1.0 INTRODUCTION

Qualifications

1.1 My name is Daniel Shepherd. I hold a PhD in psychoacoustics, a Masters of Science degree in psychology, a Bachelor of Science degree in psychology and biology, and a Bachelor of Arts degree in history and politics. My PhD dissertation was a study on the abilities of human observers to discriminate between low level sounds. My Masters thesis investigated a newly emerging paradigm in physics, stochastic resonance, and applied it to the processing of low level sounds in humans.

1.2 Currently I am a Senior lecturer (Above the Bar) at the Auckland University of Technology, lecturing in the areas of psychological assessment, biopsychology, and statistical analyses at both the undergraduate and postgraduate levels. Since 2005 I have undertaken substantial supervision of postgraduate students engaged in a range of psychological and healthS research, including psychoacoustical topics. At the University of Auckland I am an honorary research fellow in the Department of Psychology, an associated staff member in the Department of Chemistry, and have a strong working relationship with members of the University of Auckland's School of Audiology and School of Population Health. In 2008 I co-founded the World Health Organisations' Quality of Life (WHOQOL) field centre in New Zealand.

1.3 I have published papers on the psychophysical measurement of human hearing abilities and have presented at numerous international conferences on the topic. In the past year I have accepted invitations from top-tiered psychoacoustic and health journals to peer review scientific manuscripts.

2.0 Preamble

2.1 I have been invited by the Ohariu Preservation Society to provide an evaluation of the impact of turbine noise on health and well-being. I have accepted this invitation and present findings from research projects I have personally initiated and undertaken in the last five years. I previously presented on their behalf at the original consent hearing in 2008. At this hearing I noted that the commissioners had not had time to read my statement prior to my arrival. I also indicated during this hearing that Meridian Energy should undertake a psychoacoustical survey of the Ohariu Valley in order to ascertain the prevalence of noise sensitive individuals and other vulnerable groups.

2.2 On more than one occasion I have visited the Ohariu Valley and familiarised myself with its layout and character. I have personally visited the Makara Valley on three occasions in the last year, and on one occasion had the opportunity to listen to the turbine noise. Additionally, on numerous occasions I have heard the noise coming from turbines situated in the Tararua ranges in the Manawatu.

Current Knowledge

2.3 Wind turbines are a new source of community noise, and as such their effects on public health are only beginning to emerge in the literature. The recognition of a new disease, disorder, or threat to health usually follows a set pathway. First, doctors and practitioners attempt to fit symptoms into pre-defined diagnostic categories or to classify the complaints as psychosomatic. Second, as evidence accumulates, case studies begin to appear in the literature, and exploratory research is undertaken to obtain better descriptions of the symptoms/complaints. Third, intensive research is undertaken examining the distribution and prevalence of those reporting symptoms, the factors correlating with the distribution and prevalence of those symptoms, and ultimately to cause-and-effect explanations of why those reporting symptoms may be doing so.

2.4 In my reading of the literature the health effects of wind turbines are only beginning to be elucidated, and is caught somewhere between the first and second stages described in 2.3. The important point to note is that case studies (e.g., Harry, 2007; Pierpont, 2009) and correlational studies (e.g., Pedersen et al., 2007; van den berg, 2008) have already emerged in relation to the health effects of wind turbine noise, and so the possibility of detrimental health effects due to wind turbine noise must be taken with utmost seriousness. In this statement I present the results of a pilot study conducted in and around the Makara Valley that likewise urges a cautious approach to turbine placement.

2.5 Finally, as with other noise sources there is individual variation in regards to the effects of wind turbine noise. However, it is a fallacy to argue that because only some suffer symptoms while others do not then those who claim to be suffering the symptoms must be making them up. In the field of epidemiology the differential susceptibility of individuals are known as risk factors, and assuming that individuals of a population can be represented by the average characteristics of the population is known as the ecological inference fallacy. In terms of wind turbine noise these risk factors are still under study, and one important risk factor is noise sensitivity. In assessing the health impact of turbine noise in the Ohariu Valley it is crucial that noise sensitive individuals be assessed in isolation and not 'averaged out'.

Scope of Evidence

2.6 In this statement I focus on the health impacts of wind turbine noise, and I do not focus on issues outside of noise. Thus references to cell phone or cell phone tower emissions or electromagnetic radiation from electricity transmission lines have no relevance to the current context, and should be discarded out of hand. These arguments constitutes a form analogy (e.g., weak or false analogy), which are not accepted as valid scientific critique. For example, a person confined to a room has no way of knowing whether they are being exposed to cell phone radiation but can easily detect the presence of an everyday sound. Additionally, these examples of 'health scares' are not explained by plausible mechanisms, whereas there is a clear and proven link between noise, sleep, annoyance, and health impacts.

2.7 Having considered the context I structure this statement as per Figure 2.0.

2.8 The terminus of the statement coincides with a summary section and a recommendation that consent should not be granted for this proposal.

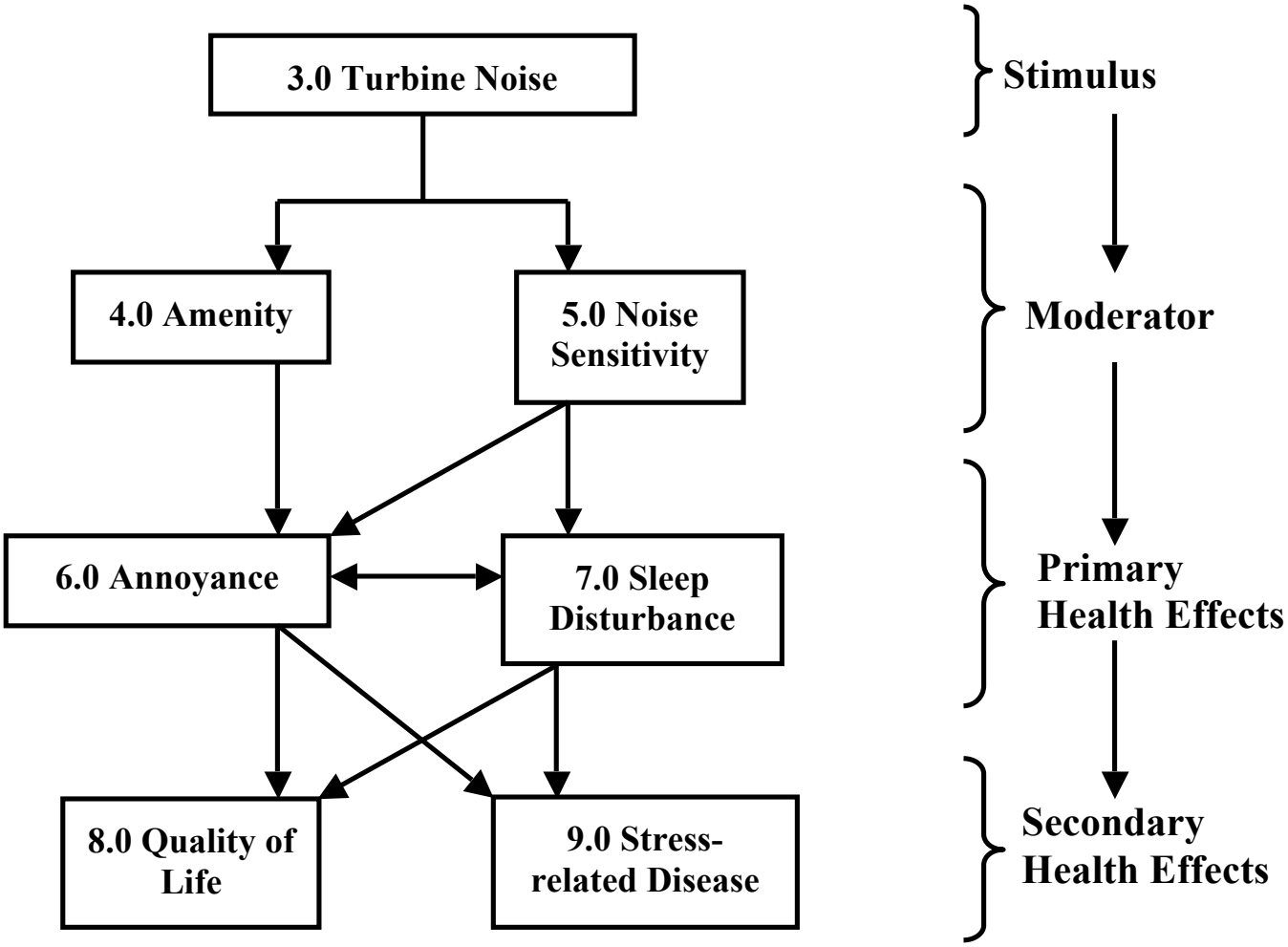


Figure 2.0: A schematic representation of the relationship between noise and health, as contextualised to turbines placed in life style areas. The numbers correspond to sections in this statement. Arrows represent hypothesised or actual cause-and-effect relationships. The statement ends with concluding remarks.

Expert Witness Code of Conduct

I have received and read sections 5.1 to 5.4 of the Environment Court Consolidated Practise Note 2006 headed *Expert Witnesses - Code of Conduct*. I understand all of the clauses contained within the Code proper, and unconditionally agree to comply with it.

3.0 Turbine Noise and noise levels

3.1 Level is that measure of sound which we associate with the perception of loudness. Figure 3.0 demonstrates that, for equivalent noise levels, people judge wind turbine noise to be of greater annoyance than aircraft, road traffic, or railway noise. The most recent research to hand (van den Berg, 2008) has confirmed the relationship reported in Figure 3.0, and I have added van den Berg's data to the figure.

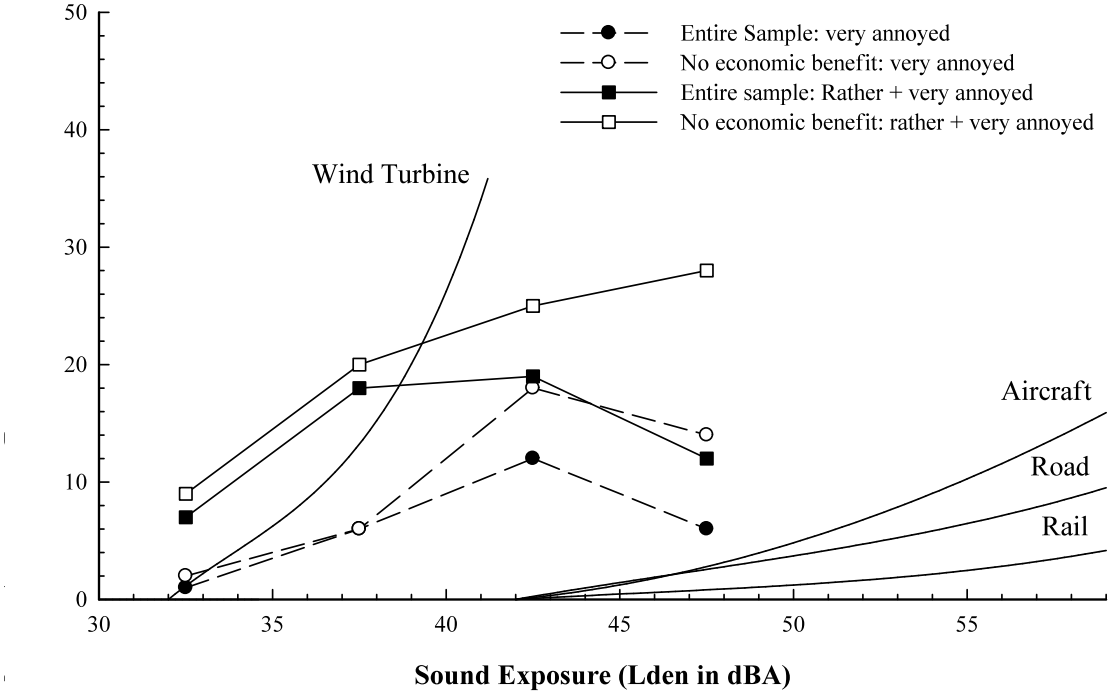


Figure 3.0: Annoyance plotted as a function of noise level for four theoretical models (rail, road, air: Miedema and Oudshoorm, 2001; wind turbines: Pedersen et al., 2004) and four sets of data obtained from van der Berg et al., (2008). For the data, closed symbols are for the entire sample, while open symbols are for those who identified that they had no economic interest. Circles represent the percentage of "very annoyed" responses whilst squares represent the sum of "very annoyed" and "rather annoyed" responses.

3.2 The lack of equivalence evident in Figure 3.0 is due to the unique characteristics of turbine noise, that is, clusters of turbines present a cumulative effect characterized by a dynamic or modulating sound as turbines synchronise. Table 3.0, which displays data I collected early this year to inform a subsequent noise study, displays annoyance ratings for the top ten rated annoying sounds out of 100 sounds played to a group of undergraduate students. Sounds with an (M) indicate audio samples that could be described as periodic, and in that sense modulating. Note that seven of the ten most annoying samples fall into this category, and that these results concur with those in the literature indicating that modulating sounds tend to be of higher annoyance.

Table 3.0: Mean annoyance ratings and standard deviations (SD) for ten audio files rating on a scale from 1 (not annoying) to 9 (Extremely annoying).

	Annoyance Rating	
Sound	**Mean**	**SD**
Girl Yelling	8.08	0.99
Fire alarm (M)	7.91	0.79
Alarm (M)	7.83	1.33
Dentist Drill (M)	7.83	0.83
Fire truck Siren (M)	7.75	1.05
Abuse	7.75	1.28
Fire warning (M)	7.66	0.98
Dial tone	7.66	0.98
Jackhammer (M)	7.33	1.30
Horns (M)	7.33	1.43

3.3 Level is actually a very poor predictor of the human response to noise, and its role in health is commonly over-emphasised. For example, noise standards emphasise noise level as the primary factor in noise-induced health deficits, however, over 40 years of laboratory and epidemiological research has discredited this stimulus-orientated approach. For this reason noise standards promoting only noise level as the metric to assess health impacts should be approached with caution. That noise standards are not necessarily definitive is further demonstrated by the lack of agreement that can exist amongst experts on standards. The quarrelling surrounding the revision of the New Zealand standard for acceptable wind turbine noise (NZS6808) is testament to this (see, for example, the September 2010 Edition of the NZ Acoustical Society Journal, *New Zealand Acoustics*).

3.4 Noise standards, even those advocated by the WHO in the past, are based on the dose-response curve. The dose-response curve plots noise annoyance as a function of noise level. Users of a dose- response curve define a level of annoyance that they are willing to accept and then, either graphically or numerically, determines the level of noise that yields the predefined annoyance level. Figure 3.1 illustrates an actual equation-based dose-response curve.

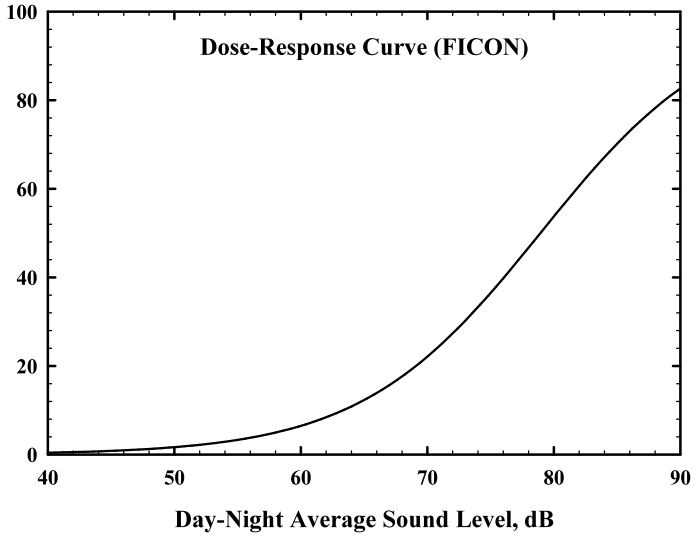


Figure 3.1: A theoretical curve formulated to model the relationship between noise level and annoyance to aviation noise.

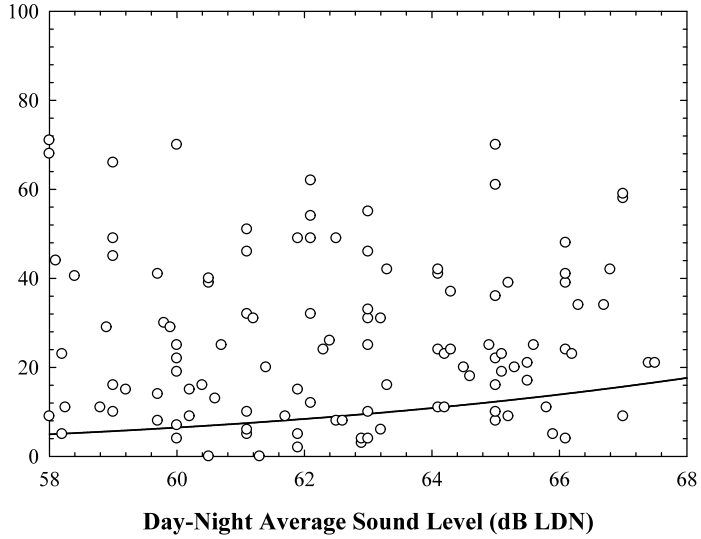


Figure 3.2: Percentage highly annoyed at aircraft noise plotted as a function of noise level. The solid curve is a portion of that presented in Figure 3.1, while the scattered points represent real measurements (data from Fidell, 2003).

3.5 Figure 3.2 is the same curve but with a shortened *x*-axis (now from 57 to 68 dB) accompanied by actual measurements of noise annoyance from numerous studies reporting annoyance to aircraft noise. Note the incompatibility of the theoretical curve (solid curve) and the empirically derived data (data taken from Fidell, 2003). Scrutiny of Figure 3.2 reveals that annoyance reactions to noise vary substantially and do not appear to be correlated with noise level. Other factors associated with the listener have been found to correlate with annoyance, and need to be accounted for when attempting to predict noise annoyance. It can be concluded that the high variability between individuals and groups makes it difficult to model the relationship between noise and annoyance. Regrettably, plots such as the Figure 3.1 above are still used to determine noise standards.

3.6 Not withstanding the criticisms of dose-response relationships the WHO (Europe) have attempted to categorise different bands of noise levels in relation to health impact, specifically sleep disturbance. They set out to establish a No Observed Effect Level (NOEL) and a Lowest Observed Adverse Effect level (LOAEL) for noise and various measures of health. The WHO's (2009: Table 5.4) description of the relationship between noise level ($L_{night,\ outside}$) and health are repeated in Table 3.2:

Table 3.2: WHO Europe (2009) night time guidelines.

30 dB	Although individual sensitivities and circumstances may differ, it appears that up to this level no substantial biological effects are observed.
30–40 dB	A number of effects on sleep are observed from this range: body movements, awakening, self-reported sleep disturbance, arousals. The intensity of the effect depends on the nature of the source and the number of events. Vulnerable groups (for example children, the chronically ill and the elderly) are more susceptible. However, even in the worst cases the effects seem modest. $L_{night,outside}$ of 40 dB is equivalent to the lowest observed adverse effect level (LOAEL) for night noise.
40–55 dB	Adverse health effects are observed among the exposed population. Many people have to adapt their lives to cope with the noise at night. Vulnerable groups are more severely affected.
>55 dB	The situation is considered increasingly dangerous for public health. Adverse health effects occur frequently, a sizeable proportion of the population is highly annoyed and sleep-disturbed. There is evidence that the risk of cardiovascular disease increases.

3.7 There are a number of important points to be read from these figures, which are expanded on in the guidelines. First, the WHO recognizes the existence of vulnerable groups and acknowledges the existence of individual differences in noise sensitivity. Second, health begins to be degraded between 30 and 40 dB. Third, 30 dB is the level that can be considered "safe". Lastly, 40 dB and above can be considered "unsafe".

3.8 As best practice and goodwill to the community I argue that the appellant should be using 30 dB as their criterion. It is interesting to note that the originally WHO noise working party (2007) originally stipulated 30 dB, but in the 2009 publication 40 dB was stipulated. As originally drafted the WHO noise working party (2007) recommendation read thus:

"*The review of available evidence leads to the following conclusions...For the primary prevention of subclinical adverse health effects in the population related to night noise, it is recommended that the population should not be exposed to night noise levels greater than 30 dB of* $L_{night,outside}$ *during the night when most people are in bed. Therefore,* $L_{night,outside}$ *30 dB is the ultimate target of Night Noise Guideline (NNGL) to protect the public, including the most vulnerable groups such as children, the chronically ill and the elderly, from the adverse health effects of night noise*."

3.9 The approach of the WHO (2009) is useful in some respects, but limiting in others. The NOEL / LOAEL values were developed primarily with aviation and road annoyance data. Reference to Figure 3.0 above indicates that a universal criterion is likely to fail unless additional factors are taken into account, such as the temporal characteristics of the noise. Additionally, both NOEL / LOAEL values will not be constant across a defined population, as subgroups of that population will be more vulnerable to the effects of noise than others. While the WHO does acknowledge the existence of vulnerable groups, the 2009 levels nevertheless rest on aggregate data that for the most part do not distinguish vulnerable from non-vulnerable groups. As described in 2.6 above, such an approach constitutes an ecological inference fallacy.

3.10 Finally, as Table 3.2 attests, an $L_{night,outside}$ of 40 dB is recommended as representing the LOAEL. It should be noted however that these guidelines were produced exclusively for the European context and not the New Zealand context. For example, the WHO used a value of 21 dB for sound attenuation from outside a building to inside, which is greater than the 10-15 dB usually cited (e.g., ETSU R 97: WHO 1999). Given that New Zealand dwellings are commonly made from lighter construction materials such as timber and weather board rather than heavier materials such as concrete and stone, the 21 dB attenuation value is not particularly useful.

4.0 Amenity

4.1 Typically, noise can be quantified by sound exposure levels or audibility, and qualified in terms of unwantedness, annoyance, or loss of amenity. There is an expectation of "peace and quiet" when living in a rural area, and most choose to live in rural areas as they are bastions of tranquillity (Schomer, 2001). A rural area is defined as an area with a population density less than 500 people per square kilometre. The literature shows that those who live in rural areas have different expectations regarding community noise compared to those living in suburban, urban, or industrial areas. People expect rural areas to be quieter, and consequently exposure to noise will produce a greater negative reaction in rural areas than other areas (Pedersen & Persson, 2004). It is

evident in the literature that community setting is emerging as a powerful predictor of annoyance reactions.

4.2 If a proposed wind turbine installation encroaches rural and semi-rural areas populated by residents with a greater expectation for, and value on, peace and quiet, the reaction to the proposed wind turbines are likely to be negative. Amenity values are based upon what people feel about an area, its pleasantness, or some other value that makes it desirable place to live. Noise affects individuals and communities by modifying the extrinsic and intrinsic nature of the environment that attracts and holds people to the locality.

4.3 Survey-based investigations of wind turbine noise have demonstrated a distinction in self-reported annoyance levels between respondents living in cities and those living in rural areas. Because attitudes towards the noise source influence annoyance, then these rural residents are likely to be more annoyed than those living in suburban or urban neighbourhoods. Pedersen and Persson (2007) sum it up:

"*…exposure from wind turbines would be more negatively appraised in an area that is perceived as unspoiled than in an area where several human activities take place … People choose environments that harmonise with their self-concept and needs, and that they remain in places that provide a sense of continuity. When a new environmental stressor occurs, the individual's relationship with her or his place of residence is disrupted. Such a distortion could possibly predispose for an increased risk of annoyance… Expecting the home and its surroundings to be a suitable place for rest and recreation could conversely lead to an appraisal of the sound as threatening personal values. The sound was described as an intrusion into privacy that changed the image of a good home*."

The same report indicated that annoyance was most frequently reported when participants were relaxing outdoors or on "barbecue nights". It can be embarrassing living near sources of community noise, and there is a public stigma that only those in the lower socio-economic bracket live in the vicinity of noise generators. Such feelings discourage residents from inviting guests around to their houses, and thus community noise interferes with rest and recreational activities.

4.4 For a variety of reasons wind turbines are placed mainly in rural areas with low background sound levels. The operation of wind turbine clusters within the confines of the Ohariu Valley will undoubtedly produce noise that is incongruent with the natural soundscape of the area. The immediate and long-term effects of such noise will be to degrade amenity and impact upon the responses of a "reasonable person", to the point where they may become "forced emigrants". The affinity that rural dwellers have to the land is often difficult for their urban and suburban counterparts to comprehend, as too are their responses to unwelcome modification of their environment.

4.5 The revised version of NZS6808 includes an allowance for high amenity areas. You cannot, however, put a price on amenity and neither can you put a decibel value on

it. For the same reasons outlined in relation to annoyance (see 3.4 – 3.5 above) I would not recommend the approach outlined in NZS6808 as a guardian of amenity.

4.6 A survey recently undertaken my colleagues and I (see 8.4 below) included an open-ended question asking if there been any changes to the better or the worse in their living environment/ neighbourhood during the last year. Comments from rural areas (including the Ohariu Valley, Makara and a turbine-free rural control area) are presented in Appendix A. My interpretation of these comments is thus. First, peace, quiet, and privacy, and threats thereof, are reoccurring themes. Second, the comments from the Ohariu Valley indicate that the residents perceive the placement of turbines in the area as a threat to their quiet surrounds and amenity. The emotional intensity of these comments provides a picture of a community strongly connected with the valley, and for those opposing the turbines I predict especially strong annoyance reactions to turbine noise. Third, residents in the Ohariu Vallet report hearing the turbines from Makara, indicating the cumulative effects need to be considered. Fourth, I note that even in the control areas there is a fear amongst residents that they may be next in line for turbine installations.

4.7 In the same survey we presented two questions relating to amenity, both rated on a five-point category scale: 1) I am satisfied with my neighbourhood / living environment, and 2) My neighbourhood / living environment makes it difficult for me to relax at home. When compared statistically to the control area, the Makara sample were less satisfied with their living environment and found their living environment made it more difficult for them to relax at home than those in the control sample. The open-ended responses displayed in Appendix A suggest that these differences may be explained by the presence or absence of wind turbines.

Amenity and Visual Impact

4.8 The visual impact of the turbines can also influence reactions to turbine noise, probably because the visual presence of the turbines can act as reminders of the negative impacts that they have had on people's lives. In a Danish study, the position of the listener (on a flat landscape) relative to the wind turbine influenced their perception of the noise more than the overall level of the turbine's noise (Pedersen & Nielsen, 1994). Other studies (Delvin, 2007) have likewise reported that, as a whole, wind turbines are viewed as eyesores and visual spoilers of the environment (see cartoon, Figure 4.0). Pedersen and Persson (2004) hypothesize that, from an aesthetic perspective, those who view the wind turbines as ugly are likely to disassociate them from the landscape, and as a consequence, react more strongly to turbine noise. Their findings have direct relevance to those who value the amenity and restorative features of the Ohuria Valley:

"*Wind turbines were described as environmentally friendly, necessary, but also as ugly... Seeing a wind turbine in an otherwise non-industrial environment may reduce the individual's perception of the naturalness of the area and reduce the perception of restoration possibilities.*"

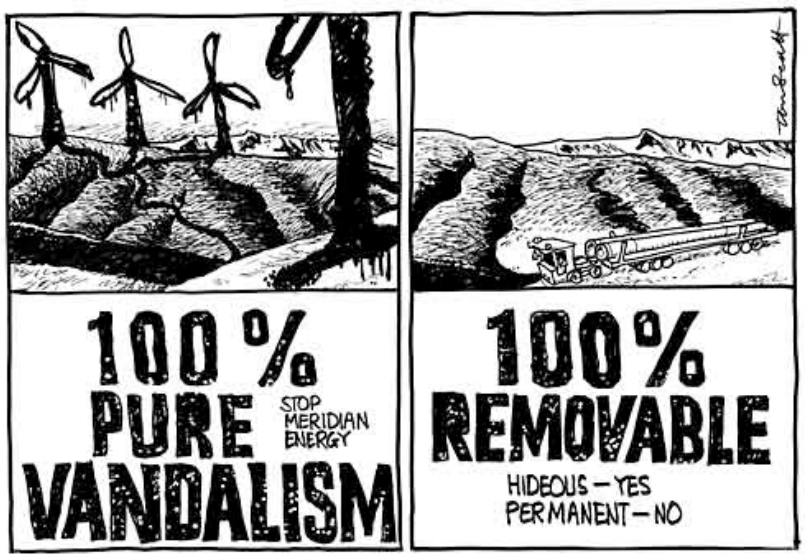


Figure 4.0: A cartoon poking fun at wind turbine installation developers (here Meridian energy) and NIMBYs (Not In My Back Yard) alike (from *www.stuff.co.nz*).

5.0 Noise sensitivity

5.1 Noise sensitivity, considered a stable personality trait that is relatively invariant across noise level, is a strong predictor of noise annoyance and is correlated with sleep quality. Noise sensitive individuals can be described by two key characteristics. First, they are more likely to pay attention to sound and evaluate it negatively (e.g., threatening or annoying). Second, they have stronger emotional reactions to noise, and consequently, greater difficulty habituating.

5.2 Note that noise sensitivity is not a symptom of mental illness, but a measurable state that differs in intensity across the population. Research has suggested that noise sensitivity is associated with mental illness. However, this does not mean that mental illness is a necessary prerequisite for reporting high sensitivity to noise, nor that noise sensitivity is a symptom of mental illness. As a trait, noise sensitivity is measured on a continuum from highly noise sensitive to highly noise resistant, and everybody falls somewhere along this continuum:

Highly noise sensitive	Highly noise resistant

5.3 I further dichotomise noise sensitivity into two different constructs; state and trait noise sensitivity. State noise sensitivity is an emotional state that is characterized by feelings of annoyance due to circumstantial factors. It is evoked when individuals are exposed to noises that are perceived as psychologically undesirable or physically threatening. The emotional state is generally transitory but can remain as long as the

noise exposure persists. Trait noise sensitivity refers to relatively enduring individual differences in sensitivity to noise. If an individual has high trait noise sensitivity, they are likely to experience state noise sensitivity reactions more often. Thus trait noise sensitivity is a measure of the probability of state noise sensitivity being experienced in future situations, judged on the frequency and intensity of the individual's experience of state noise sensitivity in the past.

5.4 Most individuals exhibit State noise sensitivity in certain situations. Those with trait noise sensitivity, however, may try and avoid noisy areas and, if given the choice, may choose to live in quieter areas. This year myself and colleagues from the Universities of Otago and Auckland collected data in both cities and rural areas, which included self-report noise sensitivity ratings. This data affords a comparison of noise sensitivity prevalence in the countryside or a city, and is presented graphically in Figure 5.0. Of remark are the disparities evident in the 'none' and 'high' sensitivity categories. Note, however, that the estimates of noise sensitivity in rural areas may represent an under estimate due to the lack of noise and therefore lack of knowledge that one may be noise sensitive.

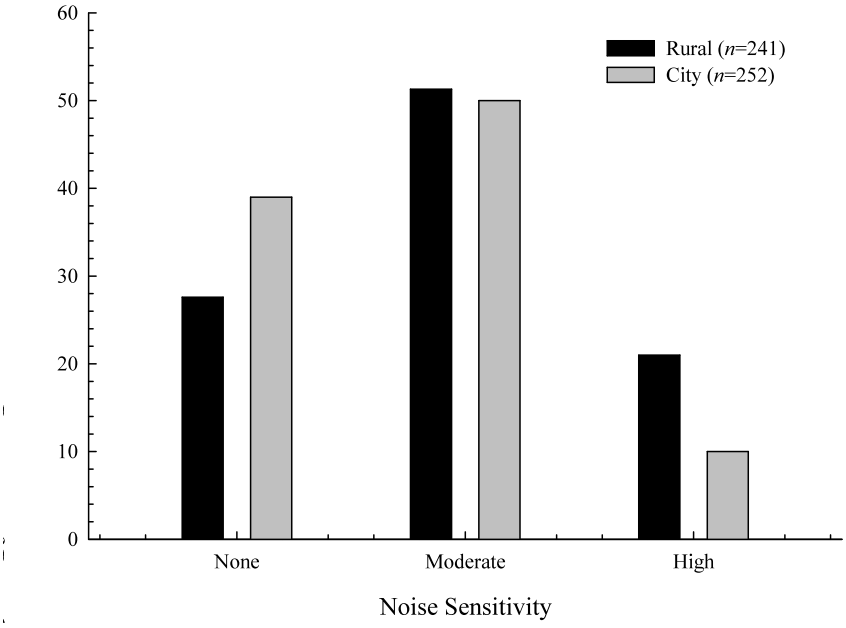


Figure 5.0: Bar graph plotting percentage of respondents indicating their category of noise sensitivity. Black bars represent respondents from rural areas whilst grey bars represent those living in a city.

5.5 A Scandinavian study on wind turbine noise and annoyance conducted in a rural area reported that fifty percent of respondents described themselves as sensitive to noise (Pedersen & Persson, 2004). This value contrasts with their estimates from urban areas (approximately 20%) and suggests that noise sensitive individuals seek out rural areas for

their lower levels of noise. From Figure 5.0 it is evident that there is a greater proportion (by a factor of 2) of noise sensitive individuals in rural areas than cities.

5.6 In the first three months of this year my team, in collaboration with Brain Injury NZ, undertook interview-based research attempting to gain further insight into the experiences of living with noise sensitivity. We chose survivors of traumatic brain injury as noise sensitivity is the strongest predictor of subsequent postconcussive syndrome, and there is a high prevalence of noise sensitivity in this clinical population. We noted two recurrent themes in the transcripts. First, the debilitating affects of high noise sensitivity, and second, the inability of current clinical practice to detect or treat the condition.

5.7 While we purposively targeted a group with a high prevalence of extreme noise sensitivity, it should be remarked that individuals with similar levels of sensitivity will exist in the general population, that their sensitivity will not necessarily be traced to injury or disease (though it might), and that these individuals will seek quiet areas in which to live. I include, in Appendix B, a selection of quotes from the transcripts in order to advance an understanding of what it is like to experience noise sensitivity. Here is one:

"*For me, I dunno, probably the noise is one of the biggest things; and if you could take one symptom away from me, if I had to choose one thing that I didn't have to have, it would be the noise sensitivity, definitely."*

6.0 Primary health effects: Annoyance

6.1 The word annoyance is often misinterpreted by the general public as a feeling brought about by the presence of a minor irritant. The medical usage, in contrast, exists as a precise technical term and defines annoyance as a mental state capable of degrading health. Suter (1991) presents a formal definition of annoyance:

"*Annoyance has been the term used to describe the community's collective feelings about noise ever since the early noise surveys in the 1950s and 1960s, although some have suggested that this term tends to minimize the impact. While "aversion" or "distress" might be more appropriate descriptors, their use would make comparisons to previous research difficult. It should be clear, however, that annoyance can connote more than a slight irritation; it can mean a significant degradation in the quality of life. This represents a degradation of health in accordance with the World Health Organization's (WHO) definition of health, meaning total physical and mental well-being, as well as the absence of disease*."

6.2 Both the physical nature of the sound and the psychological characteristics of the listener combine to produce noise annoyance. It is generally agreed that a physical threshold exists that, when exceeded, almost totally determines the levels of annoyance elicited by noise. Below this threshold however, other psychological-based factors come to the fore. While there is a strong correlation between the sound pressure level (i.e., amplitude) of a sound wave and the perceived loudness of a sound, there is no clear relationship between sound pressure level and the psychological responses that

individuals have to a sound. Annoyance can only partly be related to the physical characteristics of a sound, including amplitude (i.e., loudness), frequency (i.e., tonal characteristics), and how the sound changes across time (e.g., modulation).

6.3 Many nonacoustical factors determine how annoyed one will become towards a source of noise. Degrees of annoyance to noise cannot be measured by acoustical equipment such as sound level meters; instead it can only be described by the listeners themselves. Thus, the response of the individual to the sound is just as important as the acoustic properties of the sound wave. The "people" side of noise is commonly absent from acoustics reports, where acousticians have a tendency to treat a spectrum analyzer or a free field microphone as equivalent to a human being. The reality is that the bulk of the annoyance response is likely to be explained by a collection of interacting traits and contextual factors that include age, attitude to the noise source, personality, mental functioning, time of day and noise sensitivity. For example, van den Berg et al, (2008) notes that annoyance is also related to economic factors (**see** Figure 3.0 above), and present data showing that those who benefit economically from wind turbines are on average less annoyed than those who do not.

6.4 In the New Zealand context little research has investigated noise annoyance. Limited data does however exist. One recent urban study identified 15% of the sample as having serious concerns about neighbourhood noise, with 44.3% having some concerns (Carter et al. 2009). The proportion of those seriously concerned with neighbourhood noise exceeded all other neighbourhood issues including rubbish in the street (7.3%), walking around after dark (9.4%), smells and fumes (6%), and traffic and road safety (9.3%).

6.5 Currently there is not a single credible paper in the peer-reviewed literature stating that wind turbine noise is harmless to health. Contra to the assertion that wind turbines have no health related effects, there is an emerging body of evidence informing us that under certain circumstance wind turbine noise can have substantial physiological and psychological impacts on the community. For brevity these studies are summarised and presented in Appendix C.

6.6 Noise sensitivity has a large impact on noise annoyance ratings, lowering annoyance thresholds by up to 10 dB (Miedema & Vos, 1999). However, while there is a strong correlation between noise sensitivity and annoyance, the correlation between noise sensitivity and noise level is weak, echoing the marginal relationship found between noise annoyance and noise level.

6.7 Attitudes towards wind turbines and their operators are related to perceived annoyance. A New Zealand study (Wild, 2008) on public attitudes to wind turbine installations identified a substantial number of residents with negative attitudes induced by continual turbine breakdowns and the high levels of maintenance required. Additionally, many respondents complained of the uneven spread of benefits of wind turbine installation, and a lack of local of benefits. The same study showed that, for people living within five kilometres of the turbines, attitudes towards the wind turbine

installation appear to become more negative following the operation of the turbines (**see Figure 6.0**). This trend was not observed with those living between 5 – 15 kilometres, and one can speculate that noise was a factor in this change.
JC: not all that convincing; note "good" and "very good" also rises—the uncertain majority shifted one way or the other….

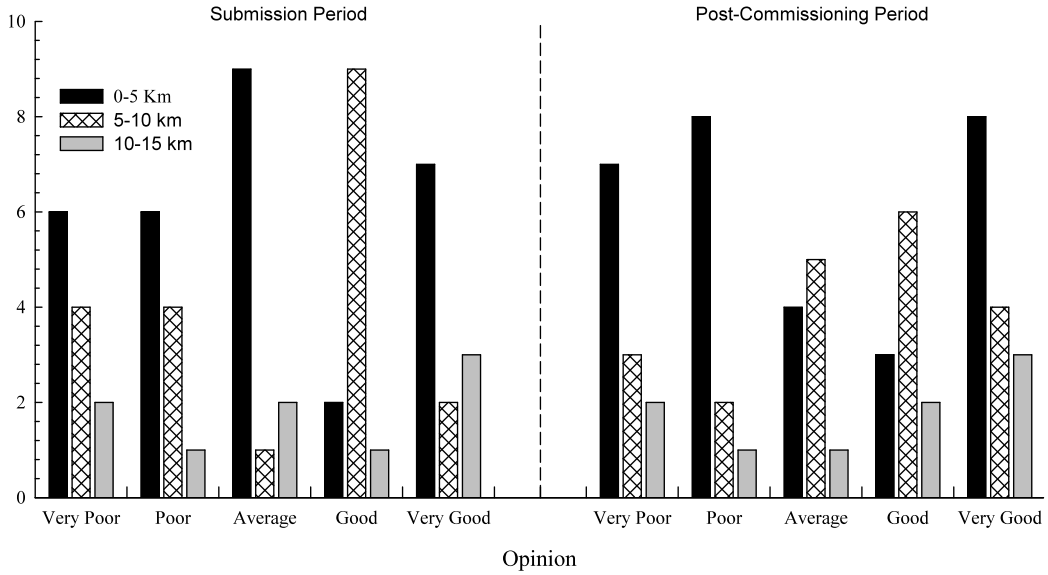


Figure 6.0: Attitude towards a wind turbine complex, before and after operation, categorised by distance from place of current residence (after Wild (2008), p. 135).

7.0 Primary health effects: Sleep disturbance

7.1 Sleep is a state of arousal characterized by an unresponsiveness to environmental stimuli and an absence of conscious activity. Every living organism contains, within its DNA, genes for a body clock which regulates an activity-inactivity cycle. Sleep disturbance and impairment of the ability to return to sleep are not trivial events. In the short term, the resulting deprivation of sleep results in daytime fatigue and sleepiness, loss of wellbeing, poor concentration and loss of memory function. Accident risks increase. In the longer term, sleep deprivation is linked to depression, weight gain, diabetes, high blood pressure and heart disease.

7.2 Noise interferes with sleep in several ways. First, it may be sufficiently loud or annoying to prevent the onset of sleep or the return to sleep following an awakening. Second, noise exposure during sleep may arouse or awaken the sleeper. Noise insufficient to cause awakening may cause an arousal. An arousal is brief, often only a few seconds long, with the sleeper moving from a deep level of sleep to a lighter level and back to a deeper level. Because full wakefulness is not reached, the sleeper has no memory of the event but the sleep has been disrupted just as effectively as if wakefulness had occurred.

It is possible for several hundred arousals to occur each night without the sufferer being able to recall any of them. The sleep, because it is broken, is unrefreshing and there is a proportional relationship between arousals and doziness, fatigue, headaches and poor memory and concentration.

7.3 A note on the quality of sleep research, be it related to noise or otherwise, is warranted. The outcome measures used to estimate sleep quality, be they subjective reports or physiological measurements, have in recent times been exposed as unreliable or meaningless. Both Krystak and Edinger (2008) and Pirrera et al., (2010) can be consulted for a critique of current methodologies.

7.4 Audible wind turbine noise has the potential to cause arousals, sleep fragmentation and sleep deprivation. It is unfortunate that noise from wind turbines are often at their loudest and most disturbing at night due to an increase in atmospheric stability. In other research directly related to wind turbines one study reported that sixteen percent of respondents experiencing 35 dB(A) or more of noise suffered sleep disturbances due to turbine noise, with all but two respondents sleeping with an open window in summer (Pedersen & Persson , 2004). Others also report that wind turbines cause sleep deprivation (Harry, 2007). Residents in the vicinity of existing wind turbine installations in the Manawatu region have reported hearing the turbines in their bedrooms at night, especially in summer even when windows are closed. Pedersen & Persson (2007), studying the effects of wind turbine noise on sleep, showed that 36% of respondents who were annoyed at wind turbine noise also reported that they suffered disturbed sleep (compare 9% for those not annoyed). The effect of wind turbines on sleep have yet to be sufficiently quantified, though it appears that chronic sleep disturbance is the most common complaint of those living near wind turbines.

7.5 Other surveys of residents living in the vicinity of wind turbine installations show high levels of disturbance to sleep. A 2005 survey of 200 residents living within 1 kilometre of a 6 turbine, 9MW installation in France showed that 27% found the noise disturbing at night (Butre 2005). A similar US survey in 2001 (Kabes 2001) of a "wind farm" in Kewaunee County, Wisconsin reported that 52% of those living within 400-800 metres found the noise to be a problem, 32% of those living within 800-1600 metres and 4% of those within 1600 and 3200 metres.

7.6 A study undertaken in the Makara Valley, and described in 8.4 below (and see Appendix A), indicated that, compared to matched-control areas, satisfaction with sleep is significantly less in turbine areas than non-turbine areas. While the noise contours presented by the appellant may claim to represent "worst-case scenario" I note that they do not represent peak noise levels, which are more likely to disturb sleep, and studies have consistently demonstrated that sleep quality is related to peak noise levels rather than aggregated measures such as dB L_{eq}. Nor does the "worst-case scenario" consider mechanical malfunction noise, which I have experienced myself on two occasions. I defer to the statement presented by Rick James as to why the estimates supplied by the appellant should be treated with scepticism, and restate again that noise levels themselves are of limited utility when predicting human response to noise.

7.7 Ohrstrom & Rylander (1990) concluded that noise sensitive individuals have lower thresholds of noise reactivity during sleep than non-sensitive individuals. They demonstrated that noise sensitive individuals take longer to fall asleep than non-sensitive individuals and that sleep quality is more likely to be compromised by noise in sensitive individuals. Marks and Griefahn (2007) replicated these findings, reporting an association between noise sensitivity and subjective sleep quality, that is, greater sensitivity is linked to worsened restoration, deceased calmness, and difficulty to fall asleep.

8.0 Secondary health effects: Quality of life

8.1 Like tobacco consumption or sun exposure, potential health deficits from noise exposure, be it turbine noise or any other variety, are unlikely to be immediate. This makes the measurement of such deficits a challenge. Indeed, objective manifestation of health effects associated with noise-induced annoyance or sleep disturbance may only be detected after 5 to 15 years since the onset of exposure, whereas subjective appraisals of wellbeing and health will suffer no such time lag.

8.2 A variety of outcome measures have been reported in the literature to assess the impacts of noise, including annoyance, sleep disturbance, cardiovascular disease, and wellbeing. One approach to health assessment involves a subjective appraisal of Health-Related Quality of Life (HRQOL), a concept that measures general wellbeing and wellbeing in domains such as physical, psychological, social, and environmental wellbeing. The WHO (2009) Noise Guidelines (Europe) likewise supports the use of quality of life measures (p. 92):

"*The effects of noise are strongest for those outcomes that, like annoyance, can be classified under 'quality of life' rather than illness. What they lack in severity is made up for in numbers of people affected, as these responses are very widespread*".

8.3 The WHO (1995; 1999; 2009) reports that noise-induced annoyance and sleep disturbance can, when chronic, compromise positive wellbeing and quality of life. Dratva et al. (2010) using the Short Form (SF36) health survey, reported an inverse relationship between annoyance and HRQOL in relation to road traffic noise. They argued that HRQOL would be expected to co-vary more with annoyance than with physical noise measurements. Along with collaborators I recently demonstrated that sleep disruption and annoyance were mediators between noise sensitivity and HRQOL (Shepherd et al., 2010). I would expect Meridian Energy to assess the potential impact of turbines on the quality of life of residents in the Ohuria Valley. If this has not been undertaken then arguably they have been negligent in their assessment of turbine impact.

8.4 To determine if wind turbine noise degrades quality of life in a manner consistent with road and aviation noise a team of New Zealand researchers undertook exploratory research in the Makara Valley, a confined rural setting in which wind turbines have been operating for the past year, and which is in close proximity to the Ohariu Valley. We

used a case-control design, the most appropriate in the context, and measured HRQOL from residents in the Makara Valley and those living in a matched control area. The response rates, 31% and 34% respectively, can be considered high for this type of research (compare to van den Berg and colleagues (2008) 37% response rate). Each house received two copies of the questionnaire, which utilised a WHO tool to measure HRQOL, a neighbourhood satisfaction survey designed to mask the intent of the study, and questions on amenity, noise annoyance, and noise sensitivity. Details of the study were recently presented at a New Zealand acoustics conference, and Appendix D contains this presentation which affords a summary of the design and findings of the study.

8.5 Statistical analysis (see Appendix D) revealed some differences and some similarities between the two areas in terms of HRQOL. First, the Makara Valley sample reported significantly lower physical HRQOL, and they were also less satisfied with their sleep than those in control areas. Second, the Makara Valley sample reported lower environmental HRQOL, a domain that can be treated as equivalent to amenity. Third, there were no statistical differences between the two areas in relation to social or psychological HRQOL, although the latter was close to significance. Finally, when rating overall HRQOL there was again a statistical significant difference between the two areas.

8.6 These results were not entirely unanticipated. At the West Wind (i.e., Makara) Hearing Dr van den Berg and Dr Robert Thorne received agreement from the Experts' Caucus to present a separate statement to the agreed matters:

"We believe that the conditions here agreed upon will protect residents from severe annoyance and sleep disturbance, but not from annoyance and loss of amenity. We believe annoyance and loss of amenity will be protected when the wind turbine noise limit would be 30 dBA L95 in conditions of low wind speed at the dwellings and modulation restricted to 3 dB."

However, because a loss of amenity is related to annoyance, and annoyance may lead to sleep disruption (see Figure 1.0), it appears from our data that while residents were protected from severe sleep disturbance, they still experience a degree of sleep disturbance that is sufficient to degrade their HRQOL.

8.7 Additionally, once turbines are installed in an area where there is local opposition a 'defeat reaction' may emerge. Rylander (2004) describes the characteristics of the defeat reaction after exposure to noise as increased vulnerability to illness and a depression of mood precipitated by intense sorrow, deep frustration, and defeat. The defeat reaction may in turn be amplified by the presence of turbine noise. A Swedish study (Pedersen & Persson, 2007) reported that, for respondents who were annoyed by wind turbine noise, feelings of resignation, violation, strain, and fatigue were statistically greater than for respondents not annoyed by wind turbine noise. The data procured from the Makara Valley marshals evidence for the defeat reaction in that the Makara sample rated themselves as significantly more feelings such as blue mood, despair, anxiety, or depression than the control sample.

8.8 These results point to a strong degradation of HRQOL in the resident of Makara. The Ohariu Valley proposal is in many was similar to the Markara proposal, and so it can be supposed that the erecting of turbines will likewise degrade the HRQOL of Ohariu residents.

9.0 Secondary health effects: Stress-related disease

9.1 Current thinking argues that both noise-induced sleep deficits and annoyance can induce stress-related disease. Any object or event that an individual perceives as a threat to their safety or to the resting and restorative characteristics of their living environments can be classified as a stressor. Noise is one such psychosocial stressor that can induce maladaptive psychological responses and negatively impact health via interactions between the autonomic nervous system, the neuroendocrine system, and the immune system (see Table 9.0).

Table 9.0: Three systems implicated in the negative relationship between stress and health

The Autonomic Nervous System

A control system in which the brain manages numerous biological processes based upon the demands of the environment. The autonomic nervous system controls, amongst other processes, heart rate, digestion, respiration rate, salivation, perspiration, diameter of the pupils, urination, and sexual arousal.

The Neuroendocrine System

The system linking processes in the central nervous system (i.e., the brain) to the endocrine system, which releases hormones. The most thoroughly studied neuroendocrine complex, the Hypothalamic-Pituitary-Adrenal (HPA) axis, has been implicated as the chief mechanism in the human stress response.

The Immune System

A collection of bodily structures and processes concerned with the identification, elimination, and disposal of foreign objects (i.e., antigens). Immune systems protect the body from infection, and when compromised, leave an individual vulnerable to disease.

9.2 It has long been accepted that either physical or psychological stressors can produce a physiological stress reaction. Stress is characterised by physiological changes that prepare the organism to survive a stressor. As Figure 9.0 shows, two main systems are activated by stressors, with noise used as an example of a stressor. The HPA axis

produces glucocorticoids such as the stress hormone cortisol. Cortisol restrains immune system activity which otherwise can become damaging, but in excess, this restraint of defence can increase vulnerability to disease. It is accepted that sleep deprivation increases cortisol levels. The SAM-axis produces, amongst other hormones, adrenalin, an important component of the sympathetic nervous system's fight-or-flight response. Adrenaline has the potential to regulate most of the body's biological systems, and increases heart and respiration rates during episodes of stress. Note that both pathways are ultimately under the control of the central nervous system (i.e., the brain), and this central regulation explains the large range of individual differences in the response to noise.

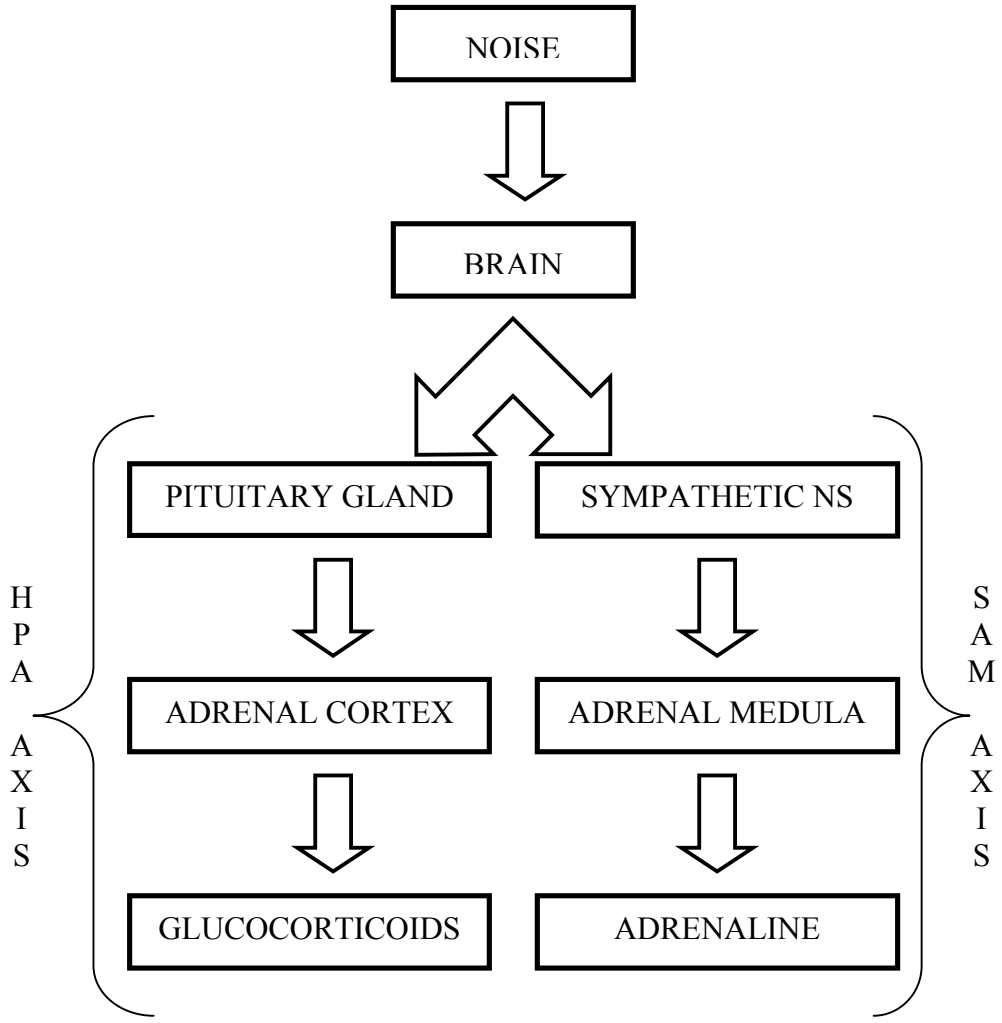


Figure 9.0: Schematic representation of the body's response to unwanted sound. Both the HPA axis and the SAM axis are regulated by a brain structure known as the hypothalamus.

9.3 How the brain and our hearing systems interact to produce a stress response has been the relatively well studied. Figure 9.1 is a contemporary conceptualisation of this interaction, and such models can help us explain, for example, noise sensitivity. Acute reactions to noise that have been explained by brain mechanisms include the startle reflex, the orienting response, and the fight/flight/freeze response. These reactions are short-lived, lasting a few seconds, and are accompanied by instantaneous physiological responses, such as cortisol release. Chronic exposure results in annoyance and sleep disturbance, both of which are health effects in the own right, and both of which can be induced by a stressor and lead to physiological stress reactions.

9.4 In 2009 I collaborated with members of the University of Auckland's Department of Psychology and investigated the physiological underpinnings of noise sensitivity. By nonlinear analyse of heart activity (i.e., the electrocardiogram) we were able to discern a significant relationship between noise sensitivity and sympathetic activity (for significance see Table 9.0), and between noise sensitivity and galvanic skin response, which is a marker of emotional response. These results replicate the findings of Dodd's (2001) pilot study, and confirm that noise sensitivity has physiological correlates. I present in Appendix E the results from a single participant to display the various analytical indices. Using a pre-validated noise sensitivity scale (the NOISEQ) this participant scored relatively high on the noise sensitivity continuum.

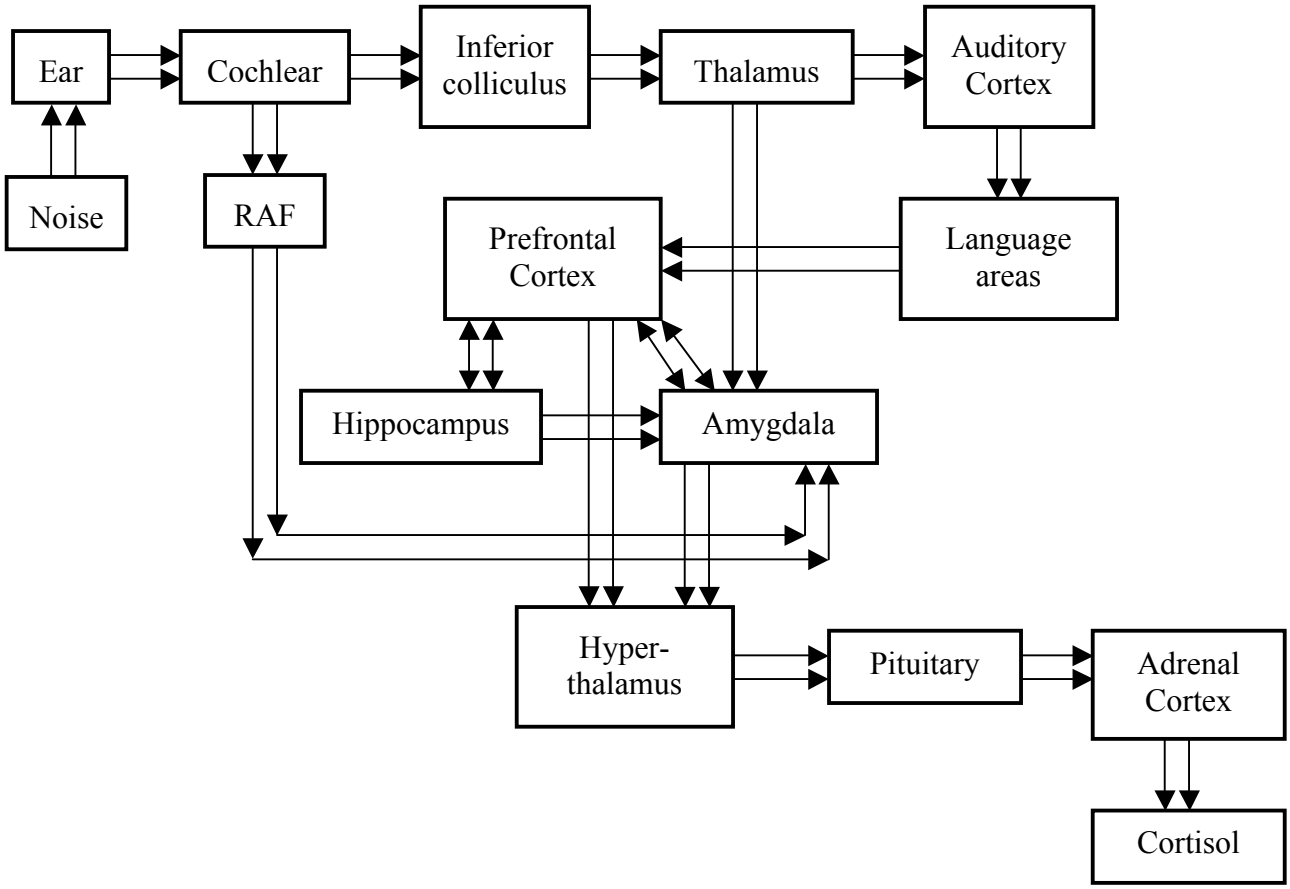


Figure 9.1: The link between noise and the hypothalamic-Pituitary-Adrenal (HPA) axis. Note: RAF = reticular activating formation.

9.5 Noise sensitivity may partly be explained by a hypoactive parasympathetic, and a hyperactive sympathetic nervous system. Noise sensitive individuals may delay the termination of sympathetic responses due to an uncoupling of the autonomic nervous system and the amygdala-prefrontal circuits (see Figure 9.1) that interpret stressful stimuli and enact the appropriate stress response. The result is that the specific brain circuits (i.e., sympathoexcitatory circuits) get caught in a positive feedback loop leading to hyper-vigilance and misattribution that then produce maladaptive cognitions (i.e., annoyance). As the stress accumulates, there is increased activation of the hypothalamic-pituitary-adrenal axis and the sympathetic-adreno-medullary system (see Figure 9.0).

9.6 Almost 50 years of quantitative research has demonstrated that long-term noise-induced annoyance and sleep disturbance are associated with stress-related disease. The literature concentrates mainly on road, rail, aviation, and other neighbourhood noise sources. There is no evidence currently published that leads me to the conclusion that wind turbine noise should not be treated the same, and as Figure 3.0 testifies, there may be good reason to suspect that turbine noise is in fact more dangerous than other forms of noise.

10.0 Concluding Remarks

10.1 In Europe (WHO, 2009) noise is a recognised environmental pollutant that degrades sleep, quality of life and general function. Utility-scale wind energy generation, involving the saturation of an optimum number of wind turbines in a fixed area, is not without health impact. However, the management of these impacts have been hindered by a systemic failure in the prediction of noise levels and sound characteristics emanating from wind turbine installations. I am not implying that these shortcomings are exercises of deceit by members of the acoustics discipline, but rather there is substantive international evidence showing that these errors are due to a lack of adequate methodology. Deceit has, arguably, been nurtured by the lack of acknowledgment regarding the limitation of current methods. Mr Rick James will describe these limitations in the statement that he presents to this hearing.

10.2 New Zealand has a poor record when it comes to the responsible positioning of wind turbine installations. Many of the turbine installations erected in the Manawatu region were initially welcomed by residents who supported renewable energy. However, this initial enthusiasm was based upon reassurances from the developers that turbine noise would not intrude into homes. The resulting lack of concordance between the predicted impacts of the noise and the actual impacts of the noise has lead to a rise in resistance to wind turbine installations in the Manawatu region. A similar situation occurred at Makara, although in this instance the turbines were not initially welcomed by the bulk of the community. Further evidence comes from a recent compliance report (Lloyd, 2010) undertaken on the Te Rere Hau wind turbine installation that indicates that the complaints made by nearby residents regarding noise exposure are justified on the basis of recent noise level readings. Note that these readings are discordant with those originally predicted and do not comply with the original resource consent conditions.

10.3 I further suggest that it is a mistake to judge potential health effects on noise level alone. Given that noise level explains between 15 – 20 percent of the variation in the annoyance response across individuals, I would recommend that noise level be given a 15 – 20% weighting in the decision as to whether the turbines should go ahead or not. Instead most weight should be placed on the potential amenity threats and the impact of vulnerable groups in the valley, including the elderly and children, and noise sensitive individuals. Because of the discrepancies between predicted and actual noise levels it would be prudent to rely on evidence coming from real people at established wind turbine installations (e.g., Te Rere Hau, Makara, Tararua) than disputed mathematical models.

10.4 Chronic (i.e., long term) exposure to unwanted sound can compromise health, and these adverse reactions to noise do not easily disappear with repeated exposures. It is proposed that adverse reactions to noise can reduce over time, a process known as habituation, which can be a physiological or behavioural. The WHO (1999) asserts that a habituation to noise is a highly individual matter. Noise sensitive individuals or individuals with certain types of mental illnesses are less likely to habituate to noise than noise resistant individuals. This lack of habituation is expected given the evolutionary significant roles undertaken by the auditory system, and as such we would predict, and indeed find, differences across individuals.

10.5 There are numerous reasons why wind turbine developers should be discouraged from placing turbines in the green belt areas around cities. The decision from this hearing is crucial in as much as it will determine the boundaries for turbine placement. Supporting the proposal will expose a good number of other lifestyle/semi-rural communities to the threat of turbines, while opposing the proposal will signal that developers need to explore less populated areas outside of the greenbelts. From the original consent hearing held in 2008 I understand that New Zealand is not lacking in wind resources and it there is vast opportunity to develop more isolated areas.

10.6 Ruling against the Mill Creek proposal will financially disadvantage a minority of the community. Supporting the Mill Creek proposal will compromise the well-being of a great many more residents. In addition, those who elicit strong emotional reactions to the loss of amenity that will accompany the turbines will also likely exhibit high annoyance responses to the turbine noise that will encroach the Ohariu Valley soundscape. Furthermore, those individuals who are highly noise sensitive will likewise suffer from the turbine noise.

10.7 It is possible that psychological therapies such as Cognitive Behavioural Therapy (CBT) could be used to reprogramme the thought processes of those experiencing annoyance through the amenity route, though such a solution may be seen as morally reprehensible by some. For the individuals with noise sensitivity CBT would not be effective as this is a trait rather than a state condition. For both these groups I would advise leaving the Ohariu Valley if the turbines are constructed

as habituation is unlikely and sleep deprivation and/or stress-related disease is likely and, from the onset, quality of life will decrease.

10.8 It is not clear to me that Meridian has undertaken sufficient duty of care in assessing the health impacts of turbines in the Ohariu Valley. For example, to the best of my knowledge they have not assessed prevalence of vulnerable groups (elderly, children) or traits (noise sensitivity) or considered factors that predict amenity values (e.g., length of residence). Nor have they reasonably dealt with the experiences of residents in the adjacent Makara Valley. There is a sense that they have attempted to suppress meaningful debate in the direct links between noise and health and instead present arguments based on fears of technology. While I have some sympathy for this argument in certain contexts (e.g., the placement of cell phone towers) the approach is not relevant to the current context.

10.9 Based on these observations (i.e., 10.8), based on data I have collected and analysed, and based on the current state of knowledge linking noise to impaired health in vulnerable persons, I opine that consent should not be granted for the proposed turbines in the Ohariu Valley.

REFERENCES

Butré J-L. (2005). French St. Crepin windplant noise survey results (2005), cited as a personal communication from J-L Butre, Ventducobage, 11-5-05 in Pierpont N. 2006.

Carter, Williams, Paterson, and Lusitini (2009). Do perceptions of neighbourhood problems contribute to maternal health?: Findings from the Pacific Islands Families study. Health and Place, 15, 622 – 630.

Devlin, E. (2005). Factors Effecting Public Acceptance of Wind Turbines in Sweden. Wind Engineering. 29(6), p503-511.

Dodd, G. (2001). Noise, Noise Sensitivity and Attention. Proc. Inter-Noise 2001.

Dratva, J. (2010). Impact of road traffic noise annoyance on health-related quality of life: results from a population-based study. Quality of Life Research, 19, 37–46.

Fidell, S. (2003). The Schultz curve 25 years later: a research perspective. Journal of the Acoustical Society of America, 114(6), p3007-3015.

Harry, A. (2007), Wind Turbines, Noise and Health. Retrieved from: http://www.flat-group.co.uk/pdf/wtnoise_health_2007_a_barry.pdf

Kabes DE and Smith C. (2001). Lincoln Township Wind Turbine Survey, Agricultural Resource Center, University of Wisconsin Extension/Cooperative Extension, May 16, 2001.

Krystal, A. D., and Edinger, J.D. (2008). Measuring sleep quality. Sleep Medicine, 9(1), S10 – S17.

Lloyd, N. (2010). Te Rere Wind Farm Noise Compliance Assessment for Palmerston North City Council. Acousafe Consulting and Engineering Limited, Wellington.

Marks, A., and Griefahn, B. (2007). Associations between noise sensitivity and sleep, subjectively evaluated sleep quality, annoyance, and performance after exposure to nocturnal traffic noise. Noise & Health, 9(34), 1 -6.

Miedema, H. M., and Vos, H. (1999). Demographic and attitudinal factors that modify annoyance from transportation noise. Journal of Acoustical Society of America, 105(6), p3336-3344.

Miedema, H.M.E., and Oudshoorm, C.G.M. (2001). Annoyance from Transportation noise: Relationship with exposure metrics DNL and DENL. Environmental Health Perspectives, 109(4),409-416.

Ohrstrom, E., Bjorkman, M., and Rylander, R. (1990). Effects of noise during sleep with reference to noise sensitivity and habituation. Environment International, 16, 477-482

Pedersen, E., and Nielsen, K.S. (1994). Annoyance due to noise from wind turbines. Delta Acoustic and Vibration Ltd. Report 150, Copenhagen, Denmark.

Pedersen, E., and Persson Waye, K. P. (2004). Perception and annoyance due to wind turbine noise: a dose-response relationship. Journal of the Acoustical Society of America, 116(6), p3460-3470.

Pedersen, E., and Persson Waye, K. (2007). Wind turbine noise, annoyance and self-reported health and well-being in different living conditions. Occupational Environmental Medicine, 64, p480-486.

Pierpont N. (2009). Wind Turbine Syndrome: A Report on a Natural Experiment. K Selected Publications. Santa Fe, New Mexico.

Pirrera, S., de Valck, E. K., Cluydts, R. (2010) Nocturnal road traffic noise: A review on its assessment and consequences on sleep and health. Environment International, 36, 492-498.

Rylander, R. (2004) Physiological aspects of noise-induced stress and annoyance. Journal of Sound and Vibration, 277, 471-478.

Schomer, P. (2001). A white Paper: Assessment of noise annoyance. Schomer and Associates Inc, Champaign, Illinois.

Shepherd, D., Welch, D., Dirks, K. N., & Mathews, R. (Accepted: In Press). Exploring the Relationship between Noise Sensitivity, Annoyance and Health-Related Quality of Life in a Sample of Adults Exposed to Environmental Noise. International Journal of Environmental Research and Public Health.

Suter, A. (1991). Noise and Its Effects. Downloaded from www.nonoise.org/library/suter/suter.htm

van Den Berg, F., Pedersen, E., Bouma, J., and Bakker, R. (2008). Visual and Acoustic impact of wind turbine farms on residents. FP6-2005-Science and Society-20, Project no. 044628. A report financed by the European Union.

Wild, T. (2008). Attitudes to Wind Farms. University of Otago Library: Masters thesis.

WHO European Centre for Environment and Health *Concern for Europe's tomorrow : health and the environment in the WHO European region*; Wissenschaftliche Verlags-Gesellschaft mbH: Stuttgart, 1995; p. 537.

WHO: Berglund, B., Lindvall, T., and Schwela, D. H.(1999). Guidelines for community noise. The World Health Organisation, Geneva.

World Health Organisation (2007). Report on the first planning meeting on night noise guidelines. Retrieved from: http://www.euro.who.int/Document/NOH/1st_NNGL.pdf

World Health Organisation. (2009). Night noise guidelines for Europe. Copenhagen.

Appendix A

Responses to an open-ended question in the Wellbeing and Neighbourhood Survey**.** Respondents were invited to share comments on the final page of the survey and were instructed thus:

If you would like to share any comments relating to your neighbourhood or this survey then please do so in the box below. For example, have there been any changes to the better or the worse in your living environment/ neighbourhood during the last year

Comments were elicited from respondents in three areas: the control areas which were demographically matched to the Makara Valley, the Makara Valley itself, and the Ohariu Valley:

Table A.1: Wellington rural control area

A1.1	I live in a rural setting. Approx 8 minutes by car to nearest shop. I have neighbours but probably not as close as town. Ave 20-50 metres.
A1.2	The idea of potential wind farms is horrifying
A1.3	We live on a lifestyle block and we love the peace and quiet. We have a variety of animals and pets.
A1.4	Where I live is fairly rural. Would have more issues if I lived in the 'burbs.
A1.5	Q8: The drug 'P' is what makes me feel most afraid as it is in every neighbourhood. Neighbours children are incredibly noisy, screaming and yelling all the time.
A1.6	Live in semi rural area 6km from Upper Hutt. More traffic from subdivision of blocks of land. More trees planted in what was once pasture so in future lack of views. Horse riders/cyclists who think they own the rural roads.
A1.7	I live in a rural environment. Subdivision of nearby farms is leading to a wee bit of over-crowding (i.e.; curtails some shooting and stock movement). But has advantages of meeting interesting people.
A1.8	Too much sub-division of rural land
A1.9	Problem with boy racers, but healthy environment, friendly neighbours who are not too close. Road has recently been widened, which has worsened the boy racer situation
A1.10	Extensive comments regarding housing development without providing infrastructure to support it, examples of problems caused were provided.
A1.11	A council introduced recycling programme is good. Housing development without upgrading the roads is putting too much pressure on the neighbourhood, making it unsafe for pedestrians, cyclists and horse riders.
A1.12	Council has a long-term plan to develop the area into high density, affordable housing. Community is concerned about social problems, noise and pollution affecting quality of life and desire to remain in the neighbourhood.
A1.13	Happy with rural lifestyle after moving from city to get away from bad neighbours, in-fill

	housing, over-crowding and lack of privacy
A1.14	Problems with mentally ill neighbours
A1.15	We don't know our neighbours
A1.16	Neighbours pets/hand reared animals are allowed to roam free into our property and eat our gardens. Our young son has been confronted by the animals and now doesn't cope well with those animals elsewhere.
A1.17	No buses in rural areas, and no street lights. The roads are dangerous without them
A1.18	Since council relinquished local landfill to private ownership, roadside & park litter increased dramatically
A1.19	Inconsiderate groups cyclists who won't pull over to let cars past, and sport-based road closures which don't take into account that people need to take children to school, or travel to work etc.
A1.20	Semi-rural environment getting more populated causes earth works, less privacy, and increased problem in narrow roads. Council also reduced recycling efforts which causes rubbish build-up
A1.21	Increase in fast traffic
A1.22	Environmental pollution of wind turbines. The proposed placement would expose us to noise pollution
A1.23	Large increase in traffic since I moved here 3 years ago
A1.24	Would like to know outcome of survey, Deanne Gabita thegabites@xtra.co.nz Neighbour has burgled them several times, affects quality of life.
A1.25	Wind turbines would be the only reason I would ever want to leave here.
A1.26	A lot of theft in our area lately.
A1.27	As long as there are no wind farms build along side us I think we'll spend the rest of our lives here!
A1.28	Joy-riding traffic is a problem in our rural area, especially for the people walking, riding bicycles, and horses.
A1.29	The roads are not safe for the amount of traffic. Bikes, children, horses and pedestrians sharing the road with cars, trucks, farm vehicles etc.
A1.30	No wind turbine was a great relief for everyone. Motorcross drivers & logging trucks are dangerous on the roads. Lack of broadband is frustrating.
A1.31	Poor quality dangerous roads, & poor public transport. Commute is too long
A1.32	A walkway has just opened up, which has spoilt our seclusion
A1.33	The community is under threat by potential wind farms
A1.34	Feel threatened by the wind farm destroying their peace
A1.35	Local council is investing in the neighbourhood with things like roads, library art-work, rubbish & recycling. I feel as though my rates are benefiting me.
A1.36	Rural setting means little or no services from council such as lighting/footpaths
A1.37	Neighbours dogs constant barking
A1.38	Council don't consider local residents, and can't seem to agree with regional council
A1.39	Subdivisions mean more people, roads not up to it. Too narrow and winding. Pesky road cyclists who think they own the road.
A1.40	Subdivisions have caused friction between neighbours
A1.41	Roading can't cope with population growth in neighbourhood
A1.42	Vandalism from kids who don't live in the area, and people dumping rubbish who don't live in the area

Table A.2: Makara Valley

A2.1	I live in Makara which is a rural community. The Westwind farm has been commissioned in the last 12 months. This has had a considerate or great affect on my way of life, and has changed the way I live and also deprived me of my greatest interests and activities.
A2.1	Installation of wind turbines have had a negative effect on my environment
A2.1	There is only 1 issue in our neighbourhood that causes concern and that is the building of an industrial wind generation site called Westwind by Meridian, an SOE. In many ways it has brought this community closer together to fight the common foe. The problem is not the visual. The problem is the noise generated by the wind turbines. We are concerned about the adverse health effects and sleep deprivation that is caused by them. Well over 1000 complaints have been logged on the 0800 complaints line, but little has been done to improve the situation, the wind industry noise standard NZS6808 is not adequate to protect residents when the turbines are built with no consultation with residents. We didn't want them there, and the Government and their SOE rode roughshod over our concerns.
A2.1	We live in Makara, have been here 6 years, moved here for the quiet life plus having more land to enjoy. We enjoy being outside working on our land. I work full time in the CBD so look forward to coming home to the quiet, but unfortunately in the last two years we have had turbines installed. We see twelve of them from our home. When I sit in my chair in the living room, this is alright but when they get noisy this is what I get upset about. You go to bed to sleep and the noise is there, it sounds like a plane that keeps going around and around and does not fly away, or it is the vibration we feel. I have not had a decent night's sleep in that time. I can wake up to about six times in the night so my quality of life has changed for the worse. Nobody wants to know. Basically we are left to get on with it. If we complain we are a pack of whiners or whingers. Our rural lifestyle is horses, no transport, no lighting, but we do have a café.
A2.1	We live in a rural village – access to shops, medical, public transport etc in a 10/15 min drive over a winding road up a steep hill. We have been inflicted by a wind farm with visual and noise pollution, completed late last year.
A2.1	Not in the last year, but previously. Turbines have been built behind our property causing grief, lack of sleep and lack of stress in family harmony.
A2.1	Wind turbines have spoilt the district.
A2.1	I live on a lifestyle block on the fringe of Wellington city.
A2.1	I live within 2.3 of 5 turbines. They are to the North + Northwest (prevailing wind) of me + some to the south. I live on the valley flat. The sound is noticeable during the day BUT at night it bothers me when I am a) trying to go to sleep b) if I wake up.
A2.1	It is not a loud noise but it is a vibration. I admit it probably meets sound conditions of the resource consent BUT this says more about what is allowable under resource consent than about what is reasonable and comfortable. Without

	adequate sleep or with disturbed sleep I begin to feel anxious and stressed and it is hard to separate out what is contributing most to the stress I experience. I have just returned from 5 days away in the South Island. I had a fantastic trip so probably my ratings reflect that.
A2.1	Power station wind farm has destroyed the recreational and tranquillity of the region with unexplained vibrations and noise pollution. People working outside are effectively bombarded with frequencies with cause headaches, dizziness, and motion sickness. This is amplified at night when sleeping.
A2.1	The biggest change in my living environment has come from the direct impact of the wind farm built in our district despite strong opposition from residents. I now have 11 visible turbines in my direct line of sight – the closest is 1.2 KMs ranging to 2.9 kms. I am disturbed by noise, sight, vibration, flickering shadows and red lights on top of turbines. My sleep is disturbed. I live in a rural environment for its peace, lack of housing, beauty, relaxed lifestyle. The wind farm has changed all that, we are not compensated nor draw any direct benefit from them (unless of course I include some notion of a reduction of green-house gasses and global warming etc etc)
A2.1	As far as my community is concerned, this questionnaire would have great relevance and significance if it were to study the extremely harmful effects of living within a short distance of wind turbines. Overseas studies are beginning to show how people and communities in general are suffering. To apply pressure on the government and energy suppliers, they need to see a properly conducted survey that hopefully would stop wind turbines being sited so close to people's homes. All universities and the NZ WHOQOL group could make a significant contribution. Please think seriously about doing this.
A2.1	Meridian Energy has completed construction of "West Wind" wind farms in our quiet rural area. It at times produces noise into the environment that dominates the background noise levels and sounds. Residents have no compensation for their changed living environment. Most consumers of power don't think about the consequences of their usage – our quality of life is effected.
A2.1	The biggest change has been the building and operating of the wind farm. I have had to de-tune my ears and senses to the noise created by the turbines. Generally I sleep all night and the turbines have woken me on several occasions, and I have not been able to sleep. The generally absolute silence we loved living here has gone. Sydney – Balmain is quieter than our property now.
A2.1	Our living environment has changed dramatically in the last year or so. Meridian Energy has built 'West Wind', a wind power station with turbines along the ridges that face our homes. The turbines are too close to homes; there are around 125 private homes within 2km of the turbines. Many homes lie downwind from the turbines – the prevailing wind flows over the power station site towards homes. As we said, this carries the noise for greater distances. The company told the general public that: "the turbines will not be noisy for the residents of Makara" – and so got the general public to support their proposal. Now it is noisy for us, the company says they always said there would be some noise!! The trucks started at 3:30am every morning except weekends (when on Saturday it was 6am) – during construction. The background sound levels at my

	home have been measured at 14.1dba at night – so the traffic woke me up, and then I could not get back to sleep. Meridian assured the court construction traffic would not start until 6am. It took six months to get the 3:30am start stopped – by that time I was exhausted (and my husband too) with the lack of sleep. My husband's work also suffered. The power company has treated our community with utter disdain – as if we do not exist even. They did not carry out the background noise testing that they were supposed to have carried out – they get away with whatever they want – leaving the community powerless and with a completely changed – for the worse – environment. This is unjust, as they have profited from their dishonesty and cavalier disregard while the community has suffered, yet the community was always honest in it's claims. Meridian has stopped access to the Makara Farm/Terawhiti which we have always been able to access in the past to go over the hill to access the coast further south, so considerably restricting recreation opportunities that used to abound in our environment. Our landscape has been changed from an outstanding natural landscape to a vast and kinetic industrial landscape. What we used to enjoy and appreciate has been lost. We cannot avoid seeing turbine blades from our deck and the garden around our home which faces towards the NW to catch our sun. We have spent most weekends away from Makara and our home, to escape.
A2.1	We have a good neighbourhood (rural). Meridian West Wind project has caused all sorts of issues – initially, we had a mutual enemy that brought us together. However, now, the reverse seems to be happening – with some people taking what they can from Meridian and others who have serious noise issues find that attitude obnoxious – so the turbines are causing rifts that were never there when we moved out to Makara. Endless giant piloted truck movements through our formally quiet rural roads to fix broken turbines is annoying. The council doesn't really care.
A2.1	Before the turbines were built, there was no loss of sleep, nausea and headaches. Within three months of their construction the symptoms started. It's terrible now when the wind comes from the north of northwest. The quality of life is gone. How the government and the city council have allowed this to be built is completely beyond my comprehension.

Table A.3: Mill Creek

A3.1	Many changes for the worse, more houses being built, neighbours closer (sounds travel in the countryside), townies with no idea of animal control and pest control, and consideration, and fencing issues etc. Don't respect boundaries, animals straying, more traffic – speeding, boyracers, motorbikes, ATVs. People cutting down trees and not replanting. Damage and silt affecting streams and running off neighbourhood properties. Rubbish along the road – dumped from vans and cars. Windfarm issues – changed whole wellbeing feeling of the neighbourhood and split families etc. Some positives, some people planting trees, native bush: more birds. Some going organic, reducing spray use and fencing off streams from stock.
A3.2	The proposal of a windfarm in our neighbourhood has had an extremely negative impact on our local/neighbourhood community. It goes to the environment court late in the year.

A3.3	Problem, erecting windmills, luckily we still fight. Neighbours, great, quiet, pleasant. Bugger all street lights – thank god!
A3.4	We live in a rural area, now fighting wind farm. Too many houses and subdivisions being allowed with little or no consideration to existing landowner house sitings. This is putting huge pressure on the quality of life in this rural area and seems the "rules" for subdivision are not being followed at all.
A3.5	We live on a lifestyle block in Takara Gorge Road, Ohariu Valley. We have noticed an increase in road traffic over the last year. This is in part due to improved road surfacing encouraging more users, especially in the weekend. Speed and noise is a constant issue and concern, especially with our community foot traffic on the road, ie house/children + also cyclists being unsafe as a result. Since west wind turbine installations have become fully operational we can hear the turbines and we are more than 8 km from them. We don't hear them every day but it is concerning that we hear them at all. Many of our neighbours can hear them and are suffering disturbances to their sleep and quality of life. We are deeply concerned about the proposed mill creek wind turbine installation which will be much closer to our home.
A3.6	Some levels of stress related to proposed windfarm (Mill Creek). Stress related to neighbours not getting on so well (those for vs those opposed to wind farm). Worry over potential effects of noise and how this may affect our quality of life. Currently we can not really hear the turbines at Makara – just occasionally and not too intrusive.
A3.7	Road into the valley has got busier with more trucks and general traffic. Our outlook to the south (Makara) is now dominated by 20 – 30 turbines. We were visited by Meridian's landscape expert earlier this year as our property has been identified as being significantly affected by their proposed Mill Creek wind farm. Photo simulations show that most of the windfarm is potentially visible from our property. During their visit they commented that we could be surrounded by turbines. We find this very distressing as our surroundings are very important to us and we put our heart and soul into creating a special environment for our family. It has been a shock for our community that (80%) to learn that our homes have no protection and we have no representation and support from the council or government. In the past year we have installed solar hot water and solar panels which provide all the electricity we need with any excess going into the grid. This has not caused any disturbance to our neighbourhood!
A3.8	The main problem is the divide in the community about the proposed turbines, which would very much affect our household with visibility, noise, glare, and vibrations. Otherwise we enjoy the peace, tranquillity, and privacy and that's why we choose to live in this area.
A3.9	We have a peaceful rural lifestyle that we relish and I feel this contributes to a high sense of wellbeing, having a sanctuary to return to at the end of the day.
A3.10	Traffic and the road seem busier. Community discussion centred around proposed wind farm. This causes mistrust and tense feeling where before there was none. Lack of protection and representation is a big issue. Destruction of community is a possibility if wind farm goes ahead. People value their lifestyle and appreciate amenity values in the valley. We can see 20-30 turbines from Makara when we were told that we would see none by the developer – this has caused us to question motives and honesty.
A3.11	Loss of community spirit due to small section of community seeking to establish a wind farm on the nearby hills.
A3.12	Our neighbourhood was the ideal rural lifestyle that we wanted and moved into the valley for, however, in the last year Project Westwind has caused some noise nuisance and the possibility of the Mill Creek wind farm proceeding is extremely concerning to us as we would be less than 2k from the nearest proposed turbines. The experiences of

	the residents at Makara are of grave concern regarding noise and health affects from the turbines not to mention loss of property value. The court processes over the proposed Mill Creek has divided the community, previously it was a very strong and close rural community, now it is divisive. I worry about our future if Mill Creek gets consent, whether we will be able to live in our houses, if it will devalue, I am very noise sensitive and worry about how I will deal being that close to turbines. This is a very real concern to myself, my husband, and many residents in the community. I am not adverse to change, technology, wind farms in general or green alternatives, but I strongly object to having my quality of life in my own home reduced by noise, vibration, visual disturbances and possible health effects on the basis of "its all for the greater good of the nation".
A3.13	We live in a beautiful rural environment however the threat of wind turbines coming into our environment has caused stress in the community and great fear of loss at our unique environment.
A3.14	We live 6-8 km from the new west wind industrial turbine complex. Since it started we have been woken and prevented from sleeping. There has been tinnitus, developing headaches, lack of concentration and disturbing feelings that courses through the body, difficulty breathing and tightness in the chest. We feel disempowered as no government minister or councillor will even meet us let alone discuss and are actively supporting plans to extend closer still to our homes.
A3.15	We are very fortunate to live in a rural area, approx 6 km from Johnsonville. We have 6 children aged between 7-17 yrs. I believe our environment has affected our children and ourselves in a positive way. Everyone is keen to stay home more and enjoy the surroundings. However, there is a lot of discord in our area due to proposed wind turbines being installed next year. We have not entered into the argument or discussions surrounding the issue.
A3.16	Since project west wind was commissioned we have had numerous occasions when we could hear them. Until Meridian fixed the special audible characteristic problem they could be heard as a distant rumbling noise in N'Westly wind conditions but on top of that noise was a clear mechanical noise like a distant aeroplane. The noise would come and go. Since SAC has been 'removed' by Meridian, the noise disturbance has reduced but on occasion it can still be heard as a distant rumbling. On one night in early June (frosty) I could hear blade swish. These turbines are 6.7 km to the west of us. We are faced with the prospect of another 31 turbines (Project Mill Creek) also a Meridian Energy Project. I am extremely anxious that the noise from these turbines will dominate our living environment here on Takarau Gorge road. The nearest 4 turbines will be between 1.7 and 2.0 km away from us in the North West if Meridian are granted consent for Mill Creek. I have visited properties that are furiously affected by noise from Makara on the lower Takarau Gorge road and on the South Makara Road. These properties are between 1.4 and 2.0 Km away. The residents are suffering noise disturbance and their sleep is affected. I know and understand these consequences. There are many families in the Ohariu Valley that refuse to believe these affects. I am concerned that they will suffer as well.
A3.17	I live a semi-rural area that has changed slowly over the last 50 yrs. The changes are currently escalating due to proposed wind turbines to be placed quite close to residences and a marked upgrade in socio-economic residents.
A3.18	Ohariu Valley has been an unspoiled part of New Zealand's history until Meridian desecrated the Makara area with 68 wind turbines. Unaware of the true disturbances these turbines would create due to the total mis-information supplied by Meridian and the lies fed to the Ohariu Valley residents by Meridian and the directors of windcorp,

	the residents unfortunately did not support the Makara community as we should have to stop the west wind project from going ahead. The true ill-health effects of turbines of this size situated so close to people's homes have been documented world wide and proven to be true yet Meridian chose to ignore them and up to now the courts have not taken seriously the extent of the effects. This has to change and these wind farms stopped in closer than at least 15 ks from the nearest home. People's lives are being ruined for a short-lived monetary gain by the likes of Meridian Energy.
A3.19	We are currently fighting a proposal to build a wind farm being erected in our gorgeous valley. This is a major stress both emotionally and financially on ourselves, our family, and our community. It will be resolved in the Environmental court this October. I suggest you repeat your survey after the outcome is known, That might teach you all a lot more!
A3.20	We now have an industrial wind farm less than 2kms away from our farm. Not only is this a noise issue but also with consent given for another wind farm to be put in on yet another lot of hills to the north of us, they (wind turbines) will also be a visual problem as well, caught in between industrial sites. No pleading from our community, re noise conditions has made any difference at all! No compensation for loss of property value, simply lack of consideration for a very unique small community that doesn't have a chance against a power company.
A3.21	I have lived in a quiet rural environment for 11 years by choice. 1. Because it is quiet. 2. Because it offers a life style choice (Horse care/farming on 62 acres). 3. Because it is close to the city where I can get part time work if needed. 4. Neighbours are too far away to be a problem. I live a comfortable, busy, rewarding life. I am now threatened by Meridian and 5 other 'neighbours' by a proposed 31 industrial wind farm less than 3 km's from my paradise. I get sleep disturbance from West Wind (West farm) at Makara – 6-8 kms away that has already been commissioned. I'm extremely anxious about: a) my property value. b) my community polarisation over this issue. c) The cost to me personally fighting to preserve my neighbourhood.
A3.22	Wind Turbine Centres. We live 4.5 km away from Makara Westwind Wind Energy Centre and I'm woken sometimes by a low frequency grinding noise, 3 – 4 am. There is another Meridian project planned 1.3 km from our house (Mill Creek) & we know that the noise will be unacceptable. The big drive behind these so called green projects comes from the E.T.S & the govt, council are hell bent on pushing them through. We're not heard by the general public as they have been brainwashed & the turbines aren't in their faces. The media, TV, Newspapers won't air our complaints as executives on their boards are also on Meridian's – ie Fairfax etc.
A3.23	Mill Creek wind farm proposal by Meridian has split the community into 2 divisive halves. Those supporting it ie farmers that have leased land & their friends + people not concerned or informed about the potential noise and health impacts & those that are concerned. The proposition has halted much of the real estate activity which is a classic demonstration that everyone want green power but not in their backyard ie lifestyle blocks were very much sought after until announcement if the wind farm came thru. Seems that it is the locals that must pay for the greater good of green energy…
A3.24	The last 2.5 years have been incredibly difficult with the proposed wind farm. The stress of your living environment potentially changing & confrontation from people proposing change has been very intimidating and as a result at times it has been difficult to sleep.
A3.25	In our neighbourhood there is a proposal to build a wind farm within 2.5 km of our home. This is of grave concern to my family due to the industrialisation of our countryside, our view from our home and the potential noise disturbance. This has caused stress and concern to us.

A3.26	Since the build and start up of the turbines in Makara I have found them visually offensive (I can see approx 20 from my home) and when they were first being built I was reduced to tears on more than one occasion. They have turned my rural views to a industrial abomination. The noise produced by these turbines (approx 8 – 10 km distant I estimate) has caused me physical distress, sleep disturbance and a funny feeling of pressure – my ears in certain wind conditions. The combination of these plus having to fundraise/put my life into a holding pattern to fight the progress of destroying Ohariu Valley with more turbines has caused some stress in my relationship both at home and at work. Ohariu Valley was one of the most loving, supportive communities I have ever living in and turbines have completely split this community into a number of groups with all the associated distrust, lies, and backstabbing as those who want the turbines (they are getting money from Meridian) try to undermine and destroy the rival group. A woman's support group that was very strong – this valley for more than 50 years is now falling apart as various woman from both sides will no longer mix socially based on their opinions of the turbines.
A3.27	This neighbourhood in Ohariu Valley used to be a wonderful, friendly, peaceful place to live. Not now: people are at war: Families have fallen out with each other, marriages broken down, & neighbours not being nice to each other all over money = the cause = wind turbines. Five families are getting millions of dollars &a almost 100-200 other families have to live with the noise, vibration, property devaluation + sleep deprivation. We are looking for somewhere else to live – but will cost a fortune to move & we would have to degrade. My life right now is not pleasant for my family and our quality of life is not good. This reflects in our daily output which is reduced. This is more than sad – it is destructive to the community = fatal for society.
A3.28	Since the greedy farmers in the valley put up wind farms they have split the community into two. The loving peaceful valley that I moved into will never return. They have destroyed the peace and harmony that has existed for over 100 years. Having the wind farm proposal going through concert has put our life on hold and even if we wanted to sell we will sell for a lot less than what we purchased it for.
A3.29	A couple of points that may (or may not) be relevant. 1) I have been recently widowed and this has affected / lowered some of my satisfaction results which would previously have been higher. 2) I live rurally so many of the issues of are non-issues. 3) The peace / tranquillity / satisfaction with my neighbourhood is threatened by a potential wind farm within the immediate vicinity. I am sensitive to noise so if this were to go ahead it would change some answers I am sure.

Appendix B

Table B: Selected comments from interviews with eight traumatic brain injury survivors experiencing noise sensitivity. Each participant received the same series of questions probing their experiences with everyday sound before and after the injury.

B.1	Um it's more frustration really, its, the frustration that I can't do anything about it and I have to live with it
B.2	I'm getting frustrated with myself cause I can't think the way I want to think, it takes a lot more effort to concentrate on my conversations or what's happening around me
B.3	And it's like god I just want to sleep and you can't, it's like you're not in control of your own brain
B.4	I'm much less tolerant of children crying around me, um....yer so I think noise differently lead to impatience with people
B.5	It really annoys me when people who can't walk without slopping their feet....it really gets on my nerves and I think, ohhh god, can't walk, can't walk near, can't be near them
B.6	I am horrendously embarrassed all the time, I didn't even want to talk to people
B.7	I felt very inadequate, I felt inadequate as a mother, as a partner because I can't understand what was going on around me on a day to day basis
B.8	Initially, initially after the head injury I thought all that stuff was going to fade into the background; I thought the noise sensitivity and that sort of stuff would just fade into the distance and life would become normal again, um, to what I had known before
B.9	When you have a lot of noise like that it increases your fatigue, if.... I guess the level of noise you hear has an effect on the stimulation on your brain and that's where the fatigue comes in, pain comes in
B.10	It's a conglomeration of noise and I find I just get overloaded to the point where I just want to escape from it
B.11	Went to a cafe in Mission Bay and we were there for an hour and I could feel my fatigue levels getting higher and higher because um....having to concentrate because there were um people just that background noise and also cars and truck driving around and as I got more tired you become more sensitive and you notice the sounds more
B.12	I find it hard to concentrate on more than one thing at a time, I think also that when it happens, when you're out, you can hear both things but can concentrate on either
B.13	I can't um, I lose my train of thought if noise comes in and interrupts me, like the phone going, er like the phone ringing....its really loud...I lose my train of thought quite quickly and can't get it back It's disrupted my thinking, it disrupts my peace, it disrupts my concentration, its, its err ....it's changed the way I live....
B.14	If I could, flick that magic switch and switch off, block out the noise that people can, can learn to block out and work with, with life would be so much easier.... I could concentrate better on my studies....
B.15	It has, the implications have been huge because it's restricted, it's restricted my entertainment side of things, I don't we use to go out a bit, I don't now....um it's restricted that its restricted activity that I would do, before I had a brain injury I use to like doing things like going on the rollercoaster's and stuff when we went away, I use to enjoy noisy activities, um and I won't, I don't even do them now like noise stuff
B.16	If I go to the gym and I have to think if I'm not having a good day then either I won't go to the gym because I know it's going to be harder because there are lots of sounds
B.17	I don't go to sports anymore, I use to be a netball player and a coach, but it, I can't stand the sound of the whistle
B.18	Taking them (two young boys) to music class and stuff like that I wish I was able to do but I would have dropped and ran
B.19	I use to go to air shows but not anymore, things like activities, my son went to the V8'sthe other weekend and I really wanted to go but I knew I wouldn't be able to stand the noise all day

B.20	I've had to let go of my dream to do my PhD and working internationally as an environmental consultant.... I've lost my job as a teacher
B.21	I stopped going to church because it was just too hard, with the singing....um it was very hard....because it made...it made the frustration greater, and going to church and having the community kind of prayer, um, was an avenue that was closed to me
B.22	It means to me ultimately pain, um, because certainly in the early days I was so sensitive to any noise that I had to wear um ear plugs if I wanted to leave the house at all
B.23	And it's like god, I just want to sleep and you can't; it's like you're not in control of your own brain
B.24	But cause my filters have been kind of out of whack um you hear it all and it's really hard for you to shut any of it out, no control
B.25	Noise probably is a far stronger one, far far stronger than light, because I feel like I can control light more, and easier than noise, ... that it's far harder to control noise cause there's so many outlining factors that you can't even, remotely touch on
B.26	It's the conglomeration of noise and I find I just get overloaded to the point where I just want to escape from it..... I would go to the furthest corner of the library away from everyone and I could still hear it
B.27	It's like um your living in a world through....with micro/speakerphones strapped to each side of your head, like sometimes it's just so much it's, you just can't get away from it
B.28	You can't choose the sound you want to hear, it's just everything magnified....where ever you are
B.29	Like I walked to the shops um Mt Albert and I should have got a cab but I was like, at that stage, I was like nah I wanna walk, I wanna actually be able to do something myself.... I ended up walking with my fingers in my ears
B.30	I need to think about where you're going, so if I'm going somewhere I might think better take ear plugs as it might be too loud and like to be able to drive or have an exit plan
B.31	It's shouting (Shopping), and it feels, to me it feels like it's really shouting so I learnt that to go shopping either late in the evenings or early in the morning
B.32	I like to go to cafes but my friends and I will only go to one that is quieter, or where we can actually get to a quieter place
B.33	um apparently I was a neurotic house wife and I had to go home and get over it...that was the first assessment I got
B.34	Like I used to ask, cause my door is right by the front door and I'd ask them could they leave out the back door, cause they wouldn't understand why would going out the front door be an issue
B.35	There was a boy in front of us who kept talking to somebody and it felt like shouting, shouting for no reason and to the point he got me so angry

Appendix C

A SUMMARY OF RESEARCH UNDERTAKEN ON WIND TURBINE NOISE*

Preamble

There are now a number of studies showing that turbine noise is annoying, and that there is a link between annoyance to turbine noise and health as defined by the WHO. A brief description of this evidence is now listed, and where possible, technical jargon has been omitted or minimised. It should be noted that, without exception, all of these studies have shortcomings, and indeed, research of this type is vulnerable to inherent limitations that serve to dampen its impact. However, the studies selected represent credible researchers undertaking difficult research.

Harry (2007)

Dr Amanda Harry, a British General Practitioner, conducted surveys of 42 residents living near several different turbine sites and reported a similar constellation of symptoms from all sites. Of the 42 respondents, 81% felt their health had been affected, in 76% it was sufficiently severe to consult a doctor and 73% felt their quality of life had been adversely impacted. This study is open to criticism for a design that invited symptom reporting and was not controlled. While the proportion of those affected may be questioned it nevertheless indicates strongly that some members of the public are severely affected by wind turbine noise at distances thought by governments and industry to be safe.

Harry, A. (2007), Wind Turbines, Noise and Health. Retrieved from:
http://www.flat-group.co.uk/pdf/wtnoise_health_2007_a_barry.pdf

Pederson et al., (2003, 2004, 2007, 2008 and 2009)

Pedersen and co-investigators have undertaken a series of investigations examining the relationship between turbine noise and health. In a 2004 paper (n=351) Pedersen reports the importance of individual and contextual factors alongside noise parameters, and the danger in generalising findings from other sources of community noise (e.g., road, rail, aircraft) to the wind turbine context (see Figure 3.0, mainbody). In a 2007 paper (n=754), Pederson further explores these individual and contextual influences. They noted that those living in rural areas are more likely to be annoyed than those from suburban areas, and that those living in complex terrain (e.g., hills or rocky terrain) were more likely to be annoyed than those living on flat ground. The study found a strong association between annoyance and both lowered sleep quality and negative emotions. A paper published in 2008 (n=1822) reanalysed pre-existing turbine noise and annoyance data and concluded that turbine noise can impede health, especially for susceptible individuals.

The paper also discussed the dangers of using noise level as a sole predictor of annoyance, and the strength of noise sensitivity indices in predicting annoyance.

Pedersen and others (2009) reported that annoyance increased with increasing sound levels, both indoors and outdoors (see Table 1). The proportions who were rather and very annoyed at different sound levels are shown in Table I. In summary, when outside, 18% were rather or very annoyed at sound levels of 35-40 and 40-45 dB(A) compared to 7% at 30-35 dB(A) and 2% at <30 dB(A). When inside, the equivalent figures were 1% at <30 dB(A), 4% at 30-35 dB(A), 8% at 35-40 dB(A) and 18% at 40-45 dB(A). Those respondents who had an economic interest in the turbines had lower levels of annoyance while negative views of the visual impact of turbines increased the likelihood of annoyance.

Although the authors do not seek to recommend minimum sound levels, they do note that turbine noise was more annoying than other sources, with the possible exception of railway shunting yards and was more noticeable at night. Reported associations between annoyance and symptoms of stress (headache, tiredness, tension and irritability) confirmed that "annoyance" is more than irritation and is a marker of impaired health. They conclude that (Pedersen et al, 2009):

"...night time conditions should be treated as crucial in recommendations for wind turbine noise limits."

Nevertheless, it is clear from this analysis that external predicted turbine sound levels should be less than 35 dB(A), considerably less than those permitted by European noise standards, in order to reduce effects on nearby residents to acceptable levels.

Table 1: Percent responding to level of annoyance towards outdoor and indoor wind turbine noise levels for five categories of level in 5-dB(A) sound level intervals. Parentheses present 95% confidence intervals. (From Pedersen 2009)

	Predicted *A*-weighted sound pressure levels dB(A)				
	<30	**30–35**	**35–40**	**40–45**	**>45**
Outdoors	*n*=178	*n*=213	*n*=159	*n*=93	*n*=65
Do not notice	75 (68–81)	46(40–53)	21(16–28)	13 (8–21)	8(3–17)
Notice, but not annoyed	20 (15–27)	36(30–43)	41(34–49)	46 (36–56)	58(46–70)
Slightly annoyed	2 (1–6)	10(7–15)	20 (15–27)	23 (15–32)	22(13–33)
Rather annoyed	1 (0–4)	6(4–10)	12 (8–18)	6 (3–13)	6(2–15)
Very annoyed	1 (0–4)	1(0–4)	6 (3–10)	12 (7–20)	6(2–15)
Indoors	*n*=178	*n*=203	*n*=159	*n*=94	*n*=65
Do not notice	87 (81–91)	73(67–79)	61(53–68)	37 (28–47)	46(35–58)
Notice, but not annoyed	11(7–17)	15(11–20)	22 (16–29)	31(22–31)	38(28–51)
Slightly annoyed	1 (0–4)	8(5–12)	9 (6–15)	16 (10–25)	9(4–19)

Rather annoyed	0 (0–2)	3(1–6)	4 (2–8)	6 (3–13)	5(2–13)
Very annoyed	1 (0–4)	1(0–4)	4 (2–8)	10 (5–17)	2(0–8)

Pedersen, Hallberg, and Waye (2007) conducted in-depth interviews with 15 people living within close vicinity of wind turbines. A qualitative method known as grounded theory was selected to inform both data collection and data analysis. Respondents opinions of the turbines and the turbine noise was largely determined by their personal values about the living environment. The feeling of intrusion was associated with feeling a lack of control, subjected to injustice, a lack of influence, and not being believed. Various coping strategies were engaged, such as rebuilding their houses or complaining. Most however displayed learned helplessness and simply tried to ignore wind turbine noise.

Pedersen, E., Hallberg, L.R.M., and Persson Waye, K. P. (2007). Living in the Vicinity of Wind Turbines - A Grounded Theory Study. Qualitative Research in Psychology, 4: 1, 49 – 63.

Pedersen, E., and Nielsen, K.S. (1994). Annoyance due to noise from wind turbines. Delta Acoustic and Vibration Ltd. Report 150, Copenhagen, Denmark.

Pederson, E. W. (2005). Human Response to Wind turbine Noise – Annoyance and moderating factors. Wind Turbine Noise: Perspectives for control, Berlin, INCE/European Conference.

Pedersen, E., and Persson Waye, K. P. (2004). Perception and annoyance due to wind turbine noise: a dose-response relationship. Journal of the Acoustical Society of America, 116(6), p3460-3470.

Pedersen, E., and Persson Waye, K. (2007). Wind turbine noise, annoyance and self-reported health and well-being in different living conditions. Occupational Environmental Medicine, 64, p480-486.

Pedersen, E., and Waye, K. P. (2008). Wind Turbines – low level noise sources interfering with restoration? Environmental Research Letters, 3, 1-5.

Pedersen, E., van den Berg, F., Bakker, R., and Bouma, J. (2009). Response to noise from modern wind farms in The Netherlands. Journal of the Acoustical Society of America. 126:634-643.

van Der Berg (2008)

van den Berg and colleagues (2008) from the University of Groningen in the Netherlands have recently published a major questionnaire study of residents living within 2.5km from wind turbines. A random selection of 1948 residents were sent a similar questionnaire to that used by Pedersen in her studies in Sweden (2003, 2004, 2007 and 2008), questions on health, based on the validated General Heath Questionnaire (GHQ), were added. 725 (37%) replied which is good for a survey of this type but, nevertheless may be a weakness. Non-respondents were asked to complete a shortened questionnaire. Their responses did not differ from full respondents suggesting the latter are representative of the population as a whole.

Questions on wind turbine noise were interspersed with questions on other environmental factors to avoid bias. The sound level at the residents' dwellings was calculated, knowing

the turbine type and distance, according to the international ISO standard for sound propagation, the almost identical Dutch legal model and a simple (non spectral) calculation model. The indicative sound level used was the sound level when the wind turbines operate at 8 m/s in daytime, that is, at high, but not maximum power. Noise exposure ranged between 24 and 54 dB(A). It is worth noting that the industry was approached for assistance in the research but refused. Complaints such as annoyance, waking from sleep, difficulty in returning to sleep and other health complaints were related to the calculated noise levels.

The research team concluded that *"Sound was the most annoying aspect of wind turbines"* and was more of an annoyance at night. Interrupted sleep and difficulty in returning to sleep increased with calculated noise level as did annoyance, both indoors and outdoors. Even at the lowest noise levels, 20% of respondents reported disturbed sleep at least one night per month. At a calculated noise level of 30-35 dB(A), 10% were rather or very annoyed at wind turbine sound, 20% at 35-40 dB(A) and 25% at 40-43 dB(A). van den Berg concluded also that, contrary to industry belief, road noise does not adequately mask turbine noise and reduce annoyance and disturbance. Bolin (2009) has shown that vegetation noise does not mask turbine noise as well as expected. With regard to health it was concluded that:

"There is no indication that the sound from wind turbines had an effect on respondents' health, except for the interruption of sleep. At high levels of wind turbine sound (more than 45 dB(A)) interruption of sleep was more likely than at low levels. Higher levels of background sound from road traffic also increased the odds for interrupted sleep. Annoyance from wind turbine sound was related to difficulties with falling asleep and to higher stress scores. From this study it cannot be concluded whether these health effects are caused by annoyance or vice versa or whether both are related to another factor."

Though the conclusion appears to contradict itself, and the assertion that only sleep is a factor cannot be concluded from their data as they did in fact find a relationship between annoyance and stress, but they could not conclude which one caused the other.

van den Berg, F., Pedersen, E., Bouma, J., and Bakker, R. (2008). Visual and Acoustic impact of wind turbine farms on residents. FP6-2005-Science and Society-20, Project no. 044628. A report financed by the European Union.

Thorne (2009)

As part of his research into the perception of low amplitude intrusive sound Thorne has found that there are significant differences in response between people living in rural areas near wind farms and people living in urban communities. Based on a series of sound simulations he found that the rural people interviewed found the sound of the turbines 'unpleasant, annoying and disturbing' whereas the urban community, who had not seen the wind farms or turbines, found the sounds 'pleasant and gentle'. A series of noise sensitivity questionnaires also indicated a statistically significant difference between the two communities with the rural community more sensitive. Further research

at two different locales near wind farms show that individuals initially accepting of wind farms can become increasingly sensitised to very low levels (outdoor LAeq 30 dB or less) of sound from wind farms due to the visual dominance of the turbines themselves and to noise that causes sleep disturbance or perceived adverse health effects. Sleep disturbance is caused by the varying nature of the wind farm noise; the 'rumble-thump' or 'swishing' sound heard inside the home at levels of LAeq 15 to 20 dB or less and cannot be avoided. The work of Thorne (2009) was to establish a practical methodology to integrate human perception of sound, personal sensitivity and relevant sound character analysis.

Thorne. R. (2008). Assessing intrusive noise and low amplitude sound. PhD thesis available online from Massey University, Palmerston North, New Zealand.

Jabben (2009)

Jabben and colleagues (2009) from RIVM, the Dutch National Institute for Public Health and Environment, were commissioned by the Dutch Government to examine the impact of different values of loudness on the ability to meet targets for onshore wind power generation. They reviewed current evidence and noted that, at present, 440,000 inhabitants (2.5% of the population) were *"receiving significant noise contribution from wind turbine noise of which 1,500 are expected to suffer severe annoyance. It is remarkable that almost half of this number already occurs within the range Lden 30-40db(A)"*.

Jabben J, -Verheijen E and Schreurs E. 2009. Impact of wind turbine noise in the Netherlands. Third International Meeting on Wind Turbine Noise, Aalborg 17-19 June 2009.

Pierpont (2009)

Pierpont (2009) has recently completed a very detailed case-series study of ten families around the world who have been so affected by wind turbine noise that they have had to leave their homes, nine of them permanently. The turbines ranged from 1.5 to 3MW capacity at distances between 305 to 1500m. The group comprised 21 adults, 7 teenagers and 10 children of whom 23 were interviewed. While this is a highly selected group, the ability to examine symptoms before, during and after exposure to turbine noise gives it a strength rarely found in similar case-series studies. The subjects described the symptoms of wind turbine syndrome outlined above and confirmed that they were not present before the turbines started operation and resolved once exposure ceased. There was a clear relationship between the symptoms, even in children, and the noise exposure. Pierpont reports also that all (actually 14 of 21) adult subjects reported *"feeling jittery inside"* or *"internal quivering"*, often accompanied by anxiety, fearfulness, sleep disturbance and irritability. Pierpont hypothesises that these symptoms are related to low frequency sound and suggests physiological mechanisms to explain the link between turbine exposure and the symptoms.

Of particular concern were the observed effects on children, include toddlers and school and college aged children. Changes in sleep pattern, behaviour and academic

performance were noted. Seven of the ten children had a decline in their school performance while exposed to wind turbine noise which recovered after exposure ceased. In total, 20 of 34 study subjects reported problems with concentration or memory.

Pierpont's study mostly addresses the mechanism for the health problems associated with exposure to wind turbine noise rather than the likelihood of an individual developing symptoms. Nevertheless, it convincingly shows that wind turbine noise is strongly associated with the symptoms she describes, including sleep disturbance. She concludes by calling for further research, particularly in children, and a two-kilometre setback distance. A recent paper (Todd et al, 2008) has shown that the vestibular system in the human ear, the part concerned with detection of movement and balance, is exquisitely sensitive to vibration at frequencies of around 100 Hz. Pierpont claims that these findings support her hypotheses.

Pierpont N. (2009). Wind Turbine Syndrome: A Report on a Natural Experiment. K Selected Publications. Santa Fe, New Mexico.

Nissenbaum (2010)

Nissenbaum (2010) has presented the preliminary results of a study of residents living downwind and within 300-1100m (mean 800m) of a wind farm at Mars Hill, Maine, USA. The 28 1.5MW turbines are sited on a 200m high ridge overlooking the homes. Thus far 22 of about 35 adult residents have been interviewed and compared with a randomly selected control group living approximately six kilometres away. Of the 22, 18 report new or worsened sleep onset disturbance at least twice a week, for 9 at least 5 times per week (controls 1/28). A further eight of the 22 report new or worsened headaches (controls 1/28) and 18/22 reported new or worsened mental health symptoms (stress 12/22; anger 18/22; anxiety 8/22; hopelessness 12/22; depression 10/22; controls 0/28).

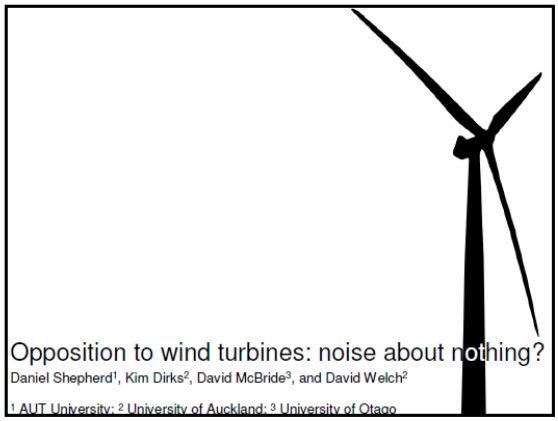
The 22 subjects received 15 new or increased prescriptions from their physicians in the 18 months between the start of turbine operation and the study, the majority for psychoactive medication (control group: 4 prescriptions, none for psychoactive medication). All but one of the 22 participants have reported reduced quality of life and 20 are consider moving away (controls: 0/28 for both). The study may be criticised for it's relatively small numbers of subjects but the presence of a control group, well matched for age and gender, adds considerable power. All differences between the groups are statistically highly significant. The turbine noise levels at this site may be enhanced by the high concentration of turbines and the geography but the severe sleep disturbance, psychiatric symptomatology and increased medication requirement in the study group confirms the potential of wind turbine noise to adversely affect health at distances claimed to be safe.

Nissenbaum, M. A. (2010). Industrial Wind Turbines and Health Effects in Mars Hill, Maine. A Retrospective Controlled Study – Preliminary Findings as of November, 2009. Personal Communication.

* The expertise and assistance of Dr Chris D. Hanning is acknowledged. His collaboration, review and feedback have substantially fortified this summary.

Appendix D

Presentation at the International Symposium on Sustainability in Acoustics, Associated Meeting of ICA 2010, Sydney Conjoint with the New Zealand Acoustical Society (NZAS) Conference, Auckland, New Zealand



- The WHO reports that community noise has the potential to impact health and amenity.
- Community noise includes road, rail, aviation and neighbourhood noise.
- Wind turbines are a new source of community noise, and as such their effects on public health are only beginning to emerge in the literature.
- In the last comprehensive study into the effects of turbine noise van den Berg et al (2008) concludes:

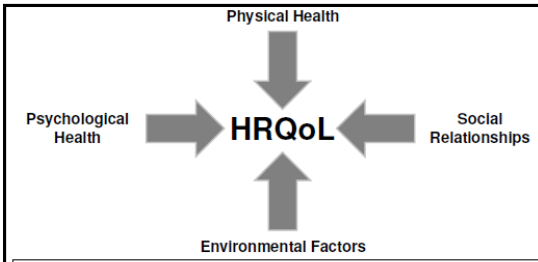
"*Annoyance with wind turbine noise was associated with psychological distress, stress, difficulties to fall asleep, and sleep interruption*"

The Constitution of the World Health Organisation (1948) defines health thus:

"Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."

Thus changes in health can be indexed by both objective measurements of maladaptive physiological processes (e.g., cortisol or adrenaline levels) and subjective measurements of well-being.

Subjective well-being is synonymous with Quality of Life (QoL), which itself is a multidimensional construct.



An interdisciplinary team is currently undertaking a study examining the association between noise and health-related quality of life across New Zealand.

Target samples include people residing in the proximity of airports, major motorways, & wind farms.

Appendix D Continued

Design: Case-control study consisting of two areas:

Control area: 250 houses in geographically and SES matched areas

Turbine area: 42 houses along the Makara and South Makara roads, all within two kilometres or less of a turbine

Each "*Neighbourhood and Wellbeing*" survey pack, delivered by a recruit from SJS, consisted of:

- Two copies of the questionnaire
- Two return-addressed pre-paid envelopes
- One Participant Information Sheet

The South Makara Valley
(From: http://www.flickr.com)

Questionnaire:

- Demographics
- WHOQOL-BREF (26 items)
- Neighbourhood amenity (2 items)
- Neighbourhood problems scale (14 items from Steptoe and Feldman, 2001)
- Annoyance to air pollution or noise (7 generic items)

Collation

- Responses were double entered by individuals not otherwise involved with the study. Data were then checked and exported to SPSS.

Preliminary Findings: Sample profile

	Makara RR: 26 / 84 = 31%	Control RR: 173 / 500 = 34%
Gender	M=37.5%, F=62.5%	M=40.2%, F=57.4%
Age	39.1% < 50 years	57.9% < 50 years
Education	37.5% University	35.5% University
Employment	59.1% fulltime	52.4% fulltime
Illness	31.8% Yes	33% Yes
Residence	*M*=12.28 years	*M*=11.4 years

Problem: Many houses in both areas had no letter box.

Preliminary Findings: Area Comparison

Subscale	Mean Rank	Significance (two-tailed)
Physical Makara Control	 75.25 100.09	*U*=1505.5, *z*=-2.049, *p*=.040
Psychological Makara Control	 78.48 99.07	*U*=1883.5, *z*=-1.524, *p*=.088
Social Makara Control	 96.49 92.63	*U*=1923.05, *z*=-0.325, *p*=.745
Environmental Makara Control	 73.89 97.92	*U*=1423.5, *z*=-1.983, *p*=.047
Overall QOL Makara Control	 76.81 99.87	*U*=1543.5, *z*=-2.133, *p*=.033

Appendix D Continued

Preliminary Findings: Amenity

I am satisfied with my neighbourhood / living environment				
1	2	3	4	5
Strongly disagree		Neither agree nor disagree		Strongly agree

U=1497, *z*=-1.981, *p*=.048 (Makara =77.09, Control = 99.14)

My neighbourhood/living environment makes it difficult for me to relax at home				
1	2	3	4	5
Strongly disagree		Neither agree nor disagree		Strongly agree

U=1519.5, *z*=-2.093, *p*=.038 (Makara =114.93, Control = 93.99)

A Frank Discussion:

- We have uncovered evidence that turbine noise, like road, rail, and aviation noise, can impact the QOL of those directly exposed to it
- Interestingly, the physical subscale also contains an item evaluating sleep quality (Q. 16)
- Significant differences were also noted in amenity ratings
- These findings are consistent with the small number of turbine studies published internationally

But:

- Case-control studies do not indicate causation
- Data is still arriving, and better matching may be necessary
- Might there be a sample bias?

Some observations about noise in general:

What we have:

Much of what we know comes from engineers

Limited translation of that knowledge to the human side

Physical processes and assessment (e.g., sound meters) do not equal human processes or assessments

Engineering solutions do not equal human solutions

What we need:

Better models of human annoyance

A model of annoyance prevention

Make better use of incident data to inform intervention

"Persons who drink little and are over-sensitive to noise become tremulous"

Hippocrates. Prorrhetic I, vol. VIII.

THE END

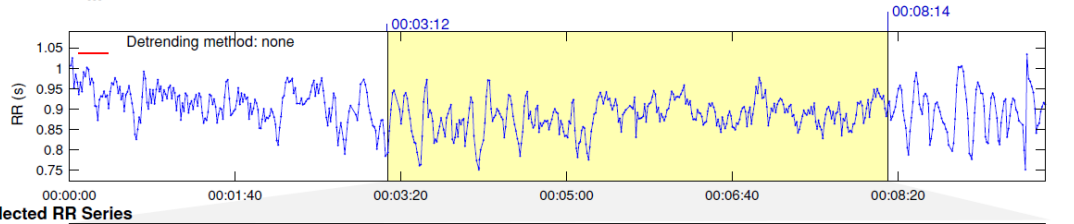
I'm a quiet living man,
Who prefers to spend the evening in the silence of his room,
Who likes an atmosphere as restful as an undiscovered tomb,
A pensive man am I, of philosophic joys,
Who likes to meditate, contemplate,
Free from humanities' mad inhuman noise,
Just a quiet living man....

From: *My Fair Lady*, By Alan Jay Lerner and Frederick Loewe

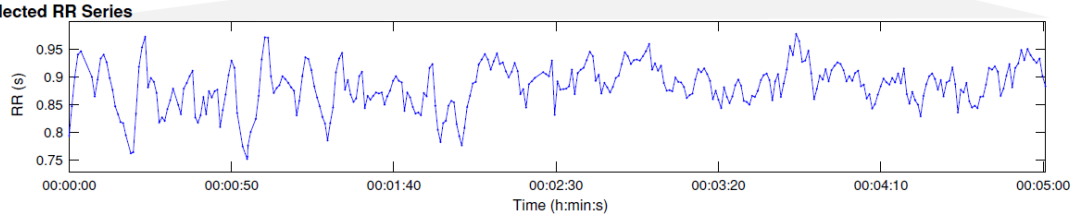
Appendix E

HRV Analysis Results

RR Interval Time Series — **Results for a single sample**



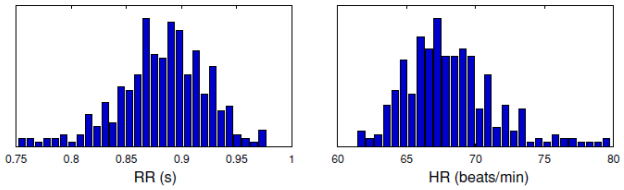
Selected RR Series



Time–Domain Results

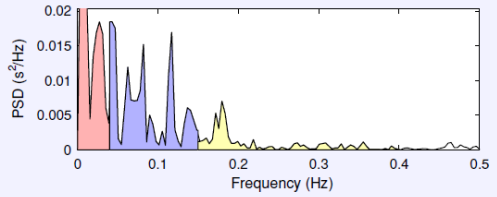
Variable	Units	Value
Mean RR*	(ms)	882.5
STD RR (SDNN)	(ms)	40.2
Mean HR*	(1/min)	68.14
STD HR	(1/min)	3.20
RMSSD	(ms)	26.8
NN50	(count)	21
pNN50	(%)	6.3
RR triangular index		11.133
TINN	(ms)	195.0

Distributions*



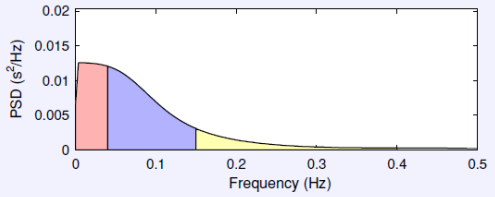
Frequency–Domain Results

FFT spectrum (Welch's periodogram: 256 s window with 50% overlap)



Frequency Band	Peak (Hz)	Power (ms²)	Power (%)	Power (n.u.)
VLF (0–0.04 Hz)	0.0039	615	41.5	
LF (0.04–0.15 Hz)	0.0430	667	45.0	76.9
HF (0.15–0.4 Hz)	0.1797	200	13.5	23.1
Total		1482		
LF/HF		3.335		

AR Spectrum (AR model order = 16, not factorized)

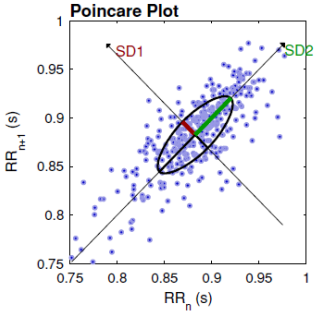


Frequency Band	Peak (Hz)	Power (ms²)	Power (%)	Power (n.u.)
VLF (0–0.04 Hz)	0.0039	484	31.8	
LF (0.04–0.15 Hz)	0.0430	829	54.4	79.8
HF (0.15–0.4 Hz)	0.1523	210	13.8	20.2
Total		1524		
LF/HF		3.943		

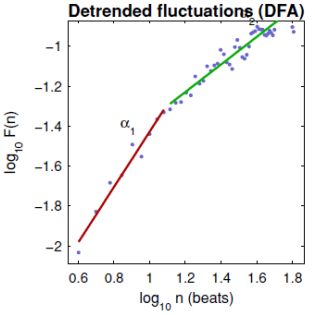
Nonlinear Results*

Variable	Units	Value
Poincare plot		
SD1	(ms)	19.0
SD2	(ms)	53.4
Recurrence plot		
Mean line length (Lmean)	(beats)	11.13
Max line length (Lmax)	(beats)	160
Recurrence rate (REC)	(%)	34.02
Determinism (DET)	(%)	98.45
Shannon Entropy (ShanEn)		3.202
Other		
Approximate entropy (ApEn)		1.131
Sample entropy (SampEn)		1.498
Detrended fluctuations (DFA): α1		1.389
Detrended fluctuations (DFA): α2		0.691
Correlation dimension (D2)		2.380

Poincare Plot



Detrended fluctuations (DFA)



*Results are calculated from the non–detrended selected RR series.