



EXPLORING PERCEPTION AND ANNOYANCE DUE TO WIND TURBINE NOISE IN DISSIMILAR LIVING ENVIRONMENTS

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ABSTRACT

A cross-sectional study with the aim to explore differences in perception and annoyance between dissimilar living environments was carried out in seven different geographical areas in Sweden 2005. Responses to wind turbine noise were measured using a questionnaire (response rate: 58.4%; 765 respondents) and outdoor A-weighted sound pressure levels were calculated for each respondent.

The result indicated that the proportion of people hearing and being annoyed by noise from wind turbines was higher among those who could see one or more wind turbines compared to among those who could not see any turbine at all sound levels. When comparing agricultural areas with suburban areas, a tendency towards higher degrees of perception and annoyance in the agricultural areas was observed. The differences could be due to (i) shortcomings of the sound propagation calculations not taking local barriers into account, (ii) variation in background sound pressure levels between agricultural and suburban areas, (iii) the variation in visibility of the wind turbines influencing the rate of noise annoyance and (iiii) resident's personal values of their living environment due to the level of urbanization of the areas (e.g. rural versus suburban).

1 INTRODUCTION

The development of wind power continues in Europe. The installed effect increased with 11 GW during 2005, which is a growth of 24% in one year. Great efforts have been made to enhance the efficiency of the turbines and they are now an economical realistic alternative for electricity production when placed onshore. However, the impact on people living in the vicinity of the turbines is not yet fully explored.

In an ongoing Swedish program investigating the impact of wind turbines on people living in the proximity of wind turbines, a dose-response relationship between A-weighted sound pressure levels (SPL) and annoyance due to wind turbine noise was found [1]. The study was performed in a flat landscape in the south of Sweden where more than 40 wind turbines are situated; most of them as single objects which gives a scattered visual impression. In the analysis several intervening variables were tried. The attitude towards the visual impact of the turbines on the landscape was found to be highly correlated to noise annoyance ($r=0.51$; $p<0.001$). There are therefore reasons to believe that the prevalence of noise annoyance could be influenced by the variation in visibility of the wind turbines between a flat landscape and a hilly ground.

Follow-up in-depth interviews with 15 informants revealed additional associations between the landscape and perception of wind turbine noise [2]. The informants' personal values about the living environment seemed to have an influence on how the exposures from wind turbines were perceived. Some informants, who considered the countryside as a place for economic growth and technical achievements, were indifferent to the exposures from the wind turbines. Others, who emphasized that the countryside should be a quiet and peaceful place suitable for restoration, felt that the noise intruded into privacy and hence had a negative impact on life quality. It could therefore be hypothesized that exposures from wind turbines would be more negatively appraised in a landscape that is perceived as unspoiled than in a landscape with several human activities going on.

The objective for the new study presented here was therefore to explore differences in perception and annoyance due to wind turbine noise between dissimilar living environments.

2 METHOD

2.1 Study areas and study population

In this cross-sectional study among people living in the vicinity of wind turbines, exposure was calculated as A-weighted SPL and response was measured by questionnaires. Seven study areas in Sweden were chosen. They all comprised wind turbines, but represented different types of landscapes with regard to topography (complex or flat ground) and character (agricultural or suburban). Each area comprised at least one wind turbine of 600 kW or larger (Table 1). Preliminary calculations of A-weighted SPL were made to establish the sizes of the study areas. All respondents exposed to $SPL>30$ dBA from wind turbines according to preliminary sound propagation calculations were included in the study population. A sample of one randomised person in each household was constructed and in total, 1309 questionnaires were sent out. The response rate was 58.4%.

Table 1. Character of the study areas and number of wind turbines.

Area	Wind turbines		Character
	N	Nominal power (kW)	
I	1	660	Complex ground. Suburban area on an island.
II	1	850	Complex ground. Wind turbine on the top of a hill. Agricultural area.
III	1	600 (variable rotor speed)	Complex ground. Wind turbine on the top of a hill. Agricultural area.
IV	2	750	Complex ground. Wind turbines placed on the local landfill. Suburban area close by.
	2	550	
V	3	600	Flat ground. Agricultural area.
	1	250	
	9	225	
VI	2	1 500	Flat ground. Agricultural area.
	2	550	
VII	1	500 (variable rotor speed)	Flat ground. Suburban area.
	3	225	

2.2 Questionnaire

The questionnaire was masked to give an impression of investigating general living conditions in the countryside. It mainly comprised questions used in a previous study on the effects of noise from wind turbines; i.e. questions regarding reactions to the exposure, attitude to the source, living conditions and well-being [1]. Annoyance due to wind turbine noise was measured with a five-graded scale (do not notice, notice but not annoyed, slightly annoyed, rather annoyed, very annoyed).

2.3 Calculations of noise exposure

The standard model proposed by the Swedish Environmental Protection Agency [3] for calculating sound imission of wind turbines was used. The model assumes down wind conditions with a wind speed of 8 m/s at 10 meters height. For distances >1000 m between the wind turbine and the respondent, the calculations are based on octave bands (Eq. 1).

$$L_{AeqT} = L_{WA} - 10 - 20\log(r) - [10\log(\sum 10^{(L_i + A_i)/10}) - 10\log(\sum 10^{(L_i + A_i - r a_i)/10})] \quad (1)$$

L_{AeqT} is the equivalent continuous A-weighted SPL (dB) within the time interval T at the respondent. No specified time interval was set, but T should be viewed upon as 2 – 5 minutes. L_{WA} is the A-weighted SPL (dB) emitted from the wind turbine at the stated weather conditions and r is the distance between the wind turbine and the respondent. L_i is the SPL (dB) for octave-band i ; A_i is the A-weighting and a_i the atmospheric absorption for the same octave band. L_{WA} and L_i (63 – 4000 Hz) were obtained from the wind turbine manufacturers.

For distances $r < 1000$ m, a modified algorithm was used (Eq. 2) in accordance with [3].

$$L_{AeqT} = L_{WA} - 8 - 20\log(r) - 0.005r \quad (2)$$

The attenuation coefficient 0.005 in the model is assumed to mainly account for the atmospheric absorption, but also includes a minor attenuation due to porous ground. For those

respondents in Area I that lived on the opposite side of a small bay compared to the wind turbine, 1.5 dBA were added to the calculated A-weighted SPL. The same was done for respondents living in Area II where the level from the wind turbine to the respondents was rather steep and this is known to enhance the sound propagation [4].

3 RESULT

3.1 Perception and annoyance

The respondents were classified into five sound categories according to the calculated wind turbine A-weighted SPL at their dwelling (Table 2).

Table 2. Number of respondents related to sound category.

Sound category	<32.5	32.5-35.0	35.0-37.5	37.5-40.0	>40.0	Total
Area I	152	48	9	5	0	214
II	2	4	1	3	6	16
III	6	0	2	4	0	12
IV	58	67	16	0	0	141
V	30	27	13	9	8	87
VI	56	8	4	3	0	71
VII	57	55	59	47	6	224
Total	361	209	104	71	20	765

There was a statistically significant correlation between A-weighted SPL and annoyance due to wind turbine noise ($r_s=0.34$; $n=755$; $p<0.001$). The proportion of respondents who noticed noise from wind turbines outdoors increased with increasing A-weighted SPL (Fig. 1).

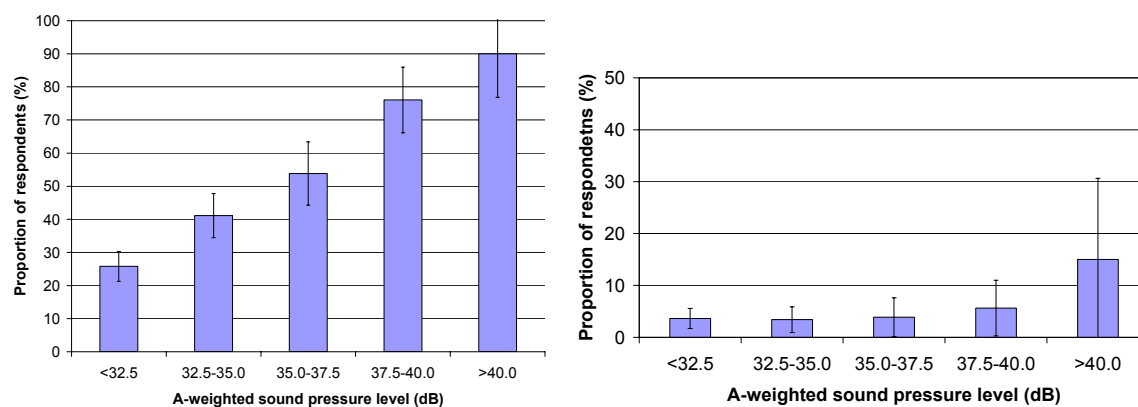


Fig. 1. Proportions, with 95% confidence intervals, of respondents who noticed noise from wind turbines (to the left) and of respondents who were annoyed (rather annoyed, very annoyed) by noise from wind turbines (to the right) related to A-weighted sound pressure level..

The proportions of respondents who were annoyed (rather and very) by wind turbine noise outdoors at their dwelling were between 3 and 6% except for those who were in the highest sound category (>40dBA) where 15% were annoyed (Fig. 1). However, this category only

comprised 20 respondents (Table 2) and the proportion of respondents annoyed was not statistically significantly different from zero.

3.2 Influence of topography, characteristics of the area and visibility

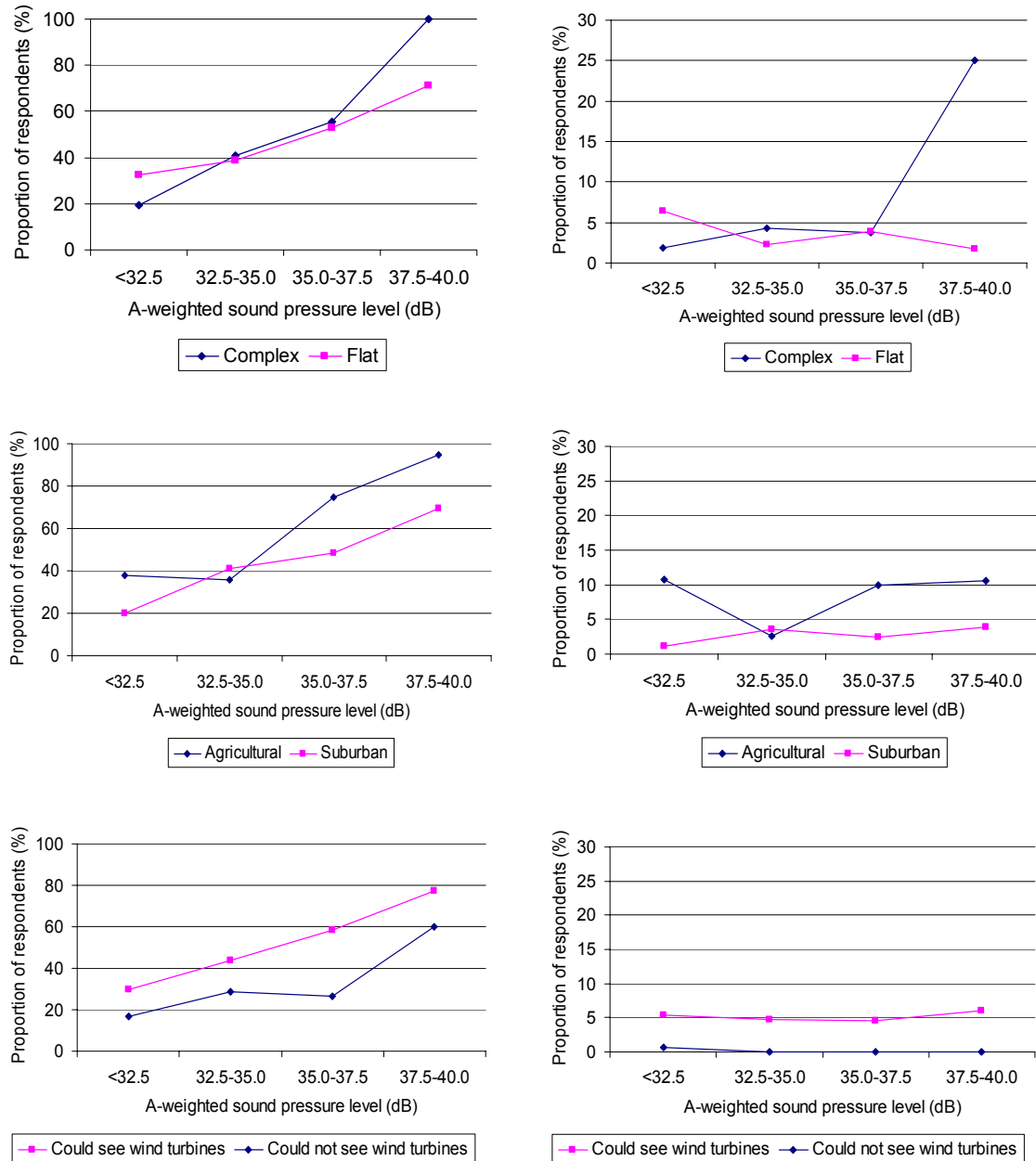


Figure 2. Proportions of respondents who noticed noise (left column) and who were rather or very annoyed by noise from wind turbines (right column) related to A-weighted sound pressure levels in areas with different topography or characteristic, and related to visibility. Sound category >40.0 dBA was excluded as it comprised only few or 0 respondents.

To explore the influence of topography, characteristics of the area and visibility, the proportions of respondents who noticed (Fig. 2; left column) and who were annoyed by wind turbine noise (Fig. 2; right column) were plotted in six diagrams. No differences in perception and annoyance between complex and flat ground were observed, except for in the highest sound category. In agricultural areas, a larger proportion of respondents noticed or was annoyed by wind turbine noise than in suburban areas in most sound categories. Those respondents who could see one or more turbines noticed and were annoyed by wind turbine noise to a higher degree than those who could not see any turbines from their dwelling. Confidence intervals (95%) overlapped, but explorative analyses using Mann-Whitney U-test indicated statistically significant differences at several sound pressure levels.

4 CONCLUDING REMARKS

The different degrees of perception and annoyance observed among respondents who could not see any wind turbines versus those who could, could be due to miss-classification into sound categories as barriers between the turbine and the respondent might be the cause for not seeing any turbine and also a factor decreasing sound propagation. High visibility could furthermore be associated with an agricultural landscape (compared to a suburban landscape), in which a tendency to higher degree of perception and annoyance also was found, and hence the differences could be due to variation in background sound pressure levels or in the respondent's personal values about the living environment. The visual impression of a wind turbine with rotating blades could also hypothetically be a moderating variable in a dose-response relationship between wind turbine noise and noise annoyance. All these factors should be further analyzed and tried in statistical models.

REFERENCES

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