $-10.8$ | $-2.7$ | $-9.5$ |
| The highway at a $\pi/4$ angle to the direction of both ears of the visitor | $-9.4$ | $-3.2$ | $-6.9$ | $0.0$ | $-8.0$ |
simulated road traffic noise) was played simultaneously. The experimental setup is shown in Fig. 4.

The participants were asked to adjust the playback level of each target to a maximum level acceptable to them under the conditions below, using the fader on the mixer while comparing the background sound levels. Regarding the conditions, participants were instructed to imagine that they were in the place shown in the video images enjoying the scenery. They were also told that the traffic noise comes from a highway located behind them, and therefore, they could not see the road at all unless they looked behind.

The background and target stimuli were repeated until the participants declared that they had finished the adjustment. The fader of the mixer has a scale; however, the participants watched the monitor attentively while they adjusted the sound levels, and therefore, we think that the scale was not an important clue for the participants to adjust the level.

After the participants had adjusted the playback level for each target, they removed their headphones, and then a 1-kHz-tone standard sound was recorded at the setting of the mixer-fader selected by the participants. The standard sound adjusted to 94 dB was also recorded. The adjusted playback levels were measured by comparison with these sound levels.

All stimulus combinations were presented once in a pseudo-random order in each trial. Owing to mistakes by the experimenters, five participants adjusted only the playback levels of Target 1, and two participants adjusted only the playback levels of Target 2. In this study, the results of Targets 1 and 2 were analyzed separately; therefore, the data obtained from those participants were included in the following analysis.

All participants took part in two trials to check for intra-individual differences. Twenty-two participants took part in two same-day trials with about a 10 min break between trials; the other fifteen participants took the second trial some days later.

Prior to the experiments, the participants were given a brief explanation of the experiment. They then watched once through all background stimuli (environmental sounds and video images). After the first trial, they were asked for their preference on natural environments and whether they drive cars. Also, after each trial, they were asked to describe their impression of the experiments. The experiments were performed in a soundproofed room at Fukushima University.

4. RESULTS

4.1. Intra-individual Differences of Adjusted Acceptable Levels for Each Participant

Figure 5 shows, for each of the four environmental conditions, the intra-individual differences of the adjusted acceptable levels for each participant; Fig. 5(a) shows the results of Target 1, and Fig. 5(b) shows those of Target 2. Both figures show that although there are a few intra-individual differences over 10 dB, almost 70% (67.8% in Fig. 5(a) and 76.5% in Fig. 5(b)) of the intra-individual differences were within 5 dB. The participants whose largest intra-individual difference exceeded 10 dB or three or more intra-individual differences exceeded 5 dB for the various target sounds were considered to be inconsistent evaluators, and therefore, their data were eliminated from the analysis. Consequently, only the data from 23 partic-
Participants for Target 1 and 26 participants for Target 2 were analyzed. Eight participants were eliminated from the analysis of both targets.

Next, the intra-individual differences of the adjusted acceptable levels for the participants who took part in the two same-day trials and those for the participants who took part in the two separate-day trials were compared. The averages of the absolute intra-individual differences for the participants who took part in the two same-day trials were 2.9 dB (S.D. 2.3 dB) for Target 1 and 2.5 dB (S.D. 1.8 dB) for Target 2. Also, the averages for the participants who performed the two separate-day trials were 3.0 dB (S.D. 2.3 dB) for Target 1 and 3.0 dB (S.D. 2.4 dB) for Target 2. The $t$-tests between the same-day trial responses and the separate-day trial responses showed no statistical differences between those two groups under both target conditions. Therefore, the participants were not separated by how the two trials were taken in the analysis.

Finally, the differences in the adjusted acceptable levels between the first-trial and second-trial responses were analyzed. The paired $t$-tests showed no statistical differences between the first-trial and second-trial responses. Therefore, the averages of the first and second trials of the participants were considered in the following analysis.

### 4.2. Acceptable Sound Levels of Road Traffic Noise under Each Condition

Table 3 lists the averages, standard deviations, and medians of the acceptable sound levels of road traffic noise under each environmental and road traffic condition. The acceptable levels of road traffic noise for Targets 1 and 2 are quite similar if the background environmental conditions are the same. Regarding the standard deviations of the results, those of MT1 and MT2 are greater than those of PST and SEA.

Next, interindividual differences of the acceptable sound levels were focused on. Figure 6 shows the relationship between the environmental sound levels and the acceptable sound levels of the road traffic noise for all participants. Clearly, although the interindividual differences in absolute sound levels are large, the relative relationships between the acceptable sound levels of road traffic noise at each environment, that is, the acceptable sound level is lower when the environmental sound level is lower, are similar between respective participants.

In addition, it seems that the relationship between the environmental sound levels and the acceptable sound levels

![Graph](image1)

![Graph](image2)

**Table 3** Acceptable sound levels ($L_{Aeq}$) of road traffic noise under each condition.

|       | Target 1 | Target 2 |
|-------|----------|----------|
|       | Average [dB] | S.D. [dB] | Median [dB] | Average [dB] | S.D. [dB] | Median [dB] |
| MT1   | 60.1      | 10.5     | 60.6       | 61.1        | 9.4       | 60.4       |
| MT2   | 47.9      | 11.5     | 46.8       | 49.3        | 10.3      | 48.5       |
| PST   | 51.0      | 8.6      | 50.7       | 52.1        | 6.7       | 51.2       |
| SEA   | 59.0      | 7.9      | 58.8       | 59.0        | 8.3       | 59.2       |
for each environment is linear for many participants: for example, the numbers of participants whose correlation coefficient between the environmental sound levels and the acceptable sound levels is over 0.7 are 17 (73.9%) for Target 1 and 23 (88.5%) for Target 2. The fitted regression lines between the environmental sound levels and the acceptable sound levels are obtained for each participant whose correlation coefficient between the environmental sound levels and the acceptable sound levels is over 0.7. As a result, the averages of the slopes of the fitted regression lines for each participant are 0.63 (S.D. 0.20) for Target 1 and 0.54 (S.D. 0.18) for Target 2, and all the slopes are under 1.0. This result indicates that participants tend to be more tolerant to the signal-to-noise ratio (SNR) (here, signal means the road traffic noise, and noise means background noise at each environment) in quieter environments.

Regarding the intercepts of the fitted regression lines, the averages for each participant are 16.0 (S.D. 15.8) for Target 1 and 21.5 (S.D. 13.3) for Target 2. Although a general tendency of the larger the slope, the smaller the intercept was found, no other features were found regarding the relationship between the slopes and the intercepts.

A two-way repeated-measures analysis of variance (ANOVA; factors: environmental conditions and target conditions) was applied to the data from the participants whose data were analyzed under both target conditions. As a result, significant differences between the environmental conditions \( (p < 0.01) \) and between subjects \( (p < 0.01) \), but not between target conditions were found.

5. DISCUSSION

The intra-individual differences of the two trials were almost within 5 dB, regardless of whether the participants took part in the same-day or separate-day trials. Several studies have shown that many people can recall the levels of the familiar sounds quite accurately [26,27]. Considering this fact, our results suggest that many of the participants have their own steady internal assessment standards of the acceptable sound levels of road traffic noise in scenic areas, and can reproduce those levels using recorded road traffic noise. Because this study is a pilot study for analyzing the acceptable sound levels directly, it gives weight to depicting the general tendencies of the relationship between the acceptable sound levels and the environmental sound levels in scenic areas. Thus, consistent evaluators were selected on the basis of the strict rules described in Sect. 4.1. However, more than 65% (66% for Target 1 and 81% for Target 2) of the participants were selected as consistent evaluators, and the data from 29 participants (79%) were analyzed for at least one target. This means that it is possible, and it also seems reasonable
to directly ask even ordinary people for the acceptable sound levels of road traffic noise in scenic areas.

Our results suggest that the participants’ internal assessment standards vary widely from person to person. Some participants who adjusted target sound levels to relatively low levels clearly mentioned after their trial that they had adjusted the sound levels of targets to levels at which the sounds of heavy trucks were audible only if they attentively listened for them. Nevertheless, some participants adjusted levels to where road traffic noise was easily heard. In particular, one participant explicitly stated that he never minded the sounds of vehicles.

In addition, as described in Sect. 2, how a place should sound depends on its purpose. In general, according to Miller, it is considered that sensitivity to road traffic noise is lower in places where importance is given to easy access than in places where the importance is placed on the ambience of the place [3]. In addition, it is known that visitors at viewpoints are more tolerant to aircraft noise than visitors taking short hikes in scenic U. S. National Parks [16]. Therefore, the belief is that people who want easy access to scenic places tend to be more tolerant of intrusive road traffic noise. This can be one of the reasons for the wide range in the participants’ internal assessment standards. Therefore, decision making regarding the purpose of places is essential in setting environmental quality standards in scenic areas.

Although the internal assessment standards vary widely, the relative relationships between the environmental sound levels and the acceptable intrusive road traffic noise levels for each participant were similar. Because the environmental conditions as well as road traffic conditions in this study were not sufficiently varied, we cannot judge whether a linear relationship really exists. However, we can infer that although the acceptable levels of intrusive road traffic noise in scenic areas depend on the environmental sound levels at each place, the relationship between the environmental sound levels and the sound levels of road traffic noise cannot be described by a simple SNR. There is a clear tendency that a higher SNR, which means that road traffic noise can be heard more clearly, is acceptable in a quieter area. This tendency suggests that the audibility of road traffic noise is not a major issue for people who just want to enjoy the scenery, if the overall sound level is sufficiently low. This corresponds well to the finding of Tse et al. that an individual’s acceptability of the environment is affected more by the visual comfort evaluation of landscape than by the acoustic comfort [8]. From this viewpoint, direct application of the WHO exposure guidelines, that is, existing quiet outdoor areas should be preserved and the signal-to-noise ratio kept low [28], may be too strict for scenic areas where people just want to enjoy the scenery.

Regarding the standard deviations of the acceptable levels for respective sites shown in Table 3, those of MT1 and MT2 are greater than those of PST and SEA. Here, we focus our attention on $L_{A5} - L_{A95}$, which means the level variability over time. The $L_{A5} - L_{A95}$ of MT1 and MT2 is also greater than those of PST and SEA. This can be one of the reasons why the standard deviations of the acceptable levels for MT1 and MT2 are greater.

Another factor that caused this tendency of the standard deviations is considered to be the differences in attitudes toward human voices among the participants. Several participants reported after the experiments that human voices were more annoying than the road traffic noise, and one of them clearly described that he increased the sound levels of the target at MT1 to mask the human voices. On the other hand, there were some participants who felt the road traffic noises to be more annoying at the sites where there were many people (MT1 and PST).

In addition, continuous water sounds were heard throughout the whole time at PST and SEA, whereas no such sounds were heard at MT1 and MT2. This difference in the sonic feature may affect the results.

Some participants pointed out that they were conscious of the sonic features of certain areas. For example, from these experiments, three participants considered the tranquility of the sites where nature is rich should be preserved. Another two participants pointed out that they decreased the sound levels when they heard nature sounds such as the birds chirping. These comments suggest that not only the natural features present within a scene, as pointed out by Pheasant et al. [19], but also the existence of certain natural sounds affects the acceptable sound levels of road traffic noises. To estimate the degree of the effect of the existence of natural sounds, further examinations are required.

In our results, as the medians of the adjusted acceptable sound levels shown in Table 3 indicate, over half of the participants accepted intrusive road traffic noise over 50 dB ($L_{Aeq}$) under three environmental conditions. This result corresponds well to that of Brambilla et al., that is, city parks with good acoustic quality exist, even though the sound level at these sites exceeds 50 dB ($L_{Aeq}$) [9].

Our results indicated that the acceptable sound levels of intrusive road traffic noise in scenic areas varied widely depending on the respondents and features of the areas, and that it is impossible to set guidelines or environmental quality standards for such areas using a single value or simple SNR. Therefore, we can say that abundant citizenry participation in establishing standards is required to make those guidelines or standards appropriate. Also, this means that the standards for respective scenic areas should be established individually in accordance with the features of the areas.
Finally, the noise indices for the environmental standards and guidelines for the preservation of tranquility were discussed. Currently, most countries, including Japan, use the time-averaged A-weighted sound level as the index for the standards or guidelines for road traffic noise. In addition, in some countries, \( L_{A_{\text{max}}} \) and \( L_{A_{10}} \) are also used with the time-averaged A-weighted sound level [29]. Because the validity of noise indices was not considered when the target stimuli (road traffic noises) in this study were made, we cannot judge from our results whether the time-averaged sound level or the maximum sound level is adequate as the index for the preservation of tranquility. Therefore, \( L_{A_{\text{eq}}} \) was selected as the index for the acceptable levels in this pilot study. However, as described above, there were some participants who clearly mentioned that they adjusted the target sound levels on the basis of the sounds of heavy trucks. This suggests that the adequacy of using maximum sound levels as the index for the preservation of tranquility should be examined. Thus, the validation of noise indices is required in the next step.

6. CONCLUSION

We investigated the acceptable sound levels of intrusive road traffic noise in Japanese scenic areas. The results show that the acceptable levels cannot be explained by a single simple value or a simple SNR, although these levels depended on the local environmental noise levels in each area. The acceptable levels for scenic areas depend largely on the evaluators and local features, and there is a clear tendency that a higher SNR is acceptable in a quieter area. In addition, the acceptable level of each participant varies widely, although the relative relationships between the environmental sound levels and the acceptable intrusive road traffic noise levels from each participant were quite similar. Therefore, to establish guidelines or noise standards for those areas, abundant citizenry participation is required, and the standards for respective scenic areas should be established individually in accordance with local conditions and features.

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REFERENCES

[1] A. L. Brown, “Rethinking “quiet areas” as “areas of high acoustic quality”,” Proc. Internoise 06, Honolulu, HI, pp. 472–480 (2006).
[2] National Academy of Engineering, Protecting National Park Soundscapes (The National Academies Press, Washington, D.C., 2013), pp. 1–47.
[3] N. P. Miller, “US National Parks and management of park soundscapes: A review,” Appl. Acoust., 69, 77–92 (2008).
[4] G. R. Cessford, “Recreational noise issues and examples for protected areas in New Zealand,” Noise Control Eng. J., 47, 97–103 (1999).
[5] European Parliament and of the Council, “Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise,” Off. J. Eur. Union L189, 12–26 (2002).
[6] G. Brambilla and L. Maffei, “Responses to noise in urban parks and in rural quiet areas,” Acta Acust. united Ac., 92, 881–886 (2006).
[7] M. E. Nilsson and B. Berglund, “Soundscapes quality in suburban green areas and city parks,” Acta Acust. united Ac., 92, 903–911 (2006).
[8] M. S. Tse, C. K. Chau, Y. S. Choy, W. K. Tsui, C. N. Chan and S. K. Tang, “Perception of urban park soundscape,” J. Acoust. Soc. Am., 131, 2761–2771 (2012).
[9] G. Brambilla, V. Gallo, F. Asdrubali and F. D. Alessandro, “The perceived quality of soundscape in three urban parks in Rome,” J. Acoust. Soc. Am., 134, 832–839 (2013).
[10] Ministry of the Environment: Government of Japan, “Environmental quality standards for noise,” http://www.env.go.jp/en/air/noise/noise.html (accessed 5 December, 2014).
[11] Tokyo District Court, Case (Gyo-U) 296 etc. (2005).
[12] European Environment Agency, Good practice guide on quiet areas (European Environment Agency, Copenhagen, 2014), pp. 1–53.
[13] S. Fidell, “The Schultz curve 25 years later: A research perspective,” J. Acoust. Soc. Am., 114, 3007–3015 (2003).
[14] N. H. Krog and B. Engdahl, “Annoyance with aircraft noise in local recreational areas, contingent on changes in exposure and other context variables,” J. Acoust. Soc. Am., 116, 323–333 (2004).
[15] N. H. Krog and B. Engdahl, “Annoyance with aircraft noise in local recreational areas and the recreationists’ noise situation at home,” J. Acoust. Soc. Am., 117, 221–231 (2005).
[16] G. S. Anderson, A. S. Rapoza, G. G. Fleming and N. P. Miller, “Aircraft noise dose-response relations for national parks,” Noise Control Eng. J., 59, 519–540 (2011).
[17] W. Yang and J. Kang, “Acoustic comfort evaluation in urban open public spaces,” Appl. Acoust., 66, 211–229 (2005).
[18] B. De Coensel and D. Botteldooren, “The quiet rural soundscape and how to characterize it,” Acta Acust. united Ac., 92, 887–897 (2006).
[19] R. Pheasant, K. Horoshenkov, G. Watts and B. Barrett, “The acoustic and visual factors influencing the construction of tranquil space in urban and rural environments tranquil space-quiet places!,” J. Acoust. Soc. Am., 123, 1446–1457 (2008).
[20] G. Watts, R. Pheasant and K. Horoshenkov, “Predicting perceived tranquility in urban parks and open spaces,” Environ. Plann. B: Plann. Des., 38, 585–594 (2011).
[21] G. Watts, A. Miah and R. Pheasant, “Tranquility and soundscapes in urban green spaces—predicted and actual assessments from a questionnaire survey,” Environ. Plann. B: Plann. Des., 40, 170–181 (2013).
[22] B. Truax, Ed., A Handbook for Acoustic Ecology (A. R. C. Publication, Burnaby, 1977), pp. 1–166.
[23] M. Morinaga, S. Aono and S. Kuwano, “A study on the visitors’ annoyance in urban parks,” J. INCE/J, 29, 292–302 (2005).
[24] Selection Committee of Japanese Soundscapes, “Report on ‘100 Soundscapes of Japan: Preserving Our Heritage’,” J. INCE/J, 20(4), (11 pages without page numbers) (1996).
[25] M. E. Nilsson, “A-weighted sound pressure level as an indicator of short-term loudness or annoyance of road-traffic sound,” J. Sound Vib., 302, 197–207 (2007).
[26] K. Nagahata, “What do citizens imagine is a level of 80 dB?:
A basic study of environmental communication on soundscape issues. “Proc. Internoise 06, Honolulu, HI, pp. 2623–3496 (2006).

[27] M. Hamamura, M. Aono and S. Iwamiya, “Differences in the preferred listening levels of ambient music, sound signs, public announcements, and natural environmental sounds between men and women,” J. Acoust. Soc. Jpn. (J), 71, 65–72 (2015) (in Japanese).

[28] World Health Organization, Guidelines for community noise (World Health Organization, Geneva, 1999), pp. 1–159.

[29] H. Tachibana and W. W. Lang, “Survey of legislation, regulations, and guidelines for control of community noise,” I-INCE publication, 09-1 (2009).