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4 **Factors affecting tranquillity in the countryside**
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1 **ABSTRACT**
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6 Previous work on elucidating the tranquillity of various environments has largely focussed on
7
8 prediction and validation in urban environments. The setting for the latest phase of research
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10 was an English country park and surrounding moors on the urban fringe located 8 miles west
11
12 of Bradford. Within the area selected there were a number of environments and man-made
13
14 features and sounds that were thought to significantly affect tranquillity and which were not
15
16 covered in earlier studies. The experiment extended over a number of months and utilised a
17
18 jury technique for evaluation involving leading small groups of walkers to different locations
19
20 in quasi-random order. At each location participants were asked to complete a short
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22 questionnaire and measurements of the physical soundscape and landscape images were used
23
24 to interpret the results and give insights into the importance of the various factors affecting
25
26 tranquillity. Such data will be useful for effective environmental management and
27
28 conservation in the countryside. (154 words)
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35 **Keywords:** Tranquillity; landscapes; soundscapes; parks; jury experiment
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46 **1. INTRODUCTION**
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50 The number of people visiting their local parks and countryside is increasing according to a
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52 recent survey published by Natural England [1]. An important reason given for visiting green
53
54 spaces was to “relax and unwind” and these areas can be considered restorative or tranquil
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56 environments giving relief from cognitive overload and reduction of stress. Our green spaces
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1 can be a refuge from the din of city life and the green environment provide shelter for wildlife
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3 and bird song can be heard. But are they sufficiently tranquil and what guidance do we have
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5 for improving such spaces if they are not? Tranquillity is often found in natural outdoor
6
7 environments where man-made noise is at a low level though natural sounds can be at a
8
9 relatively high level. Numerous studies have shown a link between such tranquil
10
11 environments and stress reduction, longevity, pain relief and how the brain processes auditory
12
13 signals [2,3,4,5,6]. It is therefore important to consider its protection in a variety of
14
15 landscapes and especially where visitors often seek relief from the stresses and strains of
16
17 everyday life, for example in a country park on the urban fringe. Early research for the
18
19 Campaign to Protect Rural England (CPRE) showed graphically how tranquil areas in the
20
21 countryside are under threat from intrusive developments and new roads and motorways [7]
22
23 and the latest UK design guidance for roads and bridges refers to tranquillity in assessing
24
25 environmental impact of new or altered roads [8]. A consideration of tranquillity involves an
26
27 assessment of “..the remoteness and sense of isolation, or lack of it, within the landscape,
28
29 which is often determined by the presence or absence of built development and traffic.” In a
30
31 further section of the guide dealing with noise and vibration assessments it is noted that noise
32
33 is one characteristic that determines the level of tranquillity [9].
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42 Previous studies at the Bradford Centre for Sustainable Environments have involved the
43
44 investigation of the environmental factors which influence the perceived tranquillity of a
45
46 place. Statistically significant factors that have been identified are the noise level (L_{Aeq} or
47
48 L_{Amax}) and the percentage of natural and contextual features in the landscape. Full details of
49
50 the results of the original studies are given by Pheasant et al [10] and the updated formula
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52 relating these factors for practical applications was reported recently as TRAPT (Tranquillity
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54 **Rating Prediction Tool**) [11] is given by:
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$$TR = 9.68 + 0.041 NCF - 0.146 L_{day} + MF \quad (1)$$

Where TR is the tranquillity rating on a 0 to 10 rating scale where 0 is “least tranquil” and 10 is “most tranquil”. NCF is the percentage of natural and contextual features in the visual scene and L_{day} is the equivalent constant A-weighted level from 7am to 7pm for mechanical noise (not natural sounds). Contextual features include listed buildings, religious and historic buildings, landmarks, monuments and elements of the landscape, such as traditional farm buildings, that directly contribute to the visual context of the natural environment. It can be argued that when present, these visually cultural and contextual elements are as fundamental to the construction of ‘tranquil space’ as are strictly natural features. The moderating factor MF is added to the equation to take account of further factors such as the presence of litter and graffiti that will depress the rating and water sounds that are likely to improve the ratings. This factor is unlikely to be large and it was demonstrated that the presence of litter depressed the rating by one scale point [12].

In some extreme cases, the predicted value of TR from (1) goes negative due to the linear regression technique used to relate these variables. In these cases, the calculated value is set to zero. Where $TR > 10$ then values are set to 10. To illustrate the nature of equation (1) Figure 1 shows the relation between L_{day} and TR for 3 levels of NCF (0, 50 and 100%). Where there are no natural or contextual features ($NCF = 0\%$) it can be observed that TR reaches zero at the relatively low noise level of 66 dB(A) but where NCF is 100% it is reached at the much higher level of 94 dB(A). This graphically demonstrates the importance for tranquillity of the natural components of the visual scene. For example a 50% increase in NCF is predicted to raise TR by approximately 2 scale points while decreasing noise level L_{day} by 14 dB(A)

1 changes TR by approximately the same amount. These trade-offs can be used to identify
2
3 suitable measures to improve tranquillity.
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8 # Figure 1 about here #
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13 Recent work carried out by SCANLab using fMRI neuro-imaging techniques informs the
14 results of these cognitive studies, by providing insights into the neuro-physiological basis for
15 auditory-visual interaction in the construction of tranquil space [6]. In fact, it has
16 demonstrated for the first time the significant differences in effective connectivity between
17 the auditory cortex and the medial prefrontal cortex under tranquil and non-tranquil
18 conditions. Specifically the medial prefrontal cortex receives significantly enhanced
19 contribution from the auditory cortex under tranquil visual conditions compared with non-
20 tranquil visual conditions. Such results indicate strongly that bi-modal stimuli are essential
21 for a full understanding of the factors affecting tranquillity of an environment.
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35 The prediction tool for the tranquillity rating TRAPT was used in a previous study to assess
36 the tranquillity in 8 green open spaces and then validate the predictions using a questionnaire
37 survey of park visitors [13]. This paper describes and reports on a jury experiment in a
38 country park (one of 8 green open spaces) and surrounding moors on the outskirts of an urban
39 area comprising Bradford to the East and Halifax to the south. Jury experiments have been
40 used successfully to assess a wide variety of products e.g. the noise nuisance of vehicles [14]
41 and sound quality of consumer items [15]. The present study by widening the range of
42 environments studied aims to elucidate further the factors affecting tranquillity.
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1 **2. METHOD**
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5 The setting for this study was Ogden Water Country Park and adjacent Ovenden Moor that
6 comprises a variety of countryside environments including a reservoir with wooded slopes
7 and access to open moorland with distant views of hillsides covered with low growing natural
8 vegetation The undulating nature of the terrain meant that much of the road was screened
9 from view except at one location though distant views of apartment blocks, housing and
10 factories were evident at other locations. The main noise sources were traffic noise,
11 aerodynamic noise from a wind farm and occasional high overflying aircraft. The closest
12 main road (A629) with an 80 km/hr (50 mile/hr) speed limit was at a distance of 350m from
13 the boundary and had a daytime flow of 550 vehicles/hr.
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17 In the present study groups of walkers were taken on separate occasions to a number of
18 predetermined places covering a wide range of environments and asked to complete a short
19 questionnaire. Leading participants to various points and asking them to list positive and
20 negative factors affecting perceptions is similar to the soundwalk technique frequently
21 employed in soundscape studies [16]. However, in the present study both auditory and visual
22 factors were considered of similar importance and consequently the questionnaire addressed
23 both factors in equal measure. In all there were 9 locations and comprised:
24
25
26

- 27 (a) Secluded overlook into a wooded steep sided valley with water sounds
 - 28 (b) Wooded path adjacent to a reservoir with sounds of water falling over a small stepped
29 weir
 - 30 (c) Wooded path adjacent to reservoir with distance view through the trees
 - 31 (d) Elevated position with views over a golf course and in the distance views of tall buildings
32 in Halifax
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1 (e) Elevated position adjacent to a wind farm (nearest turbine 95 m) and with views over
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3 surrounding moors
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6 (f) Elevated position with views over moors and adjacent to a section of road where there had
7
8 been extensive fly tipping
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10 (g) Elevated position with views over moors and a reservoir with boat club and sailing
11
12 dinghies
13

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15 (h) Position on a reservoir dam with views on one side towards a busy road and on the other
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17 side across the reservoir to wooded sides. Traffic noise was obvious and there were often
18
19 several park visitors in the vicinity
20
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22 (i) Car park with cars manoeuvring, doors opening and closing, and people talking
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28 A total of 30 walkers completed the assessment which involved walking approximately 8 to
29
30 10 km over hilly terrain. Their ages ranged from 18 to 77 with an average age of 37 years. In
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32 total there were 6 separate days on which assessments were made covering a period from
33
34 summer into autumn 2011. The actual distance was determined by the order in which the
35
36 locations were approached. The aim was to approach the locations in a different order on each
37
38 separate occasion when the experiment was run to overcome order effects. This was not
39
40 always possible as the distances involved in visiting a truly random order would on some
41
42 occasions have been prohibitive. Volunteers were instructed to wear stout shoes/boots and to
43
44 carry waterproofs, water and snack. They were also told that the walk was moderately
45
46 strenuous as the total height gained was approximately 130m with steep gradients along a
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48 number of stretches. They were told to expect a surprise gift if they completed the experiment
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50 (supermarket vouchers).
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1 **2.1 Questionnaire**
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4 The questions are reproduced below and have been successfully used in the previous survey
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6 of 8 open green spaces [13]:
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11 1. In this spot which sounds that you can hear attract your attention
12 most? _____
13
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16 2. In this spot which things that you can see attract your attention most?
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18 _____
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21 3. Rate the tranquillity of this spot by choosing a number between 0 to 10 where 0 is
22 “least tranquil ” and 10 is “most tranquil” _____
23
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25
26 4. List in order of importance the things around you that reduce the tranquillity of this
27 spot?
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29 First _____ Second _____ Third _____
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33 4(a) If the most important factor (1) were removed what would your new rating
34 be? _____
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38 5. List in order of importance the things around you that improve the tranquillity of this
39 spot?
40
41 First _____ Second _____ Third _____
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45 5(a) If the most important factor (1) were removed what would your new rating
46 be? _____
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50 6. Do you feel “more relaxed”, less relaxed” or “no change” after visiting this
51 spot? _____
52
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55 7. Rate the pleasantness of this spot by choosing a number between 0 to 10 where 0 is
56 “least pleasant” and 10 is “most pleasant” _____
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1 8. Note any other comments about this spot which may have affected your answers:
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10 Participants were instructed to:

- 11 • Refrain from discussing any aspect of the experiment with others
- 12 • At each spot to remain quiet during the 30 second assessment period and during the
13 completion of the questions immediately following. Note that the 30 second period was
14 marked with a clear “start” and then “stop” verbal signals
- 15 • During the 30 second assessment period participants were instructed to have a good
16 look all around and to listen to any sounds
- 17 • They were instructed to try and not be influenced by physical comfort or whether the
18 sun is out, whether it is overcast or it is raining at the time assessments were made

19 The questionnaire for each location filled one side of A4 paper to enable ease of completion.
20 They were contained within a hard backed clip board with front cover for weather protection.
21 A practice session was held at a wooded location close to the start in order to familiarise
22 participants with the protocol before the nine locations were assessed. At this point any
23 queries that were raised were answered.

24 It can be seen that questions 1 and 2 were general questions designed to enable participants
25 to think about key influential visual and auditory factors in the landscape. Question 3 was
26 designed to elicit an assessment of the tranquillity of the spot they were occupying during the
27 30 second assessment period. Questions 4 and 5 were designed to evaluate the importance of
28 the most important factors that detracted or improved tranquillity at that place. Participants
29 were asked to re-rate the tranquillity if these important factors were removed. Thus for
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1 question 4 the re-rated tranquillity would be the same or lower than that given in question 3
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3 while for question 5 it would be the same or higher. The change in rating gave an indication
4
5 of the importance of the factor and allowed the effect to be quantified. Question 6 was
6
7 designed to obtain an indication of how the place visited affected their state of relaxation.
8
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10 Question 7 was used to obtain an overall assessment of pleasantness.
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14 **2.2 Soundscape analysis**

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17 Soundscape studies, sometimes called acoustic ecology or ecoacoustics is a discipline that
18
19 analyzes how we interpret, and are affected by natural and artificial sounds around us [17]. As
20
21 mentioned previously soundscape factors have an important influence on perceived
22
23 tranquillity of a place and it was important to characterise important aspects. For this reason at
24
25 each of the 9 locations sound measurements were made during 30 second periods during
26
27 daytime on several separate occasions. Being in a hilly area in the north of England the sites
28
29 were exposed to frequent high winds so it proved impossible to take valid measurements
30
31 during actual jury assessment periods. However, further visits were made under calmer
32
33 conditions i.e. with wind speeds less than 6 m/s in order to take these measurements. Hence
34
35 these measurements can only be indicative of the soundscape under calm or light wind
36
37 conditions. For this purpose a calibrated B&K 2230 with third-octave analysis capability was
38
39 employed. Broadband A-weighted descriptors L_{Aeq} , L_{A50} , L_{Amax} and L_{Amin} were also recorded.
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47 For the purposes of predicting the tranquillity rating using TRAPT it was necessary to
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49 calculate the background noise level at a number of the locations closest to the main road as
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51 this was the major source of mechanical noise. Predictions were carried out at the sites using
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53 CRTN [18]. This method predicts the 18 hour L_{A10} value from 0600 to 2400 hours. Classified
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55 traffic counts were carried out and distances to the nearest road calculated using GPS co-
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1 ordinates obtained from Google Earth. The major road was essentially level with a bituminous
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3 wearing course and subject to a 80km/h (50 mile/h) speed limit.
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6 The L_{day} (equivalent constant energy level from 7am to 7 pm) was then obtained from the
7
8 official conversion formulae for non-motorway roads [19]:
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$$10 L_{day} = 0.95 L_{A10,18h} + 1.44 \text{ dB} \quad (2)$$

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18 Note that where CRTN is not the preferred prediction method other validated traffic noise
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20 models can be used to obtain L_{day} .
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26 **2.3 Landscape scene analysis**

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32 There are many means of characterising the landscape scene [20] however, from previous
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34 research it is the percentage of natural or contextual features in the scene that was found to be
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36 of significance for tranquillity (see Introduction). For this reason at each of the nine locations
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38 the percentage of natural and contextual features in the landscape that could be observed was
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40 determined using a camera giving a field of view of approximately 51 degrees in the
41
42 horizontal plane on a normal (non-zoom) setting. Seven contiguous pictures were taken at a
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44 height of 1.5m (close to the average standing eye height of adults in the UK) to give an
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46 approximate field of view of 360 degrees. These pictures were analysed using a 10 x 10 grid
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48 placed over the images to determine the percentage of natural and contextual features, NCF
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54 (see equation (1) and explanations).
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1 **4. ANALYSIS**

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6 **4.1 Predicting tranquillity**

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11 The average ratings of tranquillity made by the jury members at all nine locations were
12 compared with the predictions using equation (1). In the case of the 4 sites nearest the major
13 road (two of which tended to have noticeable water sounds) the predicted values of L_{day} were
14 used. For other location the measured background noise levels on non-windy days were used
15 as estimates. It was expected that the level of background noise from the 2 major sources
16 (traffic and wind turbines) would not vary greatly over the daytime hours so that the derived
17 values of L_{day} would reflect background noise levels during the assessment periods which
18 were in the afternoon period. Figure 2 shows the predicted and actual tranquillity ratings.
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33 # Figure 2 about here #
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38 It can be seen that the squared correlation between predicted and average ratings from jurors
39 was high ($r=0.88, p<0.001$). In addition the regression line has a slope of nearly 1 and the
40 extrapolated line passes close to the origin. It can be concluded that TRAPT is useful for
41 determining the tranquillity at a particular spot. Previous work has demonstrated its
42 usefulness for predicting the most tranquil locations in a number of mainly urban parks [13].
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4.2 Soundscape description

Third octave plots were made of the measured soundscapes on non-windy days at the nine locations and these are shown in Figure 3(a) to 3(i) below together with the average tranquillity ratings from jury members. The spectrum for the most tranquil site (overlook into wooded valley) is shown on each figure for comparison purposes.

#Figure 3 about here #

Clearly the most noisy site is the car park (55.3 dB(A)) where the third-octave band levels exceed that of the overlook at all frequencies between 10 and 20 dB. This is largely due to car engines, car doors slamming and loud voices. This dominated any natural sounds present. This difference in the level of mechanical noise is reflected in the average tranquillity rating given by the jurors, i.e. 8.3 at the overlook and only 3.2 in the car park. However we observe that the natural sound of the water splashing down a series of steps produces a level very similar to the wind farm (50.8 and 50.6 dB(A) respectively) while the *TR* values are quite different 7.6 compared with 5.0. This illustrates the importance for perceived tranquillity of identifying the sound source as natural or man-made. Note that where natural sounds were dominating the soundscape then background noise levels were predicted using CRTN.

The spectrum for the wind farm shows considerable amounts of low frequency noise similar to the findings of a previous study of a large wind turbine rated at 2.3 MW output [21]. This aerodynamic noise dominated any natural sounds. There were 23 turbines with a ground to rotor tip height of approximately 50m. Aerodynamic noise produced by the moving blades and gearbox/generator noise would account for the peaks in the spectrum. At the

1 reservoir dam traffic noise could be heard as this is the closest point to the main road from
2
3 Halifax at 350m. The spectrum shows maximum A-weighted levels between 800 and 1250Hz
4
5 which is characteristic of freely moving traffic [22]. Interestingly a minor peak at 160Hz can
6
7 be observed in several of the spectra suggesting that the wind farm is having a measurable
8
9 effect over a wide area.
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13 In terms of the sounds noticed by the respondents it was illuminating to classify the sounds
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15 into the broad categories including natural, mechanical, people sounds. Similar categories
16
17 were identified in a previous study using principal components analysis in a wide variety of
18
19 environments [23]. Figure 4 illustrates the percentages of each type of sound that was noticed
20
21 at the nine locations. The locations are ordered from left to right in terms of average
22
23 tranquillity rating. This shows a tendency noticed in the previous study [13] that as the
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25 tranquillity rating decreases the percentage noticing natural sounds decreases while the
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27 percentage noticing mechanical sounds increases.
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35 # Figure 4 about here #
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40 Figures 5a and 5b show these tendencies in greater detail by plotting these percentages against
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42 the average tranquillity rating. The graphs show more clearly the tendencies noted in Figure 4.
43
44 Using regression analysis it can be seen in Figure 5a that at a low tranquillity rating of
45
46 approximately 2 scale points it would be expected that there would be close to zero reporting
47
48 natural sounds. However, at average rating of 9 and above almost all respondents would be
49
50 expected to note natural sounds. For mechanical sounds (5b) an opposite tendency can be
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52 observed. At a tranquillity rating of 9 and above very few would be expected to record
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1 mechanical sounds but at an average rating of 3 or lower we would expect almost all
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3 respondents to report mechanical sounds.
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8 # Figure 5 about here #
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10 11 12 **4.3 Relaxation and tranquillity** 13

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17 As noted in the Introduction a major benefit of a tranquil landscape is the ability to relax more
18 easily. For this reason respondents' assessments of how relaxed they felt at each location were
19 plotted against the average tranquillity rating at these places. Figure 6 shows the form of the
20 relationship. This indicates a rising trend of respondents reporting they are more relaxed with
21 increasing tranquillity rating and is similar to the trend found in the previous study [13]. It can
22 be seen that in order to achieve at least 50% of respondents reporting being more relaxed then
23 a tranquillity rating of 7 or above is required.
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37 #Figure 6 about here#
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43 **4.4 Improvements to tranquillity** 44

45 Replies to question 4(a) allowed the importance of negative features in the soundscape
46 and landscape to be quantified. Table 1 lists the assessed improvements if the most
47 negative feature at each location were removed.
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55 # Table 1 about here #
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1 Differences were all found to be statistically significant using the T-test ($p < 0.05$). The largest
2
3 adjustment was due to the removal of the wind turbines which would result in a change from
4
5 5.0 to 6.9 i.e. nearly 2 scale points. A value of 6.9 is considered “fairly good” whereas a rating
6
7 of 5.0 is on the boundary of “acceptable” and “just acceptable” [13]. The wind turbines
8
9 produced not only considerable mechanical and aerodynamic noise as illustrated in Figure 3
10
11 (e) but comments made by the majority of respondents indicated that they were visually
12
13 annoying. Figure 7a shows the dominance of the turbines in the visual scene at the assessment
14
15 point. Figure 7a shows the dominance of the turbines in the visual scene at the assessment
16
17 point.
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22 # Figures 7a and 7b about here #
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26 The tipping site on a moorland road (see Figure 7b) was also rated negatively and an
27
28 improvement of 1.2 scale points was the average improvement. This would lift the rating to
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30 7.6 which is well within the “good” category. This adjustment is comparable with the
31
32 decreased rating of 1.0 given in a previous experiment where litter was deliberately placed in
33
34 a garden [12].
35
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38 Traffic noise from the major road was the chief concern at the dam site and this resulted in a
39
40 reduction of 1.5 scale points. Without this traffic noise the environment is pleasant with
41
42 extensive views over the reservoir to moors beyond and to wooded slopes below the dam wall
43
44 resulting in an estimated tranquillity rating without this noise of 7.4 (i.e. “good”) .
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48 As expected the presence of people and car movements in the car park resulted in the lowest
49
50 tranquillity rating. Removing these disturbances would lift the average tranquillity rating to
51
52 5.0. This improved rating is still low and probably indicates the effects of poor visual quality
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1 due to the considerable areas of rough and sometimes muddy ground provided for the parked
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3 vehicles.
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5 Distant views of buildings at the golf course and near the sailing club also depressed ratings
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7 but these were fairly modest adjustments which were only just significant at the 5% level
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9 (0.01< p <0.05) as their impact was limited due to the large viewing distances and therefore
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11 relatively small visual impact.
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18 Factors that promoted tranquillity were the presence of vegetation, low levels of man-made
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20 sounds and dominance of natural sounds. Figure 8a and 8b show two of the most highly rated
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22 locations with these characteristics.
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28 #Figures 8a and 8b here#
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34 **5. DISCUSSION OF CONCLUSIONS**

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38 It can be seen that the predicted tranquillity rating agrees well with the average obtained from
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40 jury members. There are factors that can add ‘statistical noise’ to the ratings obtained in the
41
42 country park which can affect the relationship with the predicted levels. These include
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44 weather conditions (though participants were instructed not to take this factor into account)
45
46 and the number of people present when ratings were being made. The results agree well with
47
48 the previous study of 8 green open spaces in urban parks.
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52 Overall it was found that in this country park the average tranquillity score was high at 6.5
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54 and only 2 locations were at 5 or below which is the threshold for acceptable tranquillity
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56 ratings [13]. The 2 locations were the car park and the wind farm. These results are not
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1 surprising given the relatively high levels of mechanical noise present at these locations and
2
3 degree of visual intrusion of man-made features in an otherwise natural setting. The highest
4
5 tranquillity rating was given to an overlook with views into a wooded valley with a river
6
7 audible as its waters flowed over rocks and boulders. Due to the water sound sources the
8
9 measured sound level was not the lowest but the calculated background noise level from
10
11 traffic was low thus contributing to the high tranquillity score. Note also that some natural
12
13 water sounds have been found to increase tranquillity in a laboratory setting with replayed
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15 traffic noise present [24].
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20 As found in a previous study it was shown that as the tranquillity rating decreased there
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22 was a tendency for the percentage noticing natural sounds to decrease while the percentage
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24 noticing mechanical sounds increased. This has been found in laboratory studies [10] as well
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26 as in the field [13].
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30 It was found that there was a good relationship between the percentage of respondents
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32 reporting they were “more relaxed” and the average tranquillity rating. This confirms a
33
34 similar finding in a previous study [13] and supports the findings of a laboratory showing
35
36 significant physiological stress reduction in a natural environment compared with urban
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38 environments [2]. It appears that a rating of at least 7 on the tranquillity rating scale is
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40 required before at least 50 % of respondents can be expected to report being more relaxed.
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45 Traffic noise was an issue at one of the locations which was to be expected as it was the
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47 closest point to the main road from Halifax (A629). Though the level was relatively low (44
48
49 dB(A) it was clearly audible in an otherwise natural soundscape characterised by the sounds
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51 of water fowl and resulted in a tranquillity rating change of 1.5 scale points. An obvious
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53 remedial measure would be to resurface with a low noise road surface (e.g. porous asphalt or
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1 stone mastic asphalt). However this would be costly unless it was selected when the road was
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3 due to be resurfaced and confined to the section contributing to the disturbance.
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6 The presence of litter was shown to depress ratings by just over 1 scale point and this agrees
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8 with a previous study [12]. Clearly a campaign to regularly remove the offensive material
9
10 must be put in place and perhaps additional measures to deter the offenders e.g. presence of
11
12 video cameras and larger warning signs.
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15 In the case of the wind turbines the effect was larger reaching nearly 2 scale points. Clearly
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17 the effects were relatively large as the location for rating was approximately 100m from the
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19 nearest turbine with an average noise levels of over 50 dB(A). However, the area covered by
20
21 the wind farm was large (approximately 50 hectares) and within this area tranquillity ratings
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23 would be expected to be even lower due higher noise levels and more visual intrusion than
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25 that recorded outside the boundary (i.e. <5 which is the threshold for acceptable tranquillity
26
27 ratings). Further work is in progress to assess how tranquillity might be affected over greater
28
29 distances from the wind farm and therefore to assess environmental impact (both visual and
30
31 aural). This has proved problematic as in a previous study commissioned by CPRE [7] the
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33 assessment of wind farm impact was noted in their 1994 report as “:.... loss of tranquillity is
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35 absolute within 1km of a windfarm, and partial within 2km of a windfarm. However later the
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37 figure was revised down to 0.5km though it was noted that the lower figure may well be an
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39 underestimate. It is unclear precisely how these assessments were made. Clearly the size and
40
41 number of turbines will have an impact as well as the terrain where they are operating as this
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43 will affect sound propagation and visibility. Using the prediction equation (1) it will be
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45 possible to assess the zone of influence by assessing the visual areas presented to the viewer
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47 by the rotating blades and tower and the propagation of noise with distance. This should
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49 ultimately assist in the planning process.
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1 Overall the results presented will be useful when considering improvements at the study site
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3 and in countryside areas where the public have access and intrusive traffic noise, wind
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5 turbines and dumping of rubbish are an issue. Of course other issues concerning both noise
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7 and visual intrusion may be important at further sites however the jury technique described in
8
9 this paper could usefully be applied in identifying the size and nature of any problem and
10
11 assist in devising mitigation measures.
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15 When planning new open green spaces the tranquillity prediction equation can be used to
16
17 inform soundscape and landscape designs in order to provide sufficiently tranquil areas which
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19 it can be argued are restorative and can promote health and well being. In fact the results in
20
21 the current study indicate that a tranquillity rating of 7 or more is required to ensure at least
22
23 50% of visitors are more relaxed after visiting the area. Measures to improve tranquillity
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25 include reducing man-made noise and increasing the percentage of natural and contextual
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27 features in the visual scene. Using natural sounds (e.g. water sounds) to distract or mask man-
28
29 made sounds is a further approach.
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38
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41
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43
44 allowing the survey to take place is gratefully acknowledged.
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36 37 38 39 40 41 42 43 44 **Table heading:**

45
46
47 Table 1: Average tranquility ratings (TR) and adjusted values following removal of most
48
49 important negative factor (TR_{adj}) together with 95% confidence intervals

50 51 52 53 **Figure captions:**

54
55
56 Figure 1: Linear variation of TR with L_{day} at 3 levels of NCF (0, 50 and 100%)

1 Figure 2: Predicted and average tranquillity rating from jury

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3 Figure 3: Spectra for 9 locations with most tranquil site (a) (black bars) used as a
4 comparison: (a) Overlook with water sounds, $TR=8.3$, $L_{Aeq} = 39.3$; (b) Reservoir bank,
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6 $TR=7.8$, $L_{Aeq}=41.3$, (c) Sailing club and reservoir, $TR=7.6$, $L_{Aeq}=32.6$, (d) Bank with
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8 water sounds, $TR=7.6$, $L_{Aeq}=50.8$, (e) Fly tipping site, $TR=6.4$, $L_{Aeq}=34.1$, (f) Golf
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10 course, $TR=6.3$, $L_{Aeq}=41.1$, (g) Reservoir dam, $TR=5.9$, $L_{Aeq}=43.9$, (h) Windfarm,
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12 $TR=5.0$, $L_{Aeq}=50.6$, (i) Car park, $TR=3.2$, $L_{Aeq}=55.3$
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18 Figure 4: Sounds noticed by respondents

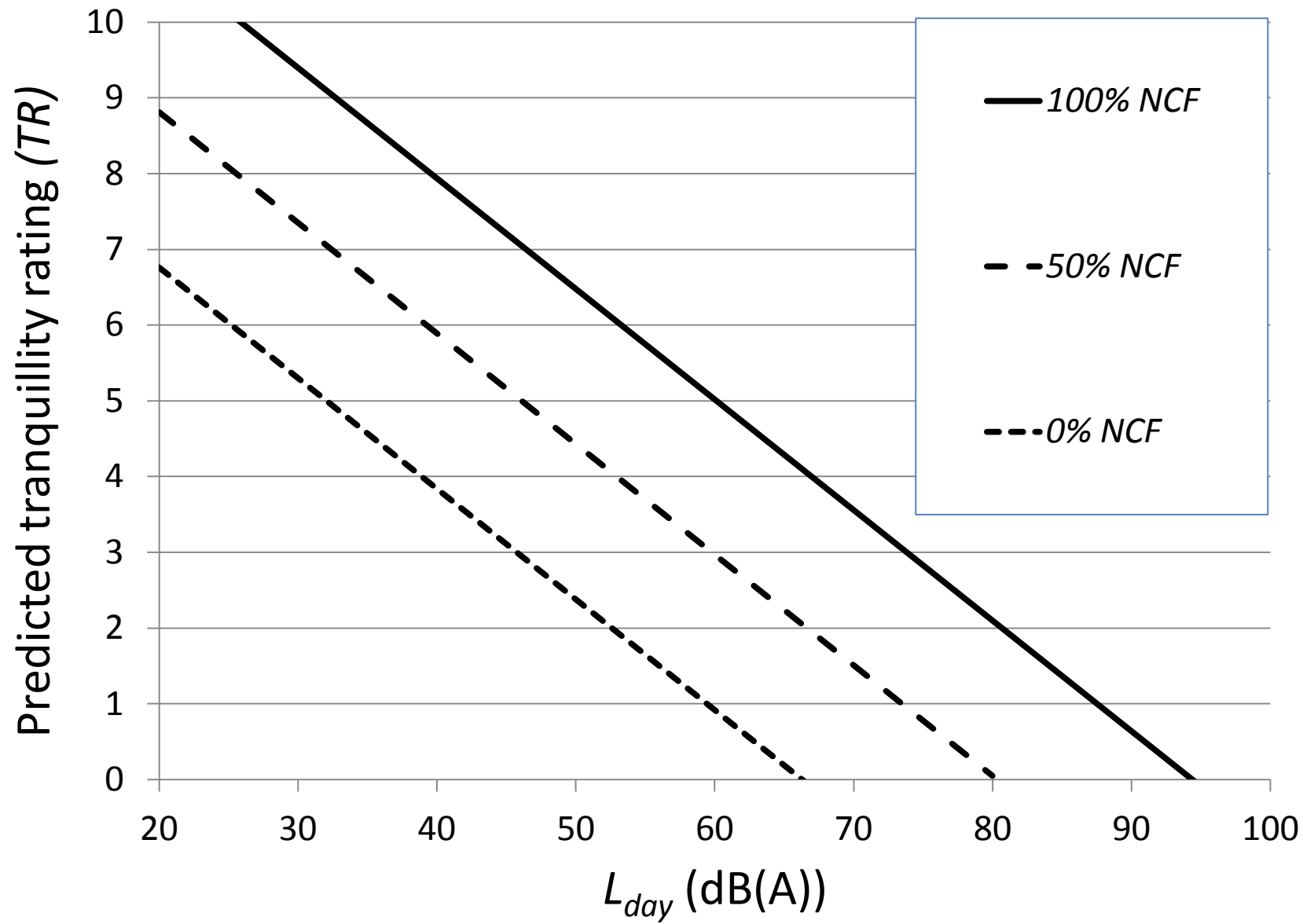
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20 Figure 5: (a) Percentage noticing natural and (b) Percentage noticing mechanical sounds by
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22 average tranquillity rating from survey
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25 Figure 6: State of relaxation and average tranquility rating

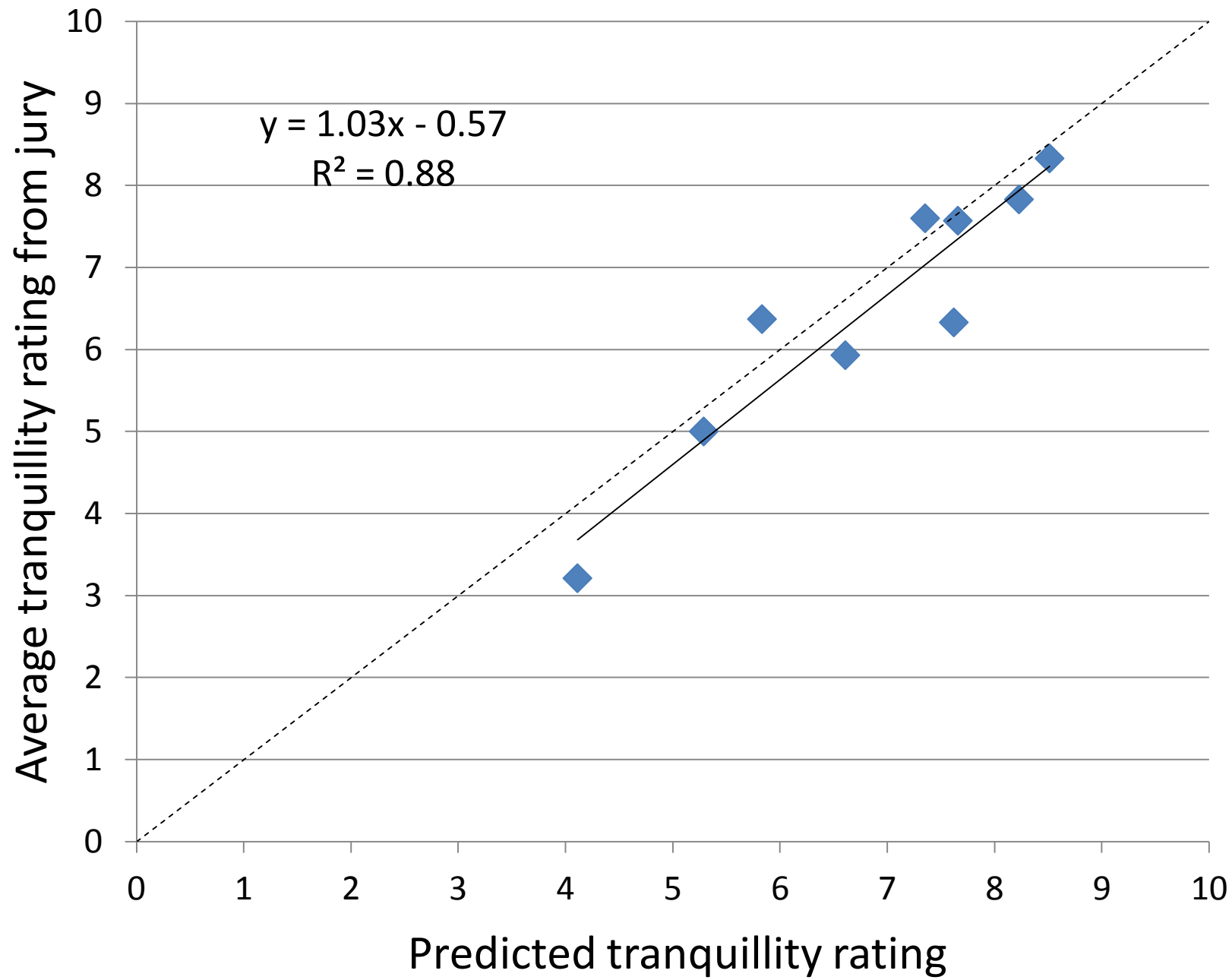
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27 Figure 7: Views at relatively low tranquillity sites (a) Wind farm and (b) Illegal tipping site

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29 Figure 8: Views at relatively high tranquillity sites (a) Overlook into a wooded valley and (b)
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31 Reservoir bank
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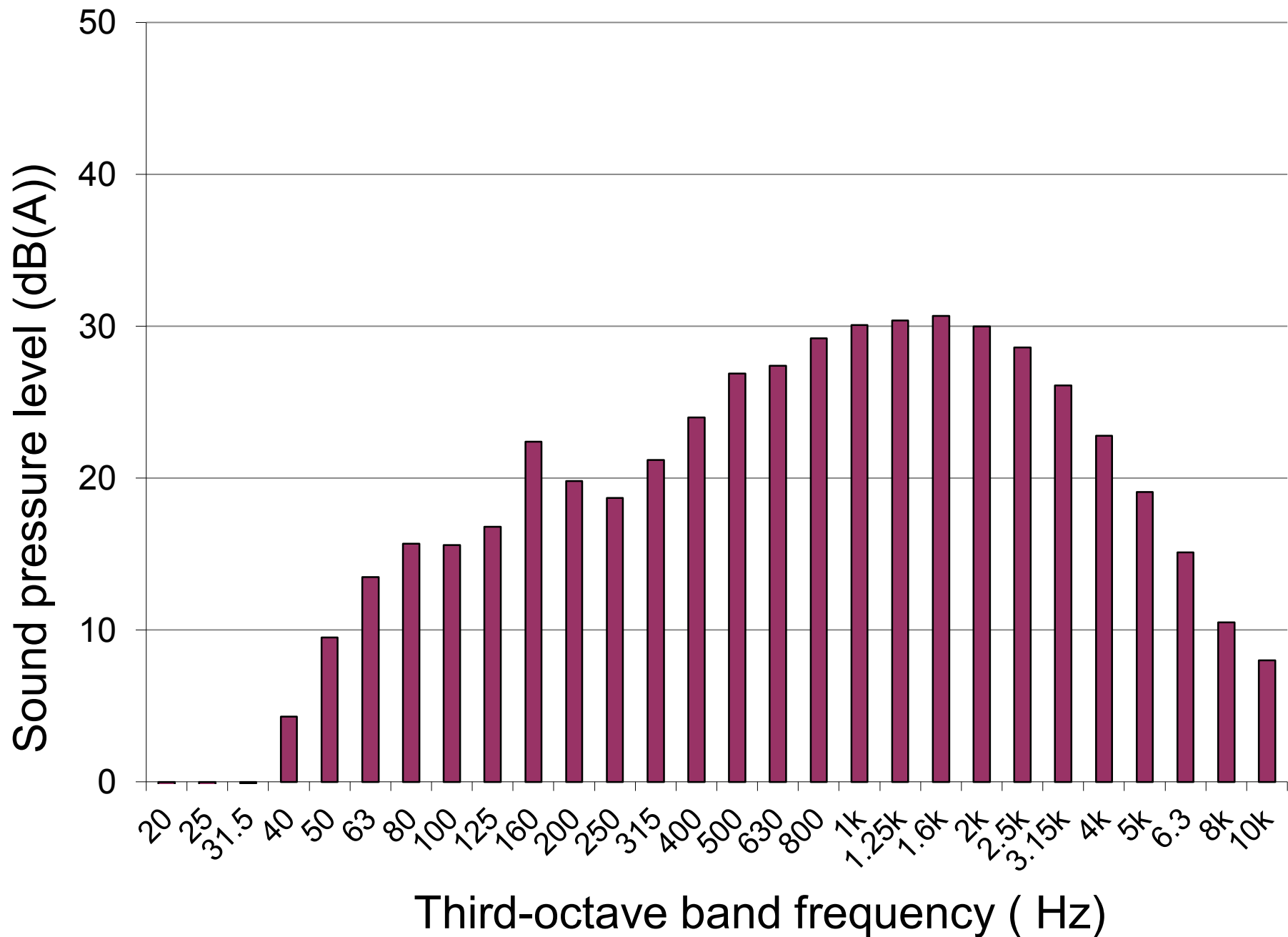
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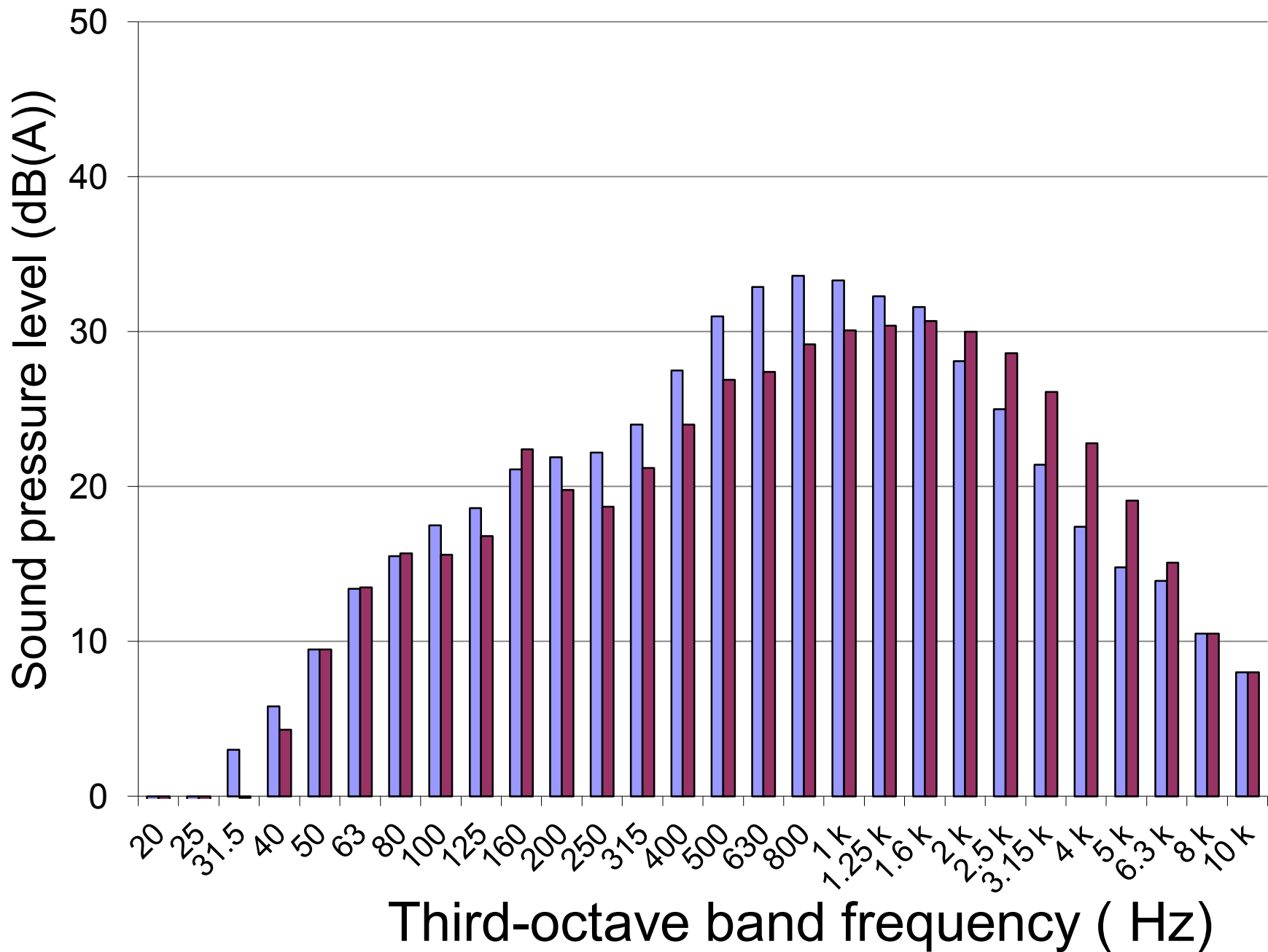
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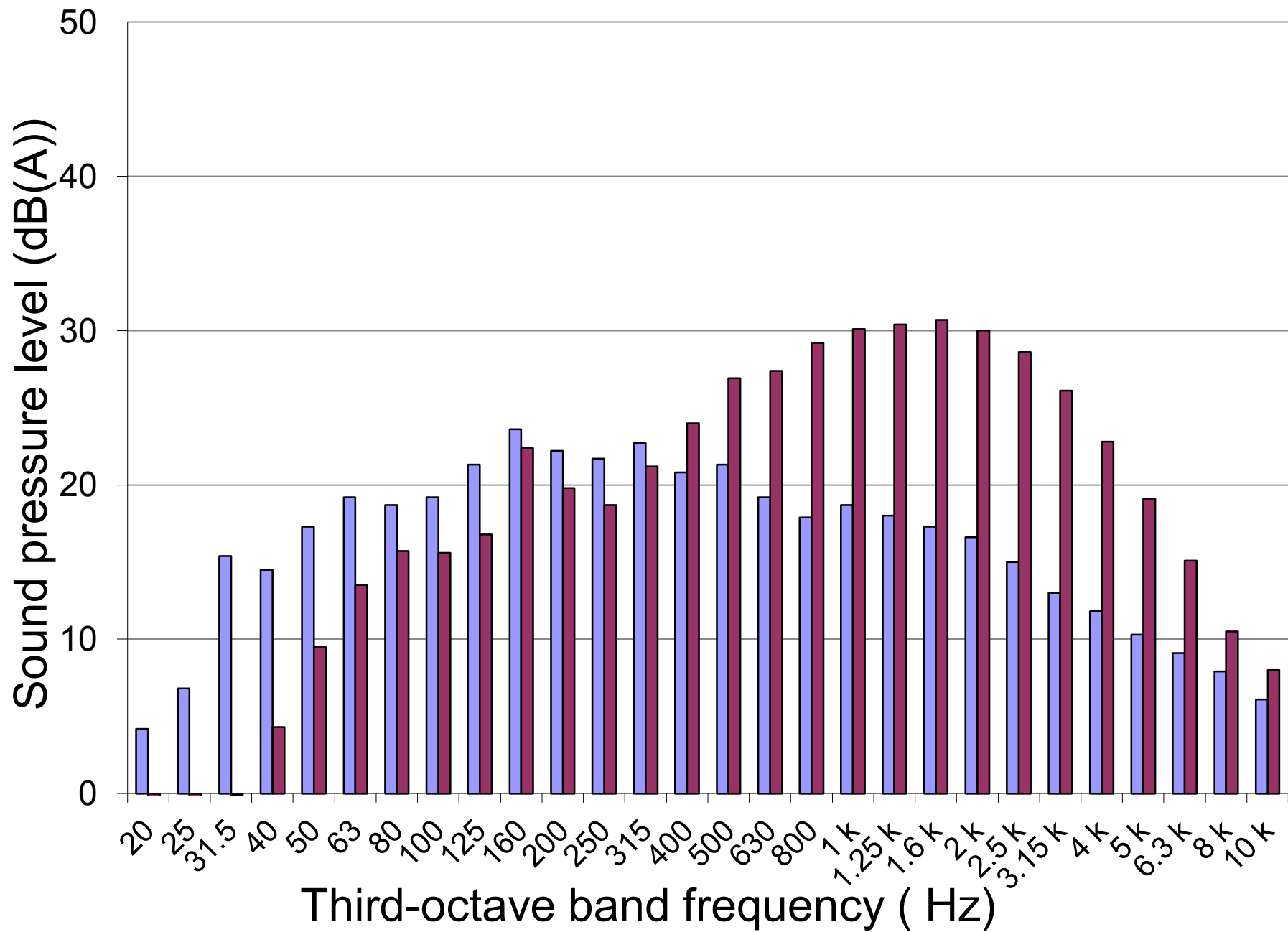
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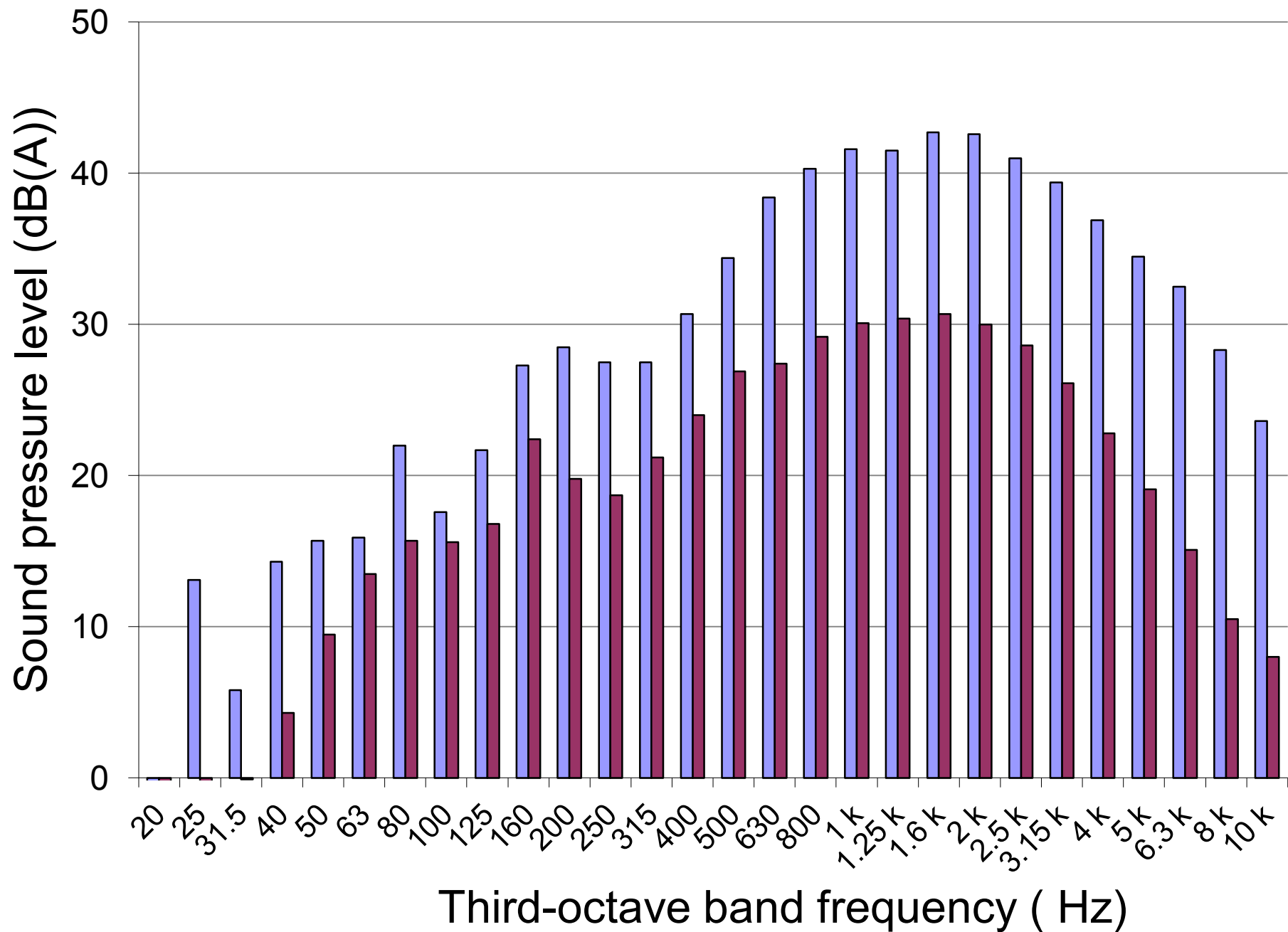
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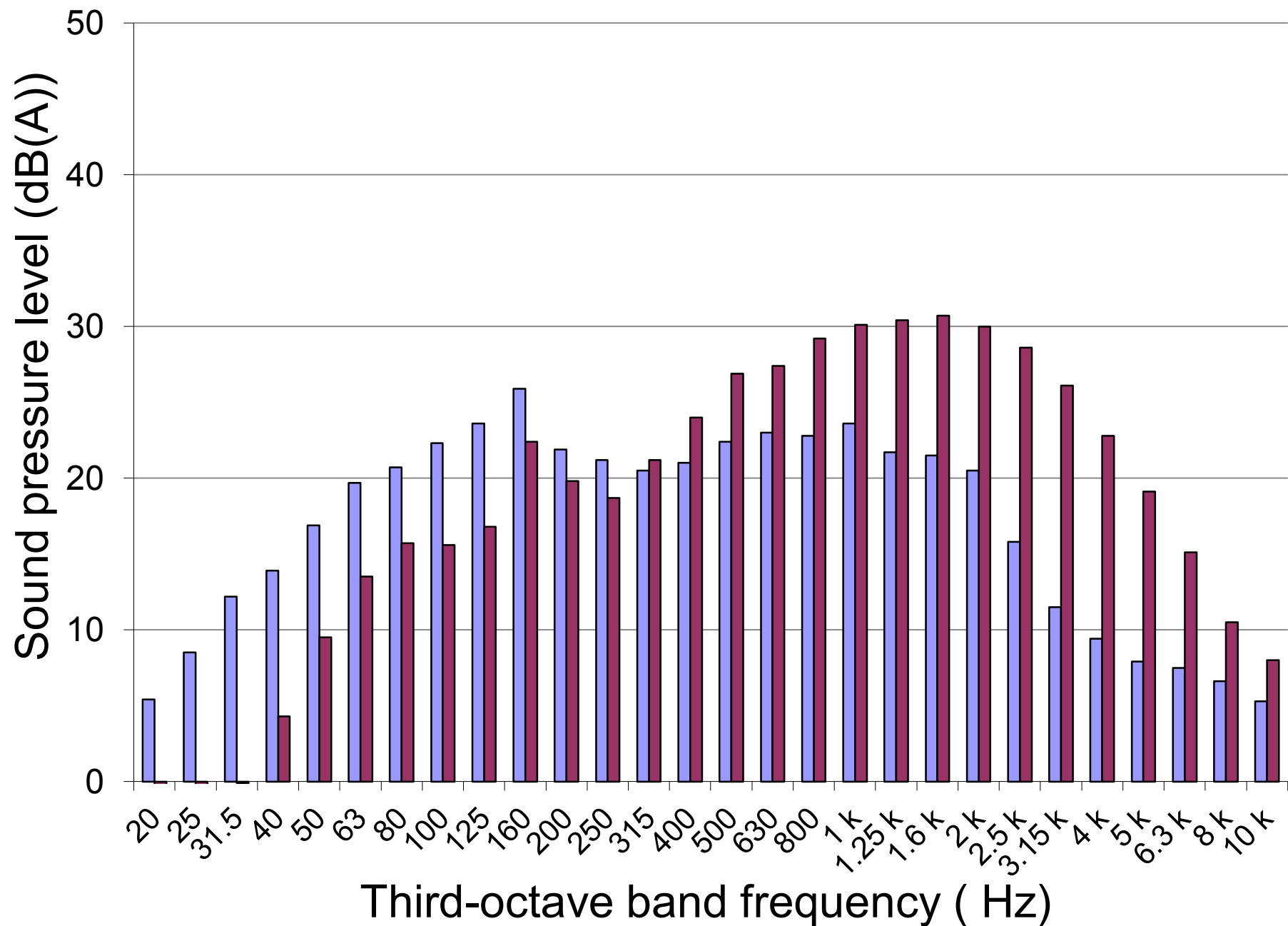
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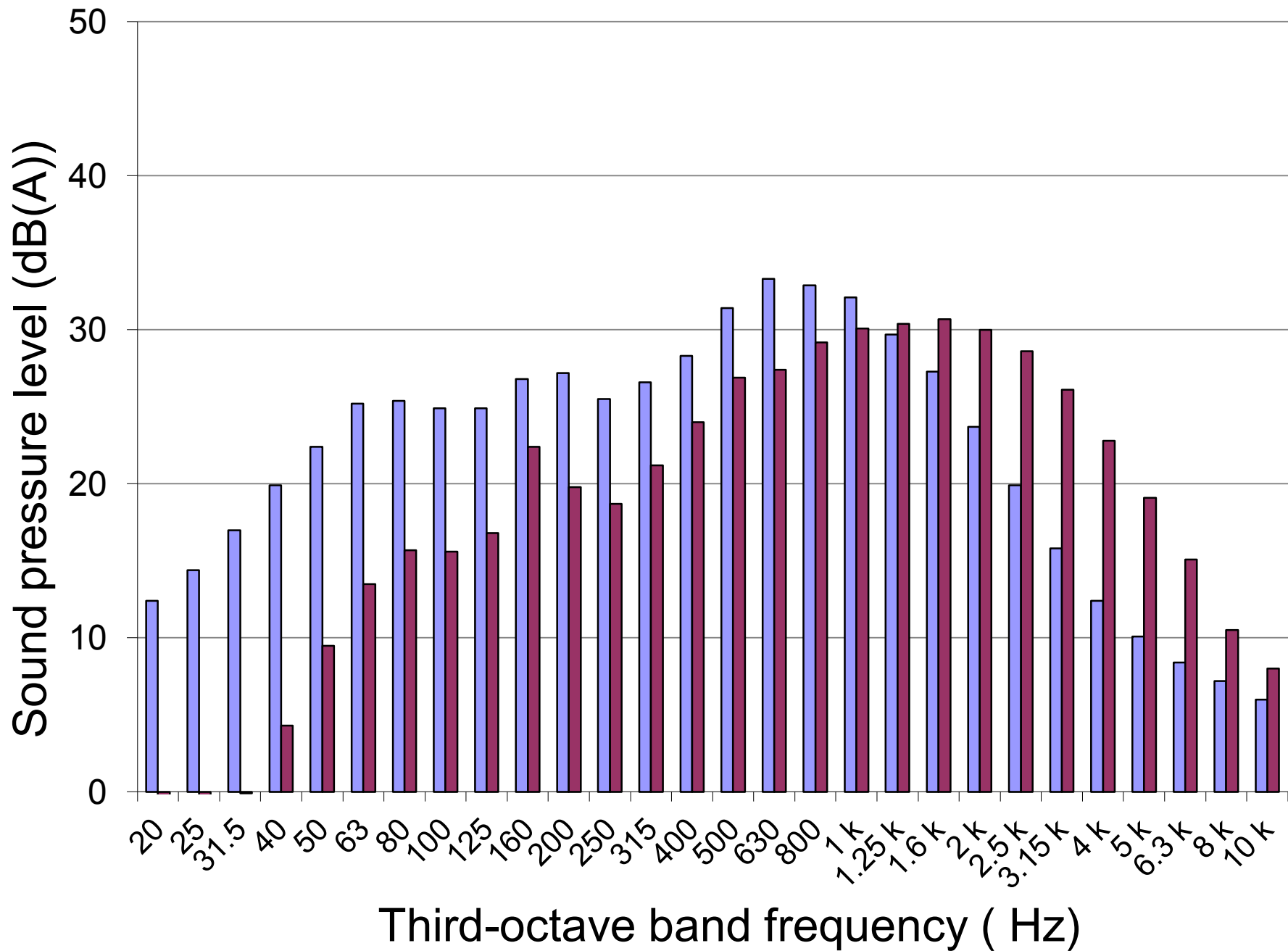
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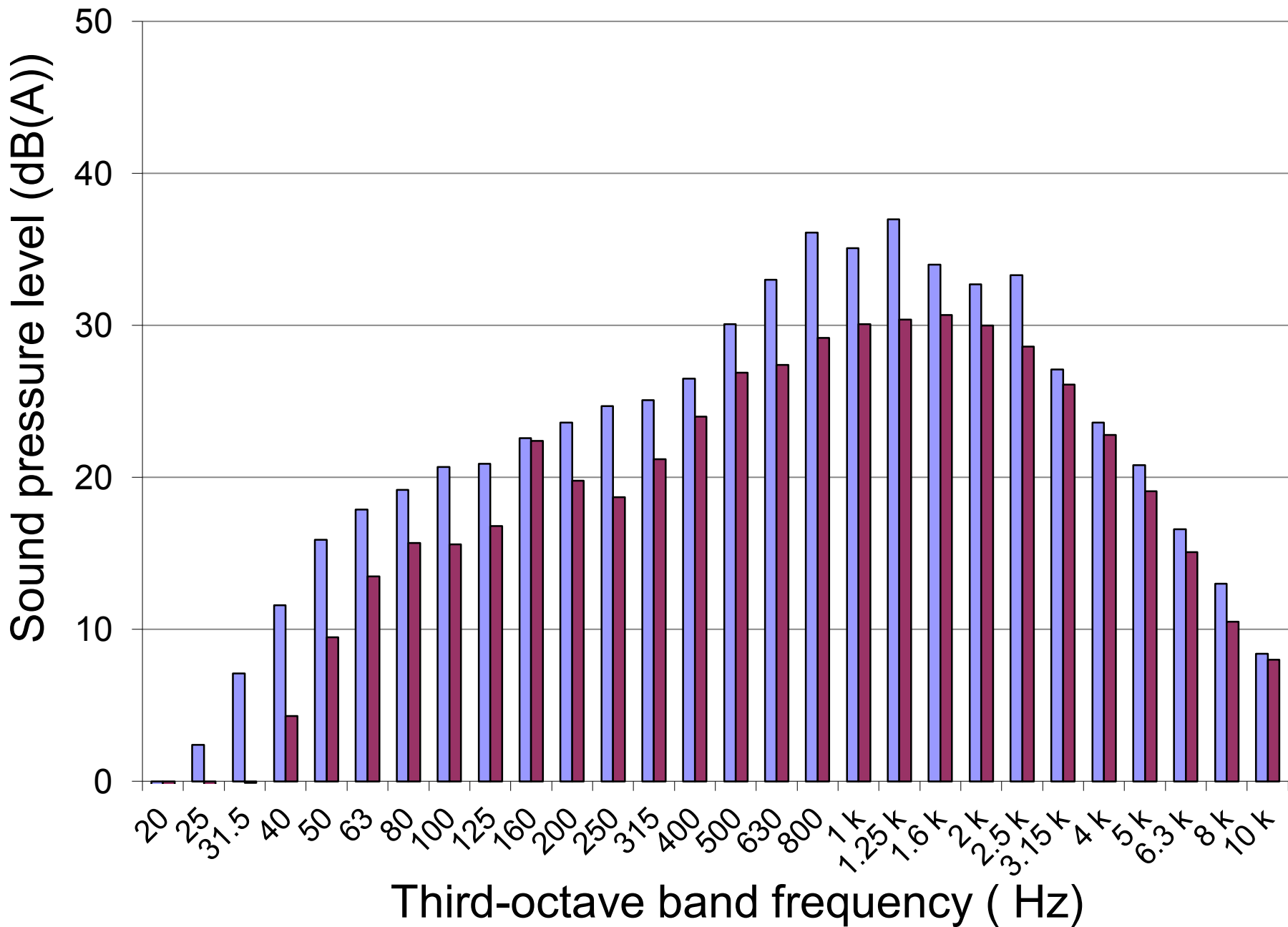
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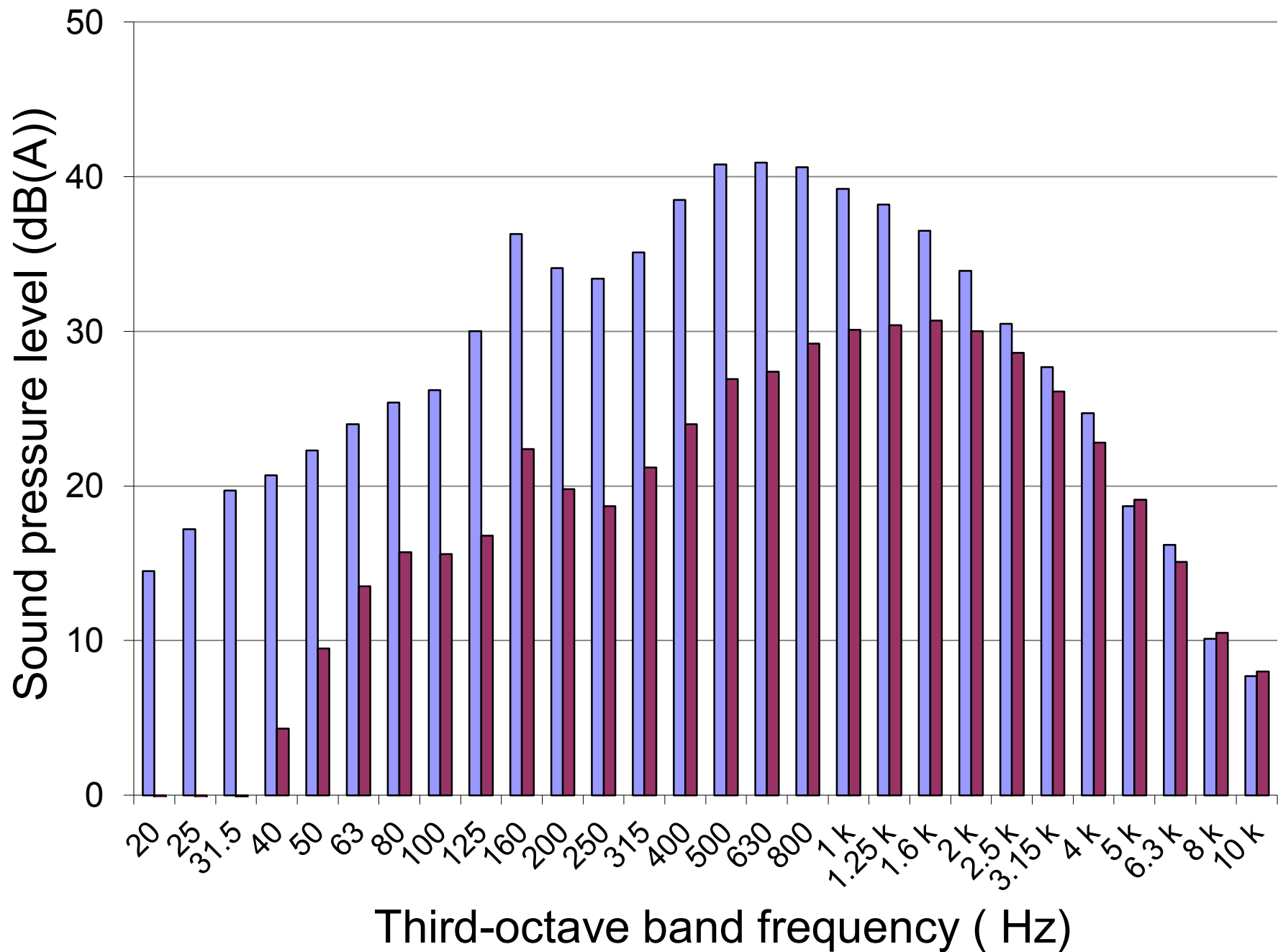
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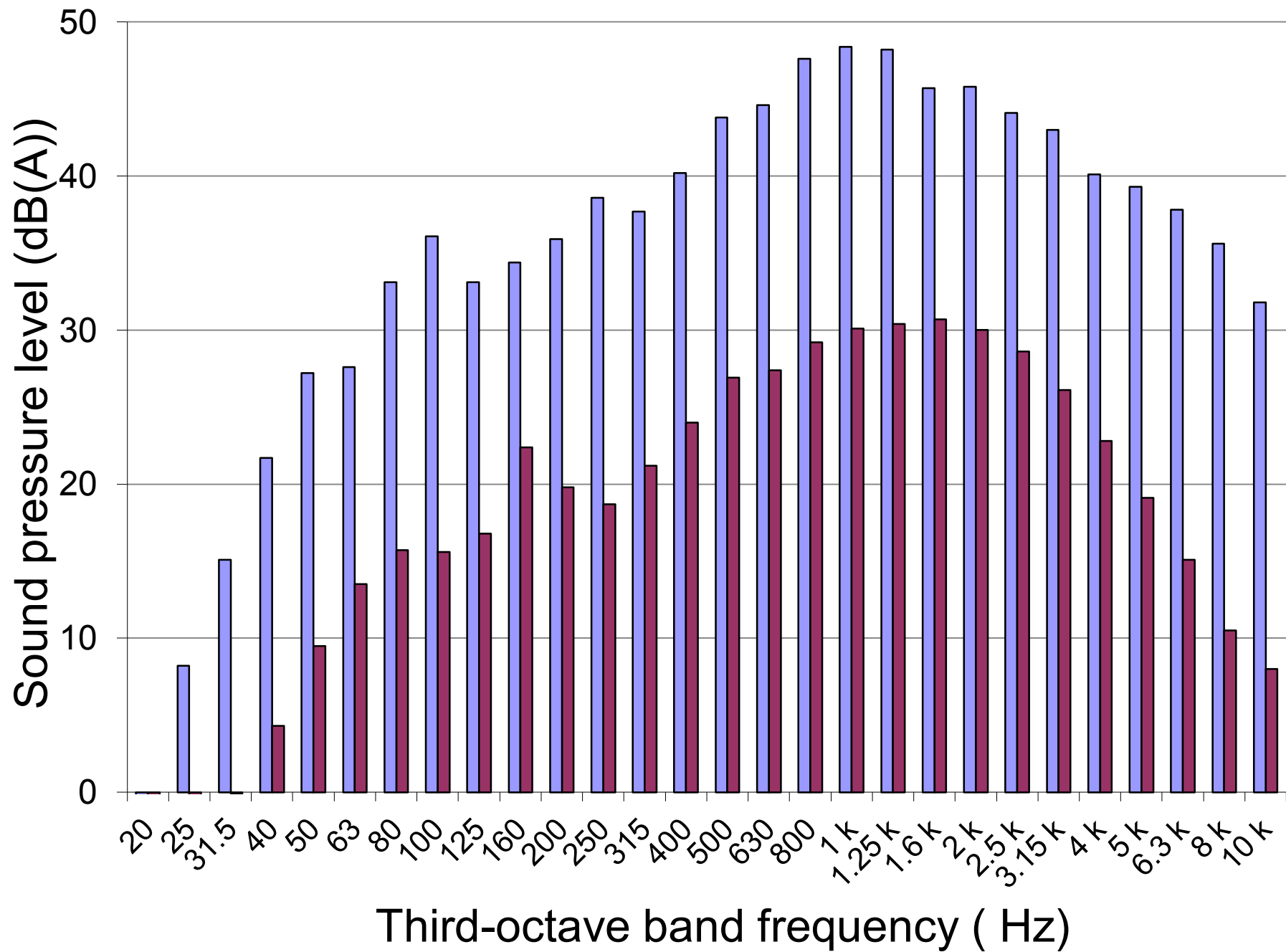
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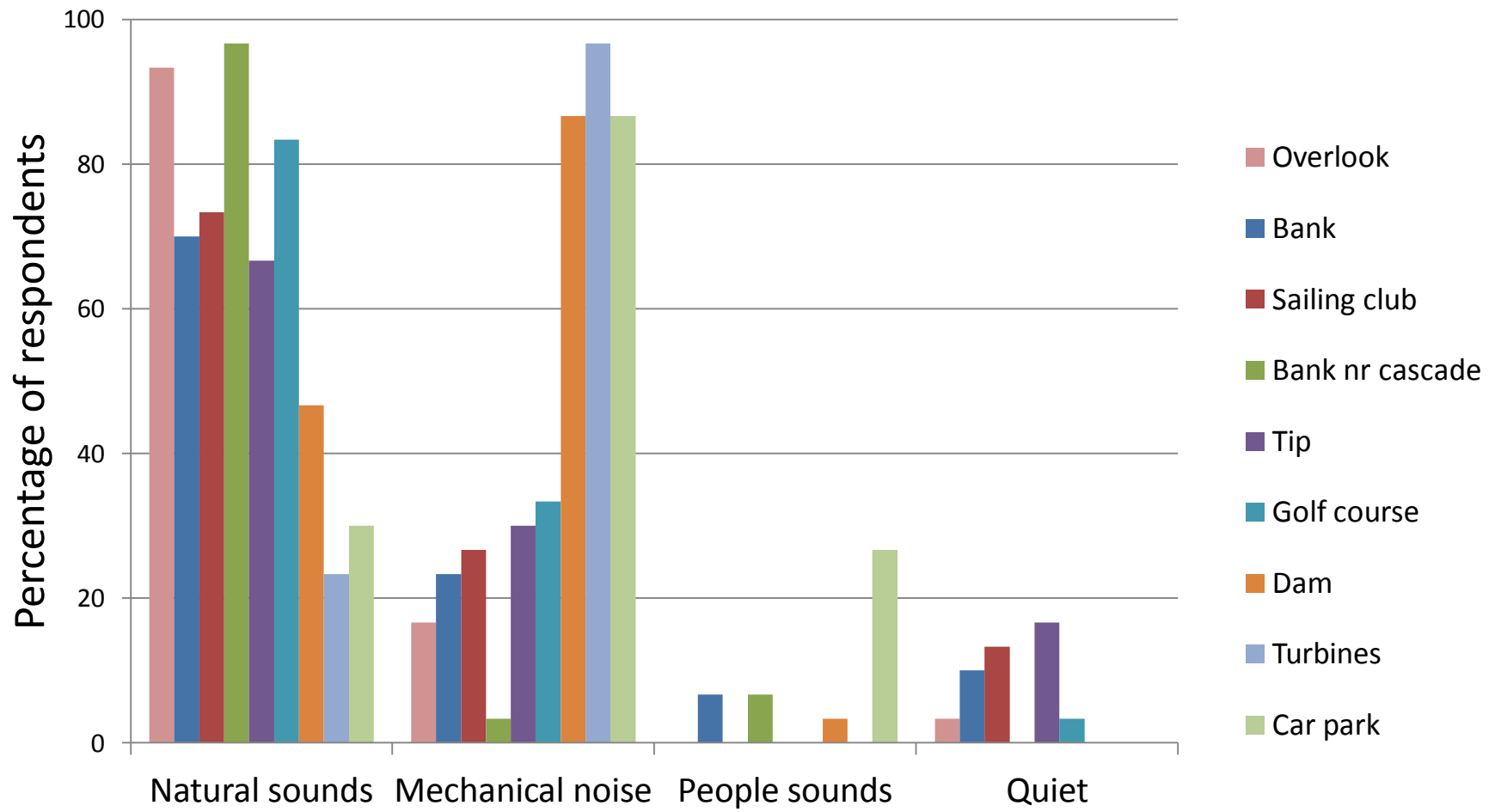
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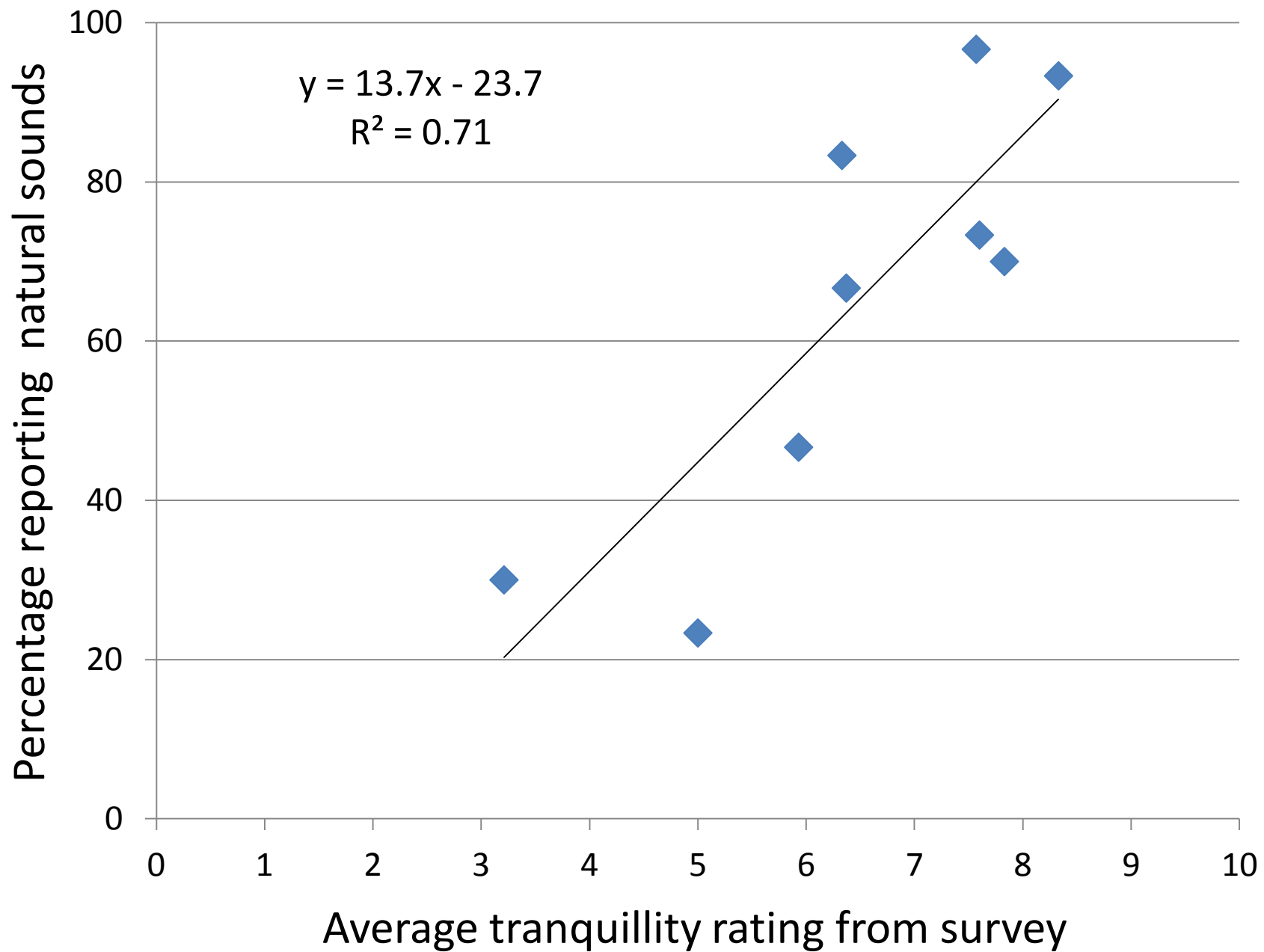
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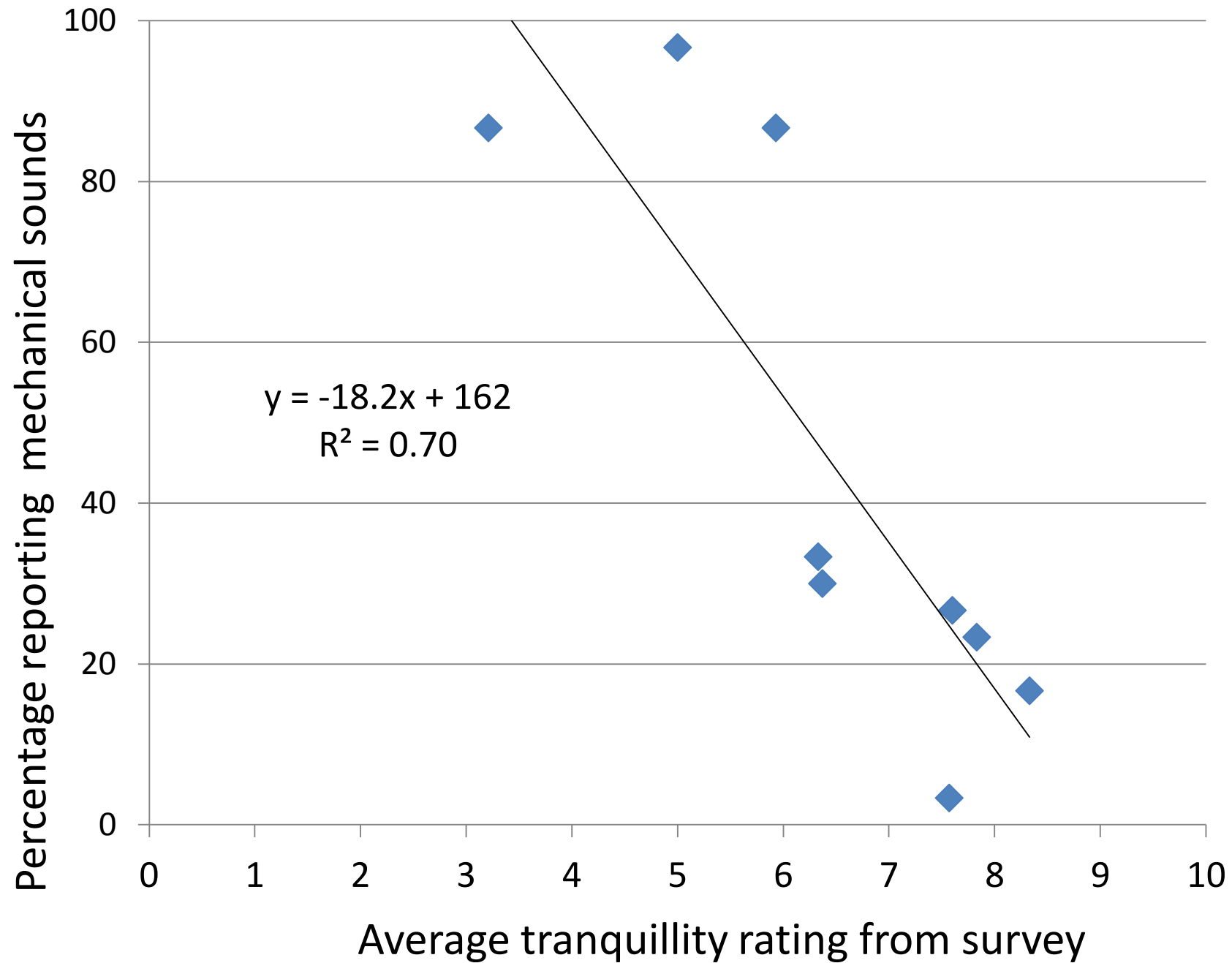
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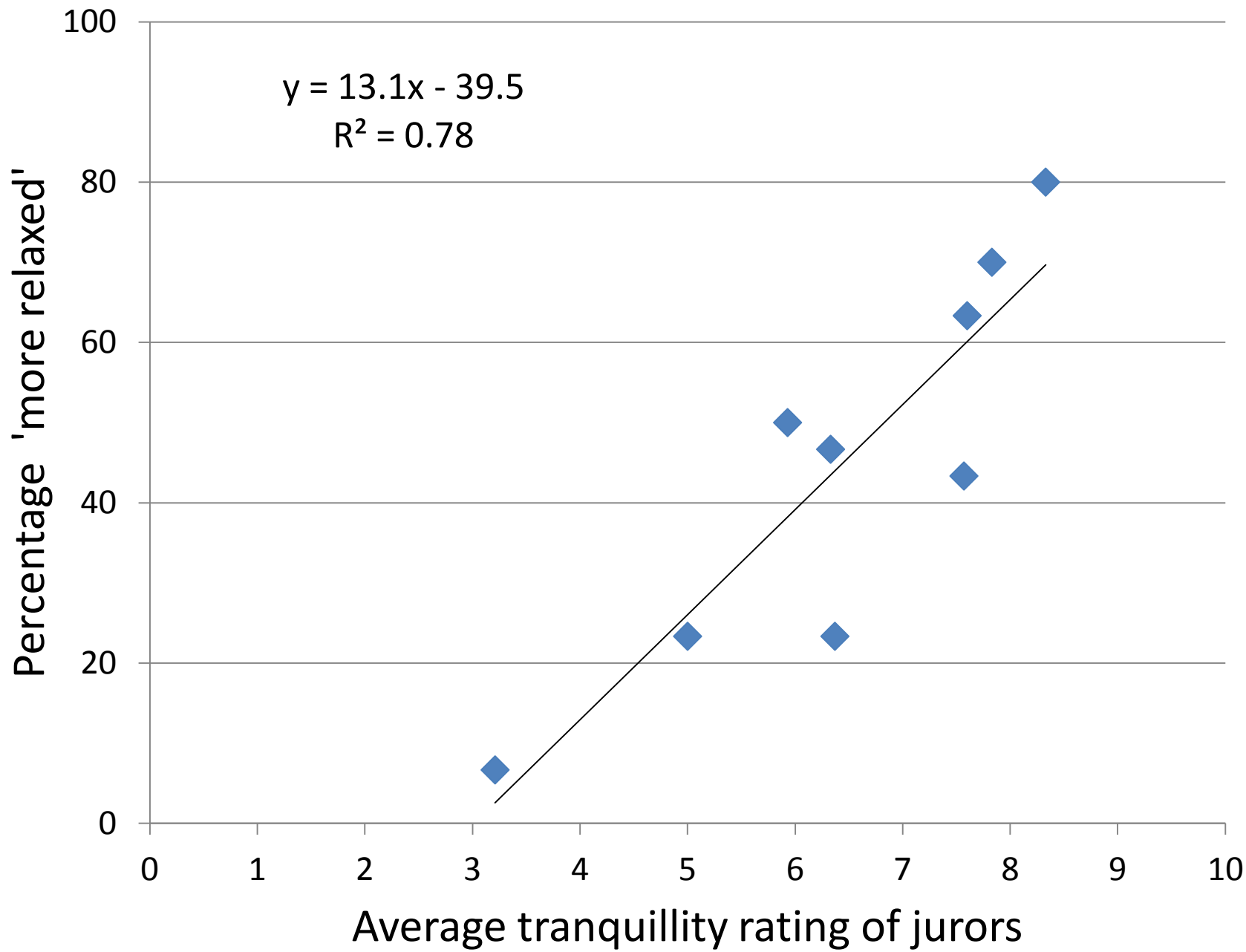
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Table

<i>Location</i>	<i>TR</i>	<i>TR_{adj}</i>	<i>Change</i>	<i>Important factors</i>
Overlook	8.33±0.44	8.86±0.40	0.53*	Nothing, plane noise, managed nature
Bank	7.83±0.56	8.54±0.49	0.71*	Traffic noise, people, restricted view
Sailing club	7.60±0.51	8.22±0.51	0.62*	Road, club buildings, fencing
Weir	7.57±0.41	8.31±0.33	0.74**	People, path, fencing, running water
Tipping site	6.37±0.76	7.57±0.68	1.20**	Litter, rubble
Golf course	6.33±0.71	7.33±0.65	1.00*	Urban view, golf course, vehicles
Dam	5.93±0.79	7.40±0.70	1.47**	Traffic noise
Turbines	5.00±0.86	6.89±0.62	1.89***	Turbines
Carpark	3.21±0.63	5.00±0.60	1.79***	Cars, people

*significant at 5% level ($p<0.05$), **significant at 1% level ($p<0.01$), ***significant at 0.1% level ($p<0.001$)