The Effects of Helicopter Noise on Perceived Tranquillity in New Zealand National Parks.

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Abstract

This study aimed to review methods of subjective tranquillity testing, which were then applied to the New Zealand population. This was done in order to determine the relationship between reported tranquillity values, and the corresponding predicted tranquillities obtained using the TRAPT equation. This was for the case of helicopter noise in New Zealand national parks. This information may potentially be used to assess helicopter noise levels in national parks, and to create a new set of noise management plans for the parks. This study involved two stages of research; a scoping study which evaluated the testing methods, and a pilot study which was used to draw conclusions on the use of the TRAPT equation in the New Zealand context. The pilot study had 32 participants, aged from 23 to 71 years of age, including both males and females, who belonged to European, Maori, Pacific Islander, or Asian ethnic groups. On-site images and sound recordings were taken at the Franz Josef Glacier Valley. These recordings and images were then used in a series of subjective laboratory tests, where participants gave subjective responses to helicopter noise levels based on a series of emotional reactions. Results indicate that although there are strong correlations between helicopter noise and both predicted and reported tranquillity values, those values are significantly different. Therefore, this implies that the New Zealand and British populations respond differently to helicopter noise. In its current state, the TRAPT equation does not accurately predict responses of New Zealanders, and the tranquillity associated where helicopter noise is present for the New Zealand population. For use in the New Zealand context, the TRAPT equation needs to be recalibrated.

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List of Abbreviations

ANSI	American National Standards Institute
ART	Attention restoration theory
AS/NZS	Standards Australia/Standards New Zealand
B&K	Brüel & Kjær
dB	Decibel
DoC	Department of Conservation
Hz	Hertz, a unit of frequency
IEC	International Electrotechnical Commission
ISO	International Standards Organization
LA_{eq}	The average A-weighted SPL, averaged over a given measurement period.
LA_{max}	The maximum measured A-weighted SPL.
LA_{min}	The minimum measured A-weighted SPL.
LA_{10}	The equivalent continuous SPL, exceeded for 10% of the measurement period
LA_{50}	The equivalent continuous SPL, exceeded for 50% of the measurement period
LA_{90}	The equivalent continuous SPL, exceeded for 90% of the measurement period
MF	Moderating factors
NCF	Natural contextual features

TR Tranquillity rating

TRAPT Tranquillity Rating and Prediction Tool

SD Secure digital

SLM Sound level meter

SPL Sound pressure level

Stats Statistics New Zealand

UK United Kingdom

UN United Nations

WHO World Health Organization

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Chapter 1. Introduction

1.1 Overview

The New Zealand Department of Conservation has identified anthropogenic noise as an issue in its national parks (DoC, 1996).This noise could come from many sources, with aeroplanes, helicopters, jet boats, off-road vehicles, and other motorised equipment such as chainsaws being recognised as particular areas for concern (DoC, 1996). This research looks specifically at the effects of helicopter noise pollution in New Zealand national parks, paying particular attention to scenic helicopter flights in the Westland Tai Poutini National Park. At present, the Department of Conservation is reviewing the National Park Management Plan for the Westland National Park, with the current plan released in 2001, and updated in 2008 and 2014 (DoC, 2001). Before any new management plans can be developed which include helicopter noise pollution, ways to assess such noise and its effects need to be established. In the United Kingdom (UK), the Tranquillity Rating and Prediction Tool (TRAPT) has been developed as a way to predict how an individual may feel in an environment, based on their visual surroundings, and the environmental noise levels (Pheasant, Horoshenkov, & Watts, 2010). This tool seems to work quite well in the United Kingdom with British subjects; however different populations may react differently to their surrounding environments. This research aims to determine the relationship between predicted tranquillities using the TRAPT equation, and reported tranquillities from the New Zealand population, using stimuli from the Westland National Park.

1.2 Anthropogenic Noise

Noise is unwanted sound that may have the potential to disturb an individual (Stevenson, 2010). What is ‘noise’ to one person may not be to someone else. Environmental noise can be defined as all noise emitted from all sources, with the exception of industrial workplaces; although some definitions do not exclude industrial workplaces in the definition (WHO, 1999). Anthropogenic noise (noise that is created by humans) increases are almost unavoidable in today's modern world. Global populations are growing, resulting in more cities, cars, roads, and consequently more noise (WHO, 2011). Anthropogenic noise can come from any number of sources; primary sources include traffic (air, rail, road), construction, industries, public work, and 'neighbourhood living' (WHO, 1999). This noise is a common occurrence, and has been identified as a major public health risk across the globe (Jamir, Nongkynrih, & Gupta, 2014; WHO, 2011).

1.3 Growing Urbanisation

The global population, as of mid-2015 was reported to be 7.3 billion (UN, 2015). Although total population growth has slowed down in recent years, it is still increasing by approximately 1.18% per year; a staggering increase of roughly 83 million people per year (UN, 2015). Population projections expect that the global population will reach 8.5 billion by 2030, 9.7 billion by 2050, and 11.2 billion by the year 2100 (UN, 2015). A report by the United Nations (UN, 2014) states that in 2014, 54% of the global population resided in urban settings. This is in contrast to the approximate 30% urban population in 1950, and the projected urban population of 66% in the year 2050 (UN, 2014).

Overall, the global population is growing, and moving into more condensed, urban areas. This urbanisation, although beneficial for economic growth and access to essential services such as education and healthcare, also has the potential to be detrimental and harmful to the population (Gong et al., 2012; Jofre-Monseny, Marín-López, & Viladecans-

Marsal, 2014; Wu et al., 2016). Although cities are growing, many are not growing fast enough to cope with the influx of people and their needs (WHO, 2008b). This is leading to the development of slums, crowded housing, and unsuitable living environments without enough infrastructures and services to adequately support them (WHO, 2008b). An increase in urban population density also encourages the spread of disease and illness; ailments that are in many cases preventable, and are therefore unnecessarily adding to the global burden of disease (WHO, 2008b).

1.4 The Urban Environment and Health

The urban environment, sometimes referred to as the 'concrete jungle', can at times seem to be exactly that; a harsh, grey environment. However, this harshness can be softened with the use of plants, gardens, and 'green' spaces. Accessibility of 'green' areas can have a significant effect on the health of the population, with increased accessibility being linked to better health outcomes (Gidlöf-Gunnarsson & Öhrström, 2007). Areas that are green or natural, such as parks or gardens, have been found to have beneficial effects on human health, both mental and physical (Nielsen & Hansen, 2007). Not only do these environments encourage exercise, but they also provide an 'escape', fresh air, and the chance to unwind and relax (Bedimo-Rung, Mowen, & Cohen, 2005; Hansmann, Hug, & Seeland, 2007; Wolf & Wohlfart, 2014).

An area of extended research has been the relationship between green areas and stress; studies show that stress levels can be dramatically decreased in individuals that have access to, and utilise green spaces (Nielsen & Hansen, 2007; Stigsdotter, Grahn, & Sveriges, 2011; van den Berg, Maas, Verheij, & Groenewegen, 2010). A section of the urban population that can significantly benefit from the use of green areas are those in lower socioeconomic brackets; a demographic that is often found to suffer from greater health inequalities (Mitchell & Popham, 2008; Theodossiou & Zangelidis, 2009; Ward Thompson et al., 2012; WHO, 2008a). Ward Thompson et al. (2012) have shown that individuals from disadvantaged communities experience less stress when frequenting natural, 'green' areas. Overall health factors and outcomes have been investigated by Mitchell and Popham (2008), whose study indicates that some health implications associated with lower socioeconomic status are less pronounced when there is greater access to green areas.

Other aspects of mental health that may be improved by accessing and using green spaces include mental fatigue, exhaustion, and attention capacity (Berto, 2005; Ohly et al., 2016). A study by Berto (2005) found that mentally fatigued subjects perform better after being exposed to a series of 'restorative' environmental images, as opposed to being exposed to geometric shapes or urban images. However, a systematic review by Ohly et al. (2016) demonstrates that although this Attention Restoration Theory (ART) is often referred to and cited in a large body of literature, there seems to be a lack of strong evidence to irrevocably prove it. ART will be covered in more detail later (see section 1.6).

The final mechanism by which urban parks or green areas may influence health (that will be mentioned in this section) is socially. Parks provide an ideal setting to meet and interact with people, and communities. Human relationships and community interactions can have an appreciable effect on health and mental wellbeing, providing all kinds of support in many different ways (Maas, van Dillen, Verheij, & Groenewegen, 2009; Na & Hample, 2016). Berkman, Glass, Brissette, and Seeman (2000) explore the relationships between social integration and wellbeing in a thorough examination; covering a wide range of concepts from politics through to self-esteem. All communities have a structure which determines how they operate. A community's levels of social support, influence, engagement, person-to-person contact, and access to resources and material goods can directly influence a community's or an individual's lifestyle. This lifestyle then affects the health of the individual and the community as a whole (Berkman et al., 2000; Maas et al., 2009).

1.5 Urban Noise

In urban environments, populations are often large and somewhat condensed, particularly when compared to their rural counterparts. In an environment where there are lots of people, noise is almost unavoidable (Barrigón, Escobar, Gozalo, & Vílchez-Gómez, 2010). To reduce the amount of noise, noise control strategies have been adopted and enforced worldwide, with varying success (Bohatkiewicz, 2016). The Christchurch area's noise control strategy is based on the Resource Management Act 1991 (N. Z. Government, 2016b). This act states that all occupiers of land are responsible for ensuring that noise does not exceed a 'reasonable level'; where an 'unreasonable level' is described as manmade noise that has the ability to unreasonably interfere with any person (N. Z. Government, 2016b). Noise control efforts are designed to make the environment more tolerable for everyone; however, policies can often be hard to define, and even harder to enforce (Meij & Rabie, 1974).

Due to the constant presence of noise in urban environments, dedicated 'quiet' areas are particularly important, providing individuals with the chance to recover from the sensory overload that is urban life (Pheasant, Fisher, Watts, Whitaker, & Horoshenkov, 2010).

1.6 Urban Planning

Due to the recognition of the importance of green areas and their effects on population health, a significant amount of research has gone into determining what makes an ideal restorative environment (Pheasant, Horoshenkov, & Watts, 2011; Pheasant, Horoshenkov, Watts, & Barrett, 2008). A restorative environment, as the name suggests, is an environment that is designed to help people to feel restored. Restored could mean any number of things to an individual, whether it is ‘recharging your batteries’, physically releasing, de-cluttering the mind, or simply feeling at peace. However, not all environments are created equal or can be restorative, and there are specific ways to increase an environment’s restorative potential.

An ideal restorative environment is difficult to define. The attention restoration theory (ART) states that there are four components that need to be considered when creating a restorative environment; these components are ‘fascination’, ‘being away’, ‘compatibility’, and ‘extent’ (FACE) (Kaplan, 1995; Payne, 2013). Fascination refers to the concept of passive, involuntary, or effortless attention; the ability of an environment to captivate the attention of the individual, without over stimulating them or preventing other stimuli from gaining attention. Being away refers to the physical or mental shift away from the individual’s normal everyday situations or stressors, towards a different environment or way of thinking. This can be further influenced by whether the individual feels the need to be away *from* something (i.e. from life stresses), or they wish to get away *to* something (i.e. to a new task or thought). Compatibility refers to the individual’s expectations, needs, or their planned behaviour, and how well the environment can meet or cater to those requirements. This aspect is highly dependent on the individual, just as much as it depends on the environment in question. The more compatible the environment is with the individual, the less focus and attention will be drawn by the shortcomings or differences in the environment, and therefore less effort will go into enjoying it. Finally, extent refers to the scope and potential of an environment; the ability of the environment to make an individual feel as though they are in a different world, which is full of possibilities and ready to be explored (Kaplan, 1995).

All of the above mentioned factors can be strongly influenced by the physical makeup of the environment (Herzog, Colleen, Maguire, & Nebel, 2003). Research has shown that the more natural the environment, the higher the predicted tranquillity levels, and the higher the restorative capabilities of that environment (Herzog et al., 2003; Pheasant et al., 2008). This is the framework for many tranquillity prediction tools that are used today, such as the TRAPT model, which will be discussed in further detail later.

Percentage of natural features is a large predictor of tranquillity, and is strongly related to the restorative nature of green areas (Pheasant, Fisher, et al., 2010; Pheasant et al., 2011; Pheasant et al., 2008). The types of natural features that are visible can also affect how restorative or tranquil an environment is perceived to be (Pheasant et al., 2008). A study by Herzog and Barnes (1999) explores the effects of different natural settings on tranquillity and preference. Subjects were asked to rate a number of images based on preference and tranquillity, as well as other emotional factors. Images consisted of three different types of natural settings, including park/forests, large waterscapes, and deserts. This study shows a greater average tranquillity rating and preference rating for large waterscapes, whereas tranquillity is lowest for desert images. This shows that although an environment may have 100% natural contextual features, it does not mean that it is the 'ideal' restorative environment. Features that seem to positively affect tranquillity include flora and water

(Pheasant, Fisher, et al., 2010).

Visual stimuli and composition are not the only aspects of a restorative environment that can affect the levels of perceived tranquillity. Sound levels can have a huge effect on an environment's restorative values, and how it is perceived by the individual (Benfield, Bell, Troup, & Soderstrom, 2010; Pheasant, Fisher, et al., 2010).Take public parks as an example; although there are almost endless numbers of public parks that are available to people, not all are considered to be true 'restorative environments'. This may be in part, due to the fact that a lot of public parks are often 'designed' to be multi-functional areas that can be used as playgrounds, sporting fields, or for any type of community event. These parks are often flat, without a lot of flora, and noise levels are rarely low; particularly in densely populated urban areas (Evensen, Raanaas, & Fyhri, 2016). Although access to any types of parks can be beneficial, not all can be considered to be 'restorative' areas (Greg Watts, Miah, & Pheasant, 2013). Features such as a lot of trees can increase an environment's tranquillity through visual stimulation, but do not act as an effective barrier to sound unless wide and dense (Greg Watts, Chinn, & Godfrey, 1999). A study by Watts et al. (2013) showed that in urban settings, more tranquil environments have higher reported levels of natural sounds. In this study, perception of tranquil sounds and vegetation are found to be related to higher levels of tranquillity (Greg Watts et al., 2013) .

1.7 Access to Green Areas

Access to green areas, natural environments, and restorative settings can often be compromised in urban areas (Barbosa et al., 2007; Neuvonen, Sievänen, Tönnes, & Koskela, 2007). In order to receive the restorative benefits from these environments, urban dwellers are often required to travel further to get to these destinations, when compared to their rural or even suburban counterparts (Neuvonen et al., 2007). This distance can result in reduced utilisation of these beneficial environments, and consequently reduced health benefits received from them. Instead of making regular use of green areas in an everyday context, the only opportunities that some people may have to visit natural settings may be during vacations, which are often few and far between.

1.8 Work Stress and Holiday Leave

The *Survey of Working Life: December 2012 quarter*, published by Statistics New Zealand, surveyed a total of 14,335 employed people in New Zealand (Stats, 2012b). The report investigates various aspects of working life such as employment status, job satisfaction, and work-life balance. It shows that 18.2% of all employed people surveyed often or always experienced work related stress over the previous 12 months. Work stress was experienced by 27.7% of 'employers', 18% of 'employees', and 14.5% of self-employed people. Out of the surveyed population, 8.4% reported feeling either dissatisfied or very dissatisfied with their work-life balance (Stats, 2012b).

Depending on the type of employment, an employee's paid leave can be granted or earned to various extents. In New Zealand, full-time permanent employees should be entitled to no less than 4 weeks of paid annual leave per year, as stipulated in the Holidays act 2003 (N. Z. Government, 2016a). Permanent part time employment entitles the employee to annual leave, proportional to the contracted hours worked; while casual employees are paid at a rate to compensate for no provision of annual leave (N. Z. Government, 2016a).

Vacations or holidays are commonly associated with de-stressing, relaxing, and unwinding; a chance to get away from everyday life stresses. Studies concerned with the actual health benefits of vacations have shown that although there can be health benefits associated with holidays, they tend to be short lived (J. de Bloom, Geurts, & Kompier, 2013; Jessica de Bloom et al., 2009). More research is needed in this area.

1.9 New Zealand Tourism

New Zealand's tourism industry is focussed primarily on the international tourism sector. '100% Pure New Zealand' is the current marketing campaign, which was launched by Tourism New Zealand in 1999. The campaign has since undergone some minor changes, but the intended message remains: "100% Pure New Zealand tells the story of how this country's unique combination of landscapes, people and activities cannot be found anywhere else in the world - it is a "100% Pure New Zealand" visitor experience" (T. N. Z. N. Z. Government, 2015).

Tourism is one of New Zealand's largest industries. In the year ending March 2016 the total tourism expenditure was $34.7 billion; of which $14.5 billion was contributed by the international tourism industry, and $20.2 billion was contributed by the domestic tourism market (N. Z. Government, 2016d). In New Zealand, the country's unique natural environment is a major tourist attraction, with national parks serving as a visitor friendly access point.

1.10 New Zealand National Parks

There are 13 national parks in New Zealand, found as far north as Tongariro and as far south as Rakiura. National parks are an important part of the NZ tourism industry, and the Department of Conservation has been charged with their management since its formation in 1987 (N. Z. Government, 1987).The Department of Conservation's outcome statement is currently: " New Zealanders gain environmental, social and economic benefits from healthy functioning ecosystems, recreation opportunities, and living our history", hopefully ensuring that "New Zealand is the greatest living space on Earth" (N. Z. Government, 2016c).

The Domestic Travel Survey showed that in the year ending December 2012, 33,874 domestic travellers stated that the North Island National Parks were their main tourism activity, while 72,851 domestic travellers identified the South Island national parks as their main tourism activity (Stats, 2012a).

1.11 Helicopters in National Parks

New Zealand National Parks are largely utilised for a number of outdoor activities, including but not limited to walking, tramping, camping, hunting, mountain biking, and fishing. There are, however, other activities that take place in and around national parks that are provided by outside organisations and businesses, including activities such as jet boat rides, scenic flights, and 'heli-hikes'. These activities provide a means to see and experience New Zealand in a different way, and to access areas that may otherwise be inaccessible to someone on foot. Although these attractions may enrich the holiday experiences of those who participate in them, they may also have the ability to detract from the experiences of other national park users. Attractions such as scenic flights produce a lot of noise which may have the ability to affect how the national parks are perceived by visitors. Helicopters and scenic flights are becoming increasingly popular, leading to increased noise pollution in the local vicinity. This has been identified as an area for concern for the Department of Conservation. This issue is so significant that signs have even been erected in the Franz Josef Glacier Valley, warning visitors that helicopter noise is to be expected (Espiner & Wilson, 2015).

One particular geographical area that is a concern for the Department of Conservation in regards to helicopter noise is the Westland National Park on the West Coast of the South Island, where approximately 92% of flights in the area have been found to be helicopters (Espiner & Wilson, 2013a, 2013b, 2015). This national park contains two large glaciers, Fox Glacier and Franz Josef Glacier; both of which have regular scenic flights going over them. Scenic flights are particularly popular in those areas because the glaciers are too dangerous to walk up to or climb, so they can only be safely accessed by air (Purdie, 2013). Various flights are offered by local companies, ranging from short scenic flights that simply fly over the glacier to provide a bird's-eye view of the area, to flights that land on the glacier, which allow a more hands-on experience of the glaciers. 'Heli-hikes' are guided tours that involve flying to and landing on the glacier, followed by a guided hike/walk around the ice formations (Purdie, 2013).

Scenic flights have been running around both glaciers for many years. The first flight over both Fox and Franz Josef Glaciers occurred in 1924, piloted by Maurice "Buck" Buckley; with regular flights starting in the 1930s, piloted by Captain James Cuthbert Mercer (Potton, 1990). Scenic flights have since been popular, with a 1966 copy of 'Handbook to the Westland National Park' identifying the flights as 'one of the highlights' (McCaskill, 1966).

A Department of Conservation publication from 1990 also included information on scenic flights over the Westland National Park, while their current website lists helicopter services as one of the 'things to do' at Franz Josef Glacier (DoC, n.d.; Potton, 1990). Due to the dynamic nature of the glaciers, and their rapid decline, not only can they be very dangerous, but they also have a finite lifespan, and they may not exist far into the future (Purdie et al., 2014). The chance to experience a natural wonder that is quickly disappearing means that helicopter flights are incredibly popular, providing a 'once in a lifetime' experience that can only be found in a few places worldwide.

Reports released by the Department of Conservation from 2013 and 2015 found that visitors to both the Franz Josef and Fox Glaciers were affected by helicopter noise during their visits. A 2015 report investigated the effects of over flights on visitor experiences in New Zealand national parks, and showed the demographics of the typical visitors to both Franz Josef and Fox Glaciers (Espiner & Wilson, 2015). It was found that members of the New Zealand population made up the largest subgroup of visitors to both glaciers. In this report, helicopter noise was identified as a significantly disliked aspect of the visitors' experiences, with 46% of questioned subjects expressing that flight noise had the potential to spoil their experience. 96% of subjects mentioned that they had noticed aircraft noise, and more flights were noticed than they would have expected, prior to their visits. 25 % of subjects expressed annoyance at the level of aircraft noise during their visit (Espiner & Wilson, 2015). Similar results were found in two 2013 reports from The Department of Conservation (Espiner & Wilson, 2013a, 2013b).

1.12 Fixed-Wing Aircraft Noise

Fixed-wing aircraft are responsible for a significant amount of manmade noise. The amount of noise made by an aircraft can be dependent on many factors such as the type of aircraft, its age, model, propulsion or jet systems, engine type, its flight path, the flight stage (i.e. take-off or landing), and the aircraft's distance and location in relation to the listener (Attenborough, Tokarev, & Zaporozhets, 2011). Aircraft noise has been identified as an area of significant concern, with a large amount to scholarly research associated with its causes, propagation, effects, and possible reduction strategies.

Studies of aircraft noise annoyance have been numerous, with the vast majority of research concerned with aircraft noise in residential areas around airports, and the effects that aircraft noise may have on the populations in those locations (Bullen, Hede, & Kyriacos, 1986; Hume, Gregg, Thomas, & Terranova, 2003). Annoyance is not only caused by the presence of noise, but also the sound level, duration, the vibrations caused by it, their regularity, an individual's sensitivity to noise, and the time of day that the noise occurs (Fidell et al., 2011; Fidell, Pearsons, Silvati, & Sneddon, 2002; Hume et al., 2003).

Most research into aircraft noise involves either airports or suburban locations surrounding such airports, which are generally flat, somewhat open spaces without a lot of forests or dense plant growth. The way that sounds move around these types of areas can be significantly different to how sound may travel in a forest or alpine environment. There is a significant lack of knowledge and research concerning how aircraft noise moves around more complex environments such as these. Many airports have regulations to manage aircraft noise; Wellington Airport has a night curfew that prevents any flights from landing or taking off between 1am and 6am, whilst Christchurch airport uses noise contours, and aims to reduce noise both at the source, and through flight paths and procedures (C. I. Airport, 2016; W. Airport, 2016).

1.13 Sound Propagation

The way that sounds travel is largely dependent on its surrounding environment. Sound moves in waves that project out from the source. Objects that are in the way of the sound's path will either absorb the sound, reflect it, or the sound may partially pass through the object. Objects can create sound shadows, reducing the sound levels behind them; they also have the ability to increase sound levels in particular areas, based on how and where sounds reflect (Kuttruff, 2007). Knowing about how sound interacts with its surroundings aids in both sound measurement and prediction models, which can then assist with noise control strategies.

1.14 Noise Measurement

Noise management is an essential aspect of environmental management and protection. Before any types of noise management strategies can be employed, noise measurement needs to be considered. Noise measurement in an environment can be used to make noise maps, and to predict how sound will move around an area based on features and characteristics of its surrounding environment (Cho, Kim, & Manvell, 2007; Lu & Lin, 2015). Noise can be measured and evaluated in a number of ways, ranging from psycho-acoustic parameters such as loudness and sharpness, to acoustic indices such as LA_{eq} and LA_{max}.

1.14.1 Psychoacoustic measurements

Psychoacoustics can be defined as the study of how humans perceive sound (Howard & Angus, 2009). How a sound is perceived depends largely on its psychoacoustic characteristics such as loudness, roughness, sharpness, and pitch. Two separate sounds may, in theory, have almost identical sound waves and physical characteristics, however, their psychoacoustic characteristics may greatly affect how they are perceived by the listener. Psychoacoustic ratings are subjective.

Sound quality is determined by the psychoacoustic characteristics of the sound, all of which can differ to varying degrees. Sound quality is a subjective characterisation of a sound, often characterised using scales.

Loudness can be defined as an attribute of auditory stimulation or sensation that orders sounds on a scale from quiet to loud(Moore, 2012). Loudness is often dependant on how one sound relates or compares to another.

Roughness can be used as a description of how ‘smooth’ a sound is perceived to be. Roughness is influenced by the frequency difference of beats for two sinusoidal sounds played simultaneously. If beats have a lower frequency difference such as 12.5-15Hz, sounds are deemed to be rough; while beats that have a higher frequency difference are more likely to seem smooth to the listener (Howard & Angus, 2009).

Sharpness is influenced by the amount of high frequency components of a sound, or how high pitched the sound is perceived to be. The more high frequency components, the sharper the sound.

Pitch can be used as a description of how an individual perceives a sound based on its frequency components (Moore, 2012). Pitch is organised on a scale of low to high pitch, and largely relates to the frequency components of the sound.

1.14.2 Acoustical Indices

Acoustical indices are objective ways of measuring and characterising sounds. In comparison to psychoacoustic measurements, acoustical indices can be given specific numerical values.

Sound pressure level, often referred to as SPL, is the measured magnitude or ‘level’ of a sound, rated in decibels (dB) (Moore, 2012). This can be measured with a number of different frequency weightings, all of which have their specific applications. A-weighted frequency measurement is most often used for environmental noise evaluations, as it closely relates to how the human auditory system responds to sounds (Moore, 2012). A-weighted sound measurements are labelled with a dBA rating. Some examples of A-weighted acoustical indices include LA_{max}, LA_{min}, LA_{eq}, LA_{10}, LA_{50}, and LA_{90}.

Frequency is the number of sound waves which pass a fixed point per second. The more waves that pass a fixed point per second, the higher the frequency.

1.15 Tranquillity Rating and Prediction

Humans are unpredictable in their nature. Previous experiences, emotional state, physical environment, and context can all affect how someone reacts to a stimulus of any sort. Although it is difficult to predict someone’s reaction, there are some tools that have been developed for that very purpose. To predict how someone will feel about an environment, one specific tool that has been developed is the TRAPT method of tranquillity prediction (Pheasant, Horoshenkov, et al., 2010). The TRAPT method utilises the following equation, where 'TR' is the tranquillity rating, 'NCF' signifies natural and contextual features, and MF stands for moderating factors (G. R. Watts & Pheasant, 2015):

$$TR = 9.68 + 0.041\ NCF - 0.146\ L_{day} + MF$$

In this equation, Tranquillity rating is affected by the percentage of natural and contextual features that are visible within the environment, the average SPL over a measurement period of 12 hours (L_{day}), and the presence of things such as litter or rubbish in the environment (MF) (G. R. Watts & Pheasant, 2015). This equation was initially developed for use in UK urban spaces, with a British population. It has, however also been validated for use in UK remote wildland areas (G. R. Watts & Pheasant, 2015). Because different populations may react differently to various environments, the equation needs to be evaluated, to determine whether or not it works for specific populations and environments. For example, Hong Kong is known for its busy urban culture, and extremely high traffic and urban noise levels (To, Mak, & Chung, 2015).It is likely that if an individual has become accustomed to an environment such as this, noise would be a constant factor, and therefore it may not bother them as much as it might others. However there is little research into noise tolerance differences between contrasting populations. To account for this, the TRAPT equation can be recalibrated for use with other populations, and altered to suit different situations, using the appropriate acoustical indices.

1.16 Practical Applications/management

Once a tranquillity prediction method has been selected and verified, it can then be applied to various environments. This method of tranquillity prediction works particularly well alongside noise mapping and noise contouring activities. Theoretically, with noise contouring maps, TR can be predicted where NCF is known, based only on the predicted noise levels of a specific location. This is possible, for example in national parks, where NCF can be assumed to be at or close to 100%. Such methods enable TR to be predicted without on-site sound measurements, potentially saving time and resources.

These types of tools may also be useful when designing spaces such as buildings or parks; using them to predict how sound propagate in these environments, possibly influencing design, construction, and material choices. For example, TRAPT has also been applied to indoor spaces such as a doctor's waiting room (G. Watts, Khan, & Pheasant, 2016).

1.17 Research Rationale

Although environmental noise has been flagged as a global health risk, research has predominantly been concerned with road traffic noise, noise in urban environments, and the impacts of aircraft noise in locations surrounding airports. While these are areas of particular importance, the effects of noise in different contexts have not been as thoroughly researched. Human responses to their environments will vary depending on both the individual and their context; consequently, they are almost impossible to predict. Too many factors could be at play, as responses are dependent on each individual, their life, personality, the situation, and their general character. Tranquillity rating and prediction is a relatively new concept, with the bulk of the literature being written over the last 10 years, by only a select few academics. The TRAPT model was initially developed for use with UK urban parks and British populations. Although this tool seems to work well under those circumstances, it is yet to be tested in an environment such as New Zealand, or with a different type of population. New Zealand is unique with both its multicultural diversity, and its natural environments; furthermore, the population's relationship with the land may differ to those in the UK.

The Department of Conservation has identified manmade noise, particularly helicopter noise, as an issue in the New Zealand national parks. However, before any new rules or regulations can be devised to reduce the impacts of such noise, it first needs to be determined how much noise is considered to be 'too much' for the New Zealand population. The Department of Conservation has stated that in an ideal situation, tranquillity levels would not fall below 8 in the national parks; therefore in this research, any sound levels that result in tranquillity ratings below a value of 8 will be considered to be 'too much'. By testing New Zealanders' responses to helicopter noise in New Zealand national parks, and comparing them to the predicted tranquillities obtained using the TRAPT equation, it can be determined whether or not the two populations (UK and NZ) would respond in the same way. If this is the case, TRAPT can be applied to environments in New Zealand, and may be employed by the Department of Conservation, in noise management strategies for New Zealand national parks.

1.18 Research Aims

There were multiple research aims for this study, largely due to the fact that this investigation involved two distinct stages of research; a scoping study and a pilot study.

The aim of the scoping study was to establish and assess methods of testing; providing a basis for activities continued in a proposed pilot study concerned with *The Effects of Helicopter Noise on Perceived Tranquillity in New Zealand National Parks*.

The aim of the pilot study was to quantify the extent of the disturbance of helicopter noise on the levels of perceived tranquillity for the New Zealand population, in New Zealand National Parks. The study aimed to determine the relationship between reported tranquillity values from the New Zealand population, and the corresponding predicted tranquillities obtained using the TRAPT equation; thereby answering the question: does the New Zealand population respond to helicopter noise in the same way as the British population? This information may potentially be used to monitor noise levels in national parks, and to create a new set of management plans for the Parks, to address the levels of tranquillity that can be maintained.

1.19 Hypothesis

It is hypothesised that increased levels of helicopter noise will correlate with decreased levels of perceived tranquillity for New Zealand residents; and that the relationship between calculated tranquillity using the TRAPT equation and perceived tranquillity obtained from the New Zealand population will be similar to that developed for British people visiting parks in the United Kingdom.

Chapter 2. Methodology

This study involved two distinct phases; a scoping study and a pilot study. The scoping study was designed to establish and assess methods of testing. These testing methods were later employed in the pilot study; used to draw conclusions on the use of TRAPT in New Zealand, particularly in relation to helicopter noise.

2.1 Ethics Approval

Ethics approval was granted by the University of Canterbury Human Ethics Committee on the twenty-second of August, 2016 (see Appendix 1). This ethics approval covered both the scoping and pilot study, which were both deemed to be of low risk. Procedures used in this study were completed in accordance with this approval, and no further amendments were made to permissions or approvals after the study's application was approved by the Human Ethics Committee.

2.2 Scoping study

2.2.1 Subjects

The scoping study involved seven participants, all over 18 years of age. As this exercise was conducted with the singular aim of establishing and evaluating testing methods, subjects were not required to meet any criteria other than the ability to hear, and understand English.

2.2.2 Procuring and setting up equipment for on-site measurements

For this study, a Brüel & Kjær (B&K) 2250 sound level meter (SLM) was used. This sound level meter was chosen because:

(1) It is a class one SLM, designed to meet the latest international standards for SLMs, based on and adapted from the IEC 61672-1:2002 standards (IEC, 2002);

(2) The SLM is user friendly, with a wide range of applications including environmental noise measurement (B&K, 2016);

(3) The machine is small and portable; and

(4) The SLM can be used without extensive training, and settings can be stored on the machine.

The SLM was sourced, and with reference to the user manual, the machine was set up to take simultaneous sound measurements and recordings, using the frequency analysis template (B&K, 2016). The SLM was then used in a series of practice recordings, in order to familiarise the operator with the machine and its settings. Measurements were taken using an A-weighting, with the measurements set to 10-second simultaneous recording and measuring. Measurements were taken with an A-weighting, as this frequency weighting most closely represents the human ears' response to sound at mid-levels (B&K, 1984, 2001, 2016). Sound files were saved to a removable secure digital (SD) card, as set up prior to the recording session(B&K, 2016).

2.2.3 On-site Measurements

In May 2016, on-site measurements were taken at Franz Josef Glacier, in the Westland Tai Poutini National Park. Using the pre-set user settings as mentioned in section

2.2.2, the SLM was set up to take 10-second simultaneous recordings and measurements. A wind shield was also placed onto the SLM during this recording session, to minimise the effects of any wind on the measurement microphone.

Prior to the recording session, a selection of recording locations had been chosen along the Franz Josef Glacier valley walk. This route was chosen due to its accessibility, its ‘easy’ difficulty rating, and the fact that it takes visitors as close to the terminal face of the glacier as is deemed to be safe. This walk is promoted as one of the more ‘popular’ walks in the Franz Josef area, likely because of these factors. Upon arrival, it was found that some of the proximal end of the walking track had been moved due to recent flooding and the dynamic, ever changing nature of the glacial environment. Because of this, some recording locations that had been chosen were no longer accessible and could not be used. Instead, recording locations were chosen en route, based on the suitability of the surrounding environment and the presence of helicopter noise (Sites A & B, Figure 1: Map of the Franz Josef Glacier Valley Walking track.

Note: the walking track is indicated by the green line, with the two main recording locations indicated as Site A and Site B.

Suitability of the recording environment was based on the surrounding environment, particularly the presence of any hard surfaces such as large rocks or walls, and also close trees, and dense shrubbery. These surroundings have the potential to influence how sound propagates, such as absorbing sound or creating reflections. Alternatively, the sound may diffract over or around solid objects, and be transmitted where density is low (i.e. through vegetation). During measurements, the measurement microphone was placed 2 meters away from any surrounding objects, with the aim of reducing the impact of possible sound reflections. This drastically reduced the amount of locations that were suitable for recording, as the first section of the walk was surrounded by close forest. Consequently, all recording locations had to be located further down the track in the open glacier valley area. In these locations, there were a lot of hard surfaces (rocks) which could reflect sound, and ambient noise levels were constantly high due to running water (river and waterfalls).

Most of the recordings were taken toward the end of the walking track, close to the base of the glacier (Site A). This point was focused on, as it was deemed to be a location where tourists were likely to spend the most time, both observing the glacier, and resting before making the return journey. This was also the location where the most helicopters were observed, as flight routes around the valley all varied slightly, however, almost all flights tended to travel with the aim of either passing over or landing on the glacier.

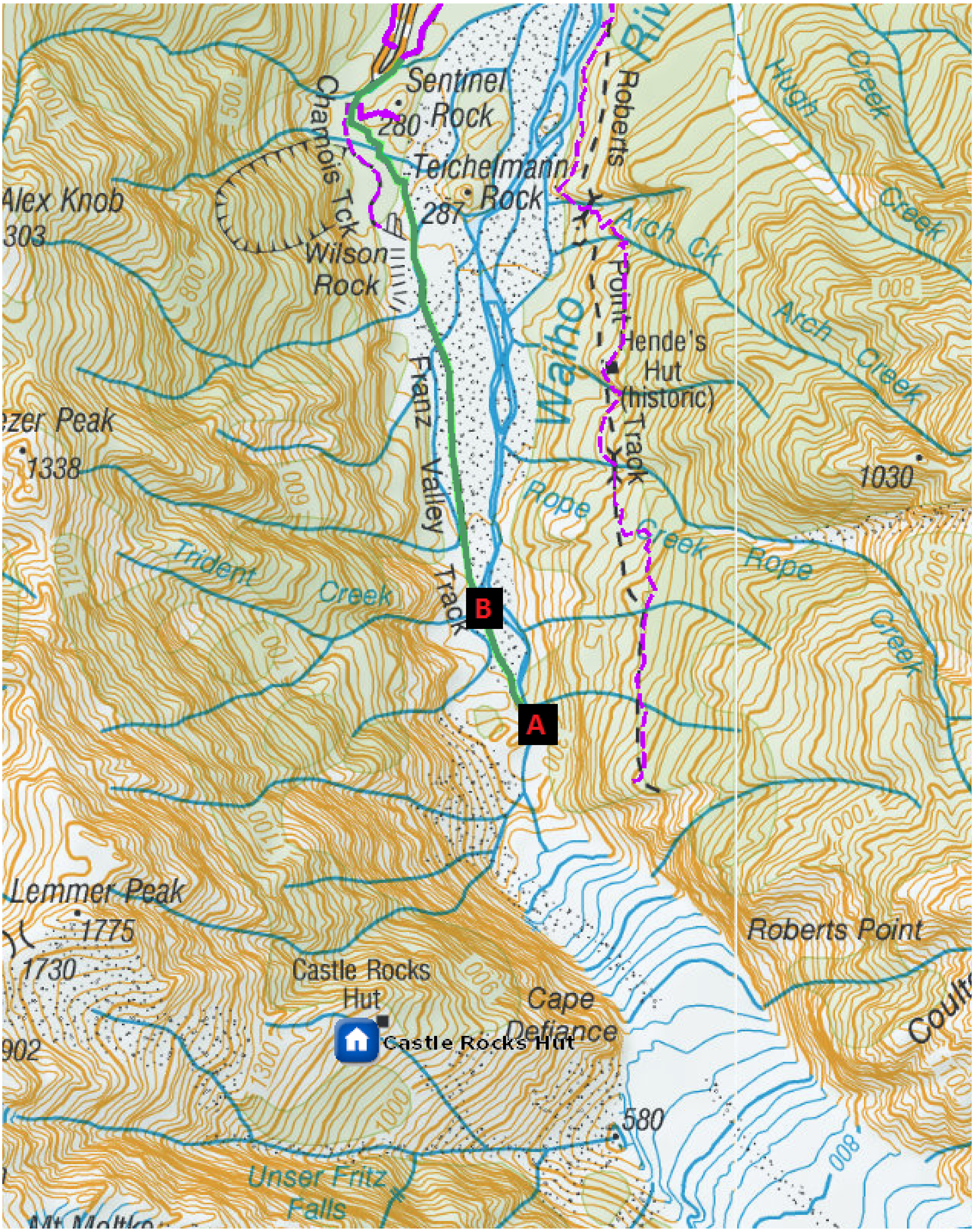


Figure 1: Map of the Franz Josef Glacier Valley Walking track.

Note: the walking track is indicated by the green line, with the two main recording locations indicated as Site A and Site B (DoC, n.d.).

Measurements were taken with the SLM held at arm's length, at approximately eye level, and the SLM microphone was pointed directly towards the source of the sound. This positioning was adopted to reduce the effects of sound shadows created by the researcher and the surrounding environment. In total, 65 sound measurements and recordings were taken over the course of one afternoon. Unfavourable weather conditions and the grounding of one helicopter operator reduced the number of flights going over the glacier, preventing any more measurements from being taken.

Throughout the recording session, photographs were also taken of the surrounding environment, using a Nikon digital single-lens reflex (DSLR) camera. Photographs were taken at locations where sound measurements/recordings were made, in order to give visual context to the recorded audio files. A selection of images were taken to represent the landscape, and its varying features; including images of the glacier, the glacier valley, the surrounding valley walls, the walking track, running water from the Waiho River, and the surrounding waterfalls. Images were composed to give a point of view (POV) shot, to represent how the environment may be viewed by a national park visitor, and to make the viewer feel like they are actually in that environment.

2.2.4Editing Sound Files and Images

Following the on-site visit, all of the recorded images and audio files were transferred and saved to a computer to be subsequently analysed.

2.2.4.1 Editing Images

Images were viewed using *Windows live photo gallery*, and were reduced in number for use in the scoping study. Image selection was based on visual factors associated with the images such as adequate lighting, composition, how realistically the environment was portrayed, and the overall quality of the images. Images were also selected to represent the vast array of scenic features in the local environment. In total, 8 images were selected for use in the pilot study. Some minor adjustments were made to a few images such as brightness reduction or contrast adjustments, to better represent the true environment. This editing was required, largely due to the fact that images with a lot of ice were difficult to capture due to brightness issues.

2.2.4.2 Sound File Selection and Editing

Sound files were transferred from the SLM to a computer by inserting the SD into an SD card reader in the computer. The files were recognised by the B&K BZ5503 Measurement Partner Suite software. This software was used to extract the data from the SD card, which was saved to the computer in multiple formats; saving the raw files, creating a B&K pack-and-go file, archiving the files into the B&KBZ5503 software, and exporting the data into an Excel file.

Sound files were initially sorted based on sound quality factors including the presence of unwanted sounds such as footsteps, talking, or clicks. This reduced the number of useable sound files from 65 down to 24. The 24 recordings were then reduced down to 11 by considering the sound levels (LA_{eq}) associated with each recording. A selection of 11 sound files were chosen that best represented the variety of different sound levels that were measured on-site.

Using a software program called *Audacity 2.1.2*, sound files were edited to fade at the beginning and end of each recording. Recordings were faded for 0.1 second at each end, leaving 9.8 seconds of each recording at full volume. This was done to ease the transition from silence to sound, reducing the potential startling effect, and removing possible clicks. All 11 sound recordings were then compiled into 3 different continuous sound files, with 20 second periods of silence placed between each recording. In each sound file, the 11 recordings were randomised in order. This process enabled the researcher to play sound files in varying orders to each subject, while controlling the time period between each sound recording. The order of the sound files was not written on any of the testing material, and the researcher could not easily identify what sound was being played until data collection was complete, and analysis commenced. The researcher was kept 'blind' as much as possible, playing sound files 1, 2, or 3, whilst not knowing the order of the sound recordings within each file.

2.2.5 Laboratory Testing

2.2.5.1 Laboratory Setup

Laboratory testing took place in booth 1, room 801 in the Rutherford building, at the University of Canterbury. This location was chosen because of its neat and tidy appearance for subjective testing, its ease of accessibility, the acoustic environment inside the booth, and the very low background noise levels within the booth. Booth 1 had been originally created as a 'sound treated' area, which was then later further renovated to meet the requirements of

AS/NZS1270: 2002 for testing hearing protectors (AS/NZS, 2002; Scott, 2015).

The booth was constructed with a double leaf roof and walls, fitted with a double door arrangement with noise seals; the floor was fitted with rubber vibration isolation mounts. Inside the booth, fittings included air vents, two sets of fluorescent lights, a selection of power and cable connection points, a sprinkler system, an emergency light, and a fire alarm. The booth was modified by others to meet the requirement of the AS/NZS 1270: 2002. Modifications included relining the interior surfaces of the booth with medium density fibreboard (MDF), replacing an existing emergency light with a newer, quieter unit, removing light covers from fluorescent lights, repairing a buzzing fire alarm, and installing a switch to turn off the external air conditioner, which was creating unwanted noise(Scott, 2015). The booth was rectangular shaped, with internal measurements of 3.05 meters by 2.84 meters, with a floor to roof height of 2.05 meters.

The booth was set up with a pair of Sennheiser HD 215 headphones for subjects, connected through the patch panel of the booth with a ¼" audio jack connector. On the other side of the patch panel was an auxiliary cable, connecting the booth and headphones to a computer, capable of playing audio files. Inside the booth was a 55" Sony Bravia flat screen television resting on top of a bench, located on the far wall, centred, and as close to the wall as possible. As shown in *Figure 2:* Laboratory setup for subjective testing: Booth 1, room 801, in the Rutherford Building at the University of Canterbury. The subject's seat was located at the other end of the booth, facing towards the television in a centred position.

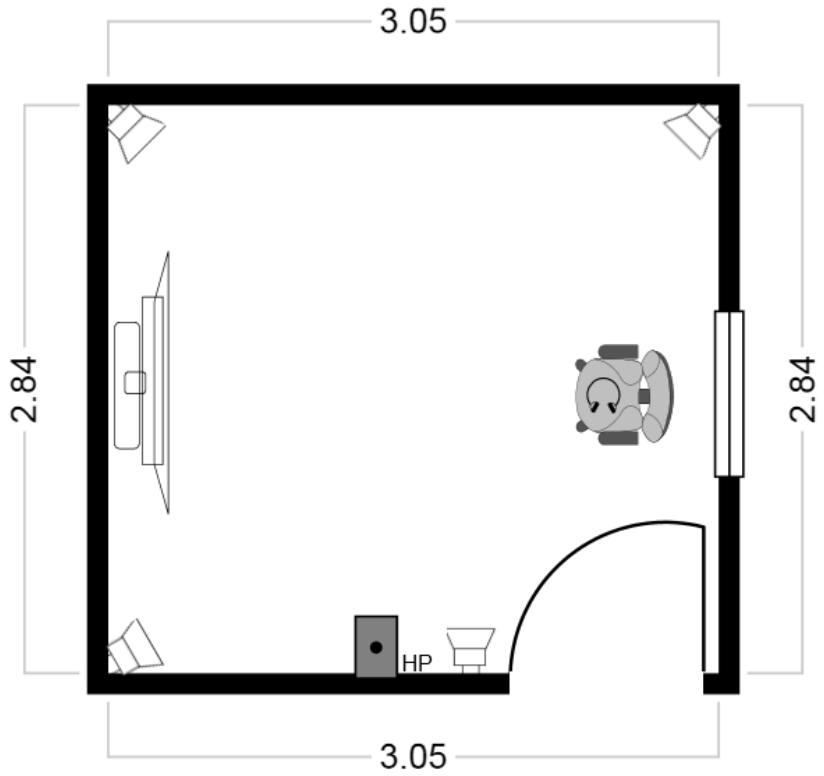


Figure 2: Laboratory setup for subjective testing: Booth 1, room 801, in the Rutherford Building at the University of Canterbury.

Note: 'HP' and the box next to it represent the location of the ¼ inch headphone jack. Room measurements that are represented on the diagram are measured in meters (m).

2.2.5.2 Visual and Audio Playback

Audio playback was through a computer, using *Windows Media Player*. To ensure that audio files were being played to the subjects at the correct sound levels, a 1 kHz tone recording was played through a set of Sennheiser HD 215 headphones, to a B&K head and torso simulator (HATS), which was connected to a B&K *Pulse* system, which was then connected back to the computer. The 1 kHz tone was recorded using the same measurement/recording settings that were used for the on-site measurements, as discussed in section 2.2.2. This recording was made in booth 101 in the audiology department at the University of Canterbury; the SLM was positioned 1 meter away from the sound source, with the microphone pointing directly towards it. The LA_{eq} for this recording was 53.9 dB SPL. To ensure that playback was at the correct level, the 1 kHz recording was played through the headphones to the HATS, and playback volume was adjusted until the Pulse system gave an LA_{eq} reading of 53.9 dB SPL. Because all of the recordings were made using the same measurement settings, once playback levels were matched for one of the recordings (the 1 kHz recording), playback levels would not need to be adjusted for any of the other recordings.

Audio playback levels were checked at the beginning of each day of participant testing, and re-checked if the computer had been turned off at any point.

Images were displayed to the participants using a Sony Bravia55" flat screen television, selecting universal serial bus (USB) image playback through the menu on the television itself, and selecting the image to be displayed.

2.2.5.3 Participant Testing

Before subjects were able to participate in the study, they were supplied with a flyer and participant information sheet (Appendix 2 & 3), providing a full explanation of the study, and then given a consent form to read and sign (Appendix 4). If the subjects agreed to participate in the study, testing commenced. Prior to testing, subjects were asked to specify their sex, age, and ethnicity for data collection purposes, and were then instructed on how to complete the testing procedure. Subjects were lead into the research booth, and seated in front of an image from a national park (Appendix 6, image H). Headphones were then placed on the subject, and they were supplied with a set of reporting sheets and a pen to write with. The participants were left alone in the booth with the lights turned off, and the door closed.

During each testing session, all three sound files were played to the subjects in differing orders. Subjects were instructed to listen to the sound clips and view the image displayed to them (Appendix 6, image H), trying to imagine that they were in that environment. Between each sound clip, the subjects were instructed to report their feelings about the environment (audio and visual) on the supplied sheets as shown in Appendix 5.Reporting sheets involved a number of scales ranging from 0 to 10, including tranquillity, remoteness, wildness, and naturalness. On the latter half of the page, self-assessment mannequins (SAM) were used as scales, including SAMs for control, pleasantness, and calmness. If they did not have enough time to complete each form, subjects were told to just leave that page, and continue on with the next sound clip and reporting sheet. This was repeated three times, once for each continuous sound file. Between each set of sounds, the participants were asked if they needed a break, or if they had any questions. If they were fine to continue, they were supplied with the next set of reporting sheets.

During testing, only one image was shown to participants, in order to maintain control in the study (Appendix 6, image H). Once the three sets of tests had been completed, the subjects were shown a series of 8 images (Appendix 6), and asked to rate them on a 0-10 scale of preference. Once finished, the subjects were debriefed, and their responses were entered into an *Excel* spreadsheet.

2.2.6 Data Analysis

Data was collected and entered into an *Excel* spreadsheet. When entering data, it was decided that the results from the first set of recordings played to each subject would not be analysed. This was because people often made mistakes in the first set of recordings, as they were familiarising themselves with the task. Only data from the second and third sets of recordings were used and analysed. Predicted tranquillity ratings were calculated for each sound recording using the TRAPT equation (see section 1.15). The L_{day} term was replaced by LA_{eq}, where LA_{eq} was adjusted for the background noise level, using the following equation:

$$10.LOG^{10}((10^{LAeq/10})\text{-}(10^{LAFmin/10})).$$

This equation was used to remove the effects of background noise on the predicted tranquillity ratings. Where only natural noises were present, a value of 26dBA was used in place of L_{day}, as in previous study designs (G. R. Watts & Pheasant, 2015). This value was used because in an environment with 100% NCF and only natural sounds, a sound pressure level of 26 dBA is the value required to reach an optimal predicted tranquillity rating of 10, using the TRAPT equation.

Once all of the data had been entered into *Excel* and organised, it was then ready to be analysed using both *Minitab* and *SPSS* statistical software packages. Analysis involved a series of correlation analyses, aiming to find the best relationship between predicted and reported tranquillity. The original TRAPT equation that was used was:

$$TR = 9.68 + 0.041\ NCF - 0.146\ LA_{eq} + MF.$$

Spearman's correlations were performed between reported tranquillity and the following variables:

(1) Predicted tranquillity using the TRAPT equation with, and (2) without corrected sound pressure levels; and

(3) Predicted tranquillity using the TRAPT equation with corrected sound pressure levels and an LA_{eq} value of 26 dBA for sound files where only natural noises were present.

2.3 Pilot Study

2.3.1Subjects

To determine the sample size required for the pilot study, a sample size calculation was completed using *G*Power* 3.1.9.2 software. The following parameters were entered into the software to determine sample size: (1) t-tests, (2) correlation: point biserial model, (3) a priori: compute required sample size – given α, power, and effect size, (4) two-tailed, (5) a large effect size of 0.5, (6) an α error probability of 0.05, and (7) a power of 0.8. From this, a total required sample size was calculated to be 26 people, with an actual power of 0.8063175. To ensure that there was enough useable data, 32 subjects were used in the pilot study.

Subjects were chosen to represent the New Zealand population demographics based on age, sex, and ethnicity, based on data from the 2013 New Zealand Census (Stats, 2013a, 2013b, 2014).

2.3.1.1 Ethnicity

Ethnicity related responses in the 2013 census showed that 74% of people identified themselves as having European heritage, 15% identified as Maori, 12% Asian, 7% Pacific peoples, and 1% identified themselves as having Middle Eastern/ Latin American/ African heritage (Stats, 2013b). However, although these percentages describe the New Zealand population well, total responses outnumber the amount of responders, and percentages of each group total to 109% of the population, rather than 100%. This implies that some individuals indicated that they belonged to multiple ethnic groups. Rather than using the above percentages, assuming that each response belongs to a different person, percentages were instead calculated as a percent of the total number of responses; not a percent of the population.

Percentages of responses showed that 67% identified as European, 13% identified as Maori, 7% had Pacific Islander heritage, 11% identified as Asian, 1% were classified as Middle Eastern/Latin American/African, and 2% of responses fell into the ‘Other’ category (Stats, 2014). These percentages were the ones used in this research.

2.3.1.2 Sex

Data from the 2013 Census showed that the New Zealand population consisted of 49% males and 51% females (Stats, 2013a).

2.3.1.3 Age

Breaking the 2013 Census age data into a selection of large sub-groups gave the following results:14% of adults were aged between 18-25 years, 25% were aged 26-40 years, 36% were between 41-60, and 25% of adults were aged 61 years and over (Stats, 2013a).

2.3.2 Sound File Collection

When this research was initially planned, a second recording session was intended for the pilot study. However, due to scheduling complications, this was not possible. To complete the study, 20 of the original sound recordings from the scoping study were used. These recordings were chosen using the method described in section 2.2.4.2; selecting a series of sound clips based on the absence of unwanted sounds such as clicks, foot prints, or speech, and ensuring that there was a wide variety of LA_{eq} values within the selection pool.

2.3.3 Sound File Editing

Sound files were edited in much the same way as was previously described in section 2.2.4.2. Using the editing software *Audacity 2.1.2* sound recordings were faded for 0.1 seconds at the beginning and end of each recording, leaving 9.8 seconds of each sound recording at full volume. All 20 sound recordings were then compiled into 4 continuous sound files, with 30 second periods of silence between each recording. In each of the 4 sound files, the orders of sound recordings were randomised. A 5th shorter sound file was also created, containing 5 of the edited sound recordings. This file was used as a practice run, before subjects were randomly assigned two full length sound files for testing.

2.3.4 Image Editing

As mentioned above in section 2.3.2, a second recording session was planned for the pilot study; this session would also have been used to gather more images of the surrounding environment. However, because a second recording session was not possible, the images from the scoping study were used in the pilot study as well. After testing peoples' reactions to images during the scoping study, it was decided that because there was little variation in responses between different images, displaying just one image would be enough. This added a sense of control to the study.

2.3.5 Laboratory Testing

2.3.5.1 Testing Environment

Laboratory testing for the pilot study occurred in the same location as the scoping study testing; booth 1, room 801 in the Rutherford building, at the University of Canterbury. Minor adjustments were made to the testing facility, including blacking out windows and doors to reduce ambient light, using an extension auxiliary cable to make headphone usage more comfortable, and a book light was attached to a clipboard, to make reading and reporting easier.

2.3.5.2Image and Audio Playback, and Checking Playback Levels

Audio file playback levels were checked daily using a 1 kHz pure tone recording, following the same procedure as outlined in section 2.2.5.2. A singular national park image (Appendix 6, image E) was displayed for the viewer, as was also described in section 2.2.5.2.

2.3.5.3 Participant Testing

Participant testing was conducted in the same way as described in section 2.2.5.3. The most significant difference was the reporting sheets that were supplied to the subjects. In the pilot study, fewer questions were included in the reporting sheets; having removed the 'control' and 'wildness' questions, as displayed in Appendix 7. Other differences included only showing one image to participants, having a shorter 5 sample practice sound file, and playing two randomised sound files, each with 20 sound clips.

2.3.6 Data Analysis

Subjective assessment data was collated using Microsoft Excel. This software was also used to generate mean values of reported tranquillity, naturalness, remoteness, pleasantness, and calmness for each of the 32 subjects' responses to each of the sound files. Data was analysed using SPSS statistical software. Descriptive statistics were generated for each variable; a Spearman's correlation analysis was completed for all acoustic and emotional variables; and a series of single sample t-tests were completed, comparing averaged reported tranquillity levels and predicted tranquillity values for each sound file.

Chapter 3. Results

3.1 Scoping Study

3.1.1 Sound Recordings

In total, 65 sound measurements and recordings were taken on-site at Franz Josef Glacier. Although there seem to be no international standards in relation to acceptable levels of environmental noise in outdoor parklands and conservation areas, the recommendation from WHO is to keep ambient noise down to a level where the signal to noise ratio is 'low'(WHO, 1999). However, a 'low' signal to noise ratio is yet to be defined, and the context of the specific sounds and their environment must be taken into consideration.

The sound recordings and measurements taken on-site included a wide range of acoustic characteristics, with the aim of representing the environment and its dynamic soundscape as truthfully as possible. Sound pressure levels measured on-site ranged from a minimum of 48 dBA, to a maximum of 74 dBA; with LAeq measurements ranging between 49 to 71 dBA. The range of sound files and their acoustic characteristics can be found in Table 1.

Table 1: The range of all 65 sound measurements/recordings from Franz Josef Glacier.

65 sound files	LA_{eq} (dB)	$LAF_{max(dB)}$	$LAF_{min(dB)}$	$LAF_{10(dB)}$	$LAF_{50(dB)}$	$LAF_{90(dB)}$
Maximum	48.98	49.76	48.05	49.34	49.0	48.6
Minimum	70.94	74.37	67.33	72.94	70.51	68.92

Sound files were reduced from the original 65 files down to 11, as displayed in Table 2. The final 11 sound recordings that were chosen for use in the scoping study included 2 baseline recordings without any helicopter sounds, and 9 recordings with various levels of helicopter noise. Environmental background noise was set at two levels, based on the recording location of each sound file (Figure 1, site A or B) and its proximity to running water.

Predicted tranquillity using the TRAPT equation (and original LA_{eq}) returned results with a median predicted tranquillity of 5.43, a standard deviation of 1.128, and a range of 3. Predicted tranquillity using SPLs adjusted for the effects of background noise gave a median value of 5.57,and a standard deviation of 1.497, with a range of 4. Finally, predicted tranquillity obtained using the TRAPT equation with adjusted SPLs and a value of 26dBA for sound files where only natural noises were present , returned results with a range of 7, and a median predicted tranquillity of 5.57 with a standard deviation of 2.270. These results can be compared to the average reported tranquillities that are displayed inTable 4, with a median value of 5.14, a standard deviation of 2.84, and a range of 7.21.

Table 2: Detailed summary of 11 sound files used in the scoping study, their acoustic characteristics and their predicted tranquillities

Note: 'original values' are those measured on site, and 'corrected' dBA refers to sound levels with the effects of background noise removed

Sound File ID	LA_{eq} (dB)	LAF_{max} (dB)	LAF_{min} (dB)	LAF_{10} (dB)	LAF_{50} (dB)	LAF_{90} (dB)	Predicted TR (using original LA_{eq} values)	Environmental background noise level (dBA)	dB SPL values corrected for background noise levels	Predicted tranquillity using corrected dBA values	Predicted tranquillity using corrected dBAs, and a value of 26dB for sound files with only natural sounds present
M017	50.8	51.6	50.0	51.2	50.8	50.4	6.4	49.7	43.1	7.5	10.0
M025	52.4	53.7	51.5	53.0	52.3	51.9	6.1	49.7	48.7	6.7	6.7
M027	55.0	58.3	52.5	57.1	54.1	53.0	5.8	49.7	53.4	6.0	6.0
M035	70.9	74.4	67.3	72.9	70.5	68.9	3.4	49.7	70.9	3.4	3.4
M050	57.2	60.5	53.0	59.5	56.7	54.4	5.4	49.7	56.3	5.6	5.6
M058	66.7	68.2	63.0	67.6	66.7	65.5	4.0	49.7	66.6	4.1	4.0
M060	52.2	54.4	50.7	53.4	51.8	51.1	6.2	49.7	48.3	6.7	6.7
M066	64.6	66.1	62.5	65.5	64.6	63.2	4.4	49.7	64.4	4.4	4.4
M073	49.0	49.8	48.1	49.3	49.0	48.6	6.6	48.1	41.8	7.7	10.0
M078	59.6	62.0	56.1	61.3	59.2	57.5	5.1	48.1	59.3	5.1	5.1
M079	68.3	70.3	66.2	69.4	68.3	67.0	3.8	48.1	68.3	3.8	3.8

3.1.2 Images

Images are displayed in Appendix 6. Table 3 shows the median reported preference values for each image, the standard deviations, and the percentage of NCF within each image. Due to the small number of participants in the scoping study, and the number of images shown to them, there was not enough statistical power to accurately, quantitatively analyse the relationships between the different images, their percentages of NCF, and the reported preference values. By looking at the data qualitatively, a few trends can be identified. The total range of median preference responses was 4, with higher values associated with images containing more greenery and water, and lower preference values associated with a more rugged, stony type of environment. Percentage of NCF did not seem to be a strong indicator of preference.

Table 3: Subjective responses to 8 images from Franz Josef Glacier (Appendix 6).

Median and standard deviation of reported preference values, and the percentages of NCF for each image.

	Image A	Image B	Image C	Image D	Image E	Image F	Image G	Image H
MEDIAN	9.00	8.00	8.00	6.00	7.00	7.00	7.00	9.00
STANDARD DEVIATION	.81650	.75593	1.39728	1.70434	1.46385	1.21499	1.51186	1.49603
Percentage of NCF (%)	91.45	93.05	90.13	84.7	94.87	95.7	86.22	100

3.1.3 Subjective testing

As stated above, there was not enough statistical power to be able to draw valid conclusions from the subjective testing section of the scoping study. Data needs to be looked at qualitatively, rather than quantitatively. Reported values (Median ± standard deviation) were 5.14±2.843 for tranquillity, 4.29±1.580 for wildness, 4.07±2.635 for naturalness, and 5.07±2.355 for remoteness. Pleasantness had reported values of 2.93±.664, whereas calmness returned values of 2.21±.713, and control gave values of 3.07±.729 (responses can be seen in Table 4). Although there was not enough statistical power, a correlation analysis demonstrated potentially strong correlations between all reported variables, all of which had p-values of 0.00 (Table 5). Negative correlations were shown for both calmness and control; however, this is likely due to systematic errors involved in the planning and distribution of the reporting sheet. This data was not used to draw conclusions on the research topic, but was rather used to guide testing and analysis techniques used in the pilot study.

Figure 3 and Figure 4 show the relationships between LA_{eq}, predicted tranquillity, and reported tranquillity for both measured sound levels and adjusted sound levels. Although for both predicted and reported tranquillity, LA_{eq} is a strong indicator of tranquillity, there is a much steeper relationship between LA_{eq} and reported tranquillity than there is for LA_{eq} and predicted tranquillity.

Sound file ID	tranquillity	wildness	naturalness	remoteness	pleasantness	calmness	control
M017	8.5	5.93	8.07	7.71	3.86	1.36	2
M025	7.71	5.64	6.64	7.07	3.21	1.93	2.29
M027	5.86	4.29	4.64	5.21	2.79	2.07	2.36
M035	1.29	2.07	0.93	1.43	1.93	3.21	3.75
M050	5.14	4.79	4.07	5.07	2.93	2.21	3.17
M058	2.21	2.57	2.36	3.29	2.21	3.21	3.5
M060	8	6.29	7.75	7.43	3.64	1.71	2.14
M066	2.21	2.86	2.5	2.29	2.43	2.79	3.36
M073	7.86	6.14	7.64	7.43	3.71	1.86	2
M078	4.14	3.93	3.93	3.93	3.14	3	3.07
M079	1.36	2.64	1.36	2.14	2.21	3.43	3.93

Table 4: Average reported tranquillity, wildness, naturalness, remoteness, pleasantness, calmness, and control ratings for 11 sound files used in the scoping study.

Table 5: Correlations between reported tranquillity, wildness, naturalness, remoteness, pleasantness, calmness, and control, for 11 sound files used in scoping study.

Correlations

		Tranquillity	Wildness	Naturalness	Remoteness	Pleasantness	Calmness	Control
Tranquillity	Pearson Correlation	1						
	Sig. (2-tailed)							
Wildness	Pearson Correlation	.982**	1					
	Sig. (2-tailed)	.000						
Naturalness	Pearson Correlation	.986**	.977**	1				
	Sig. (2-tailed)	.000	.000					
Remoteness	Pearson Correlation	.990**	.980**	.985**	1			
	Sig. (2-tailed)	.000	.000	.000				
Pleasantness	Pearson Correlation	.943**	.959**	.967**	.938**	1		
	Sig. (2-tailed)	.000	.000	.000	.000			
Calmness	Pearson Correlation	-.958**	-.929**	-.938**	-.936**	-.878**	1	
	Sig. (2-tailed)	.000	.000	.000	.000	.000		
Control	Pearson Correlation	-.971**	-.928**	-.967**	-.951**	-.908**	.941**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	

**. Correlation is significant at the 0.01 level (2-tailed).

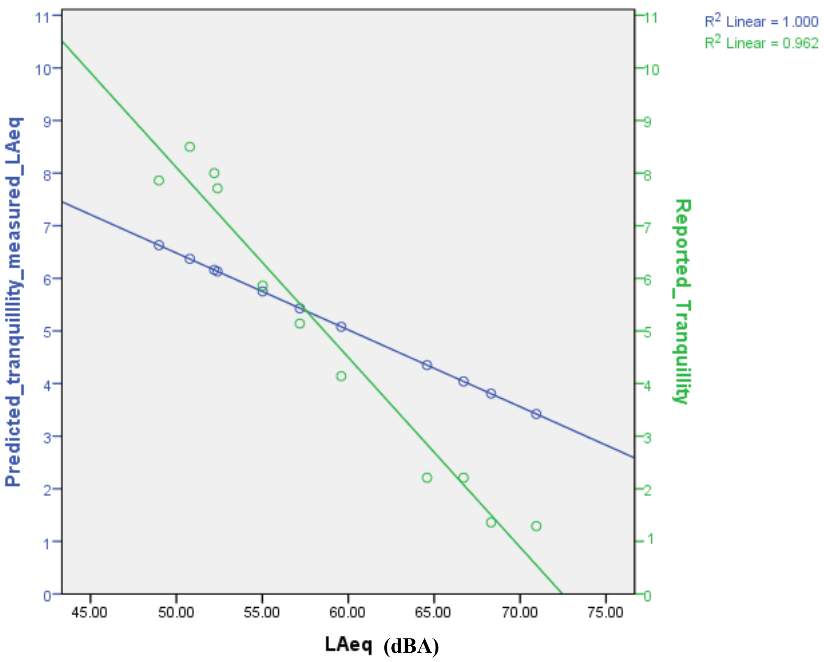


Figure 3: Graph depicting the relationships between measured LA_{eq}, predicted tranquillity and averaged reported tranquillity for 11 sound files.

Note: Predicted tranquillity in this graph was calculated with the TRAPT equation, using measured LA_{eq} values.

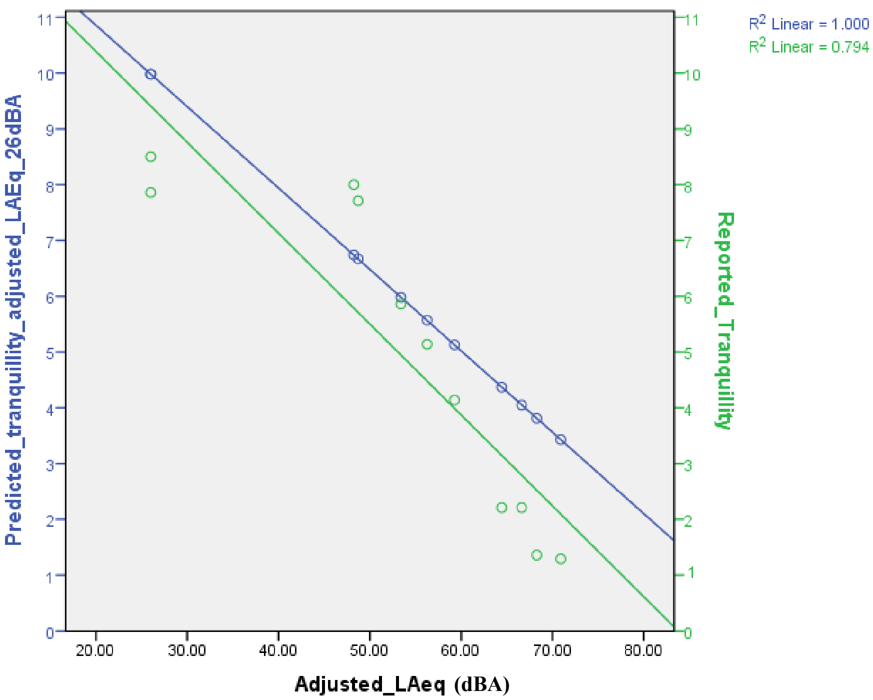


Figure 4: Graph depicting the relationships between adjusted LA_{eq} levels, predicted tranquillity and averaged reported tranquillity for 11 sound files.

Note: Predicted tranquillity in this graph was calculated with the TRAPT equation, using adjusted LA_{eq} levels to remove the effects of background noise, and using a set LA_{eq} value of 26 dBA for sound files where only natural sounds were present.

3.2 Pilot Study

3.2.1 Subjects

Subjects were chosen to represent the New Zealand population as closely as possible; covering a wide range of ages, an almost equal representation of males and females, and covering a range of ethnicities (Table 6: Pilot study subject pool characteristic). Subjects did not strictly represent the New Zealand population based on the 2013 census data, as it was difficult to meet percentages exactly, and the selection pool was limited by the amount and types of people who volunteered to participate in the study. Subjects had a large age range spanning from 23 to 71 years of age; with males representing 53% of the subjects, whilst females represented 47% of the total pool. The largest represented ethnic group was European (71.88%), followed by Maori (12.5%), Pacific Islander (9.37%), and then Asian (6.25%).

Table 6: Pilot study subject pool characteristics

	32 Subjects					
Age	Age	18-25 years	26-40 years	41-60 years	60+ years	
	Number of participants	4	10	9	9	
Sex	Sex	Male		Female		
	Number of participants	17		15		
Ethnicity	Ethnicities	European	Maori	Pacific Islander	Asian	Other
	Number of participants	23	4	3	2	0

3.2.2: 20 chosen sound files

The 20 sound files (Table 2) used in the pilot study were selected from the group of 65 original sound recordings, taken in the scoping study (Table 1). The 20 selected sound files had an LA_{eq} range of 21.96 dBA, with a median of 61.55 and a standard deviation of 7.01 (

Table 7). Predicted tranquillity using the TRAPT equation and measured LA_{eq} values returned a series of predicted tranquillities with a range of 3.21, a median of 4.79, and a standard deviation of 1.02. This can be compared to predicted tranquillities obtained using the TRAPT equation with SPLs adjusted for the effects of background noise, which gave a median value of 4.80, a standard deviation of 1.19, and a range of 4.27. Finally, predicted tranquillity obtained using the TRAPT equation with adjusted SPLs and a value of 26dBA for sound files where only natural noises were present, returned results with a range of 6.56, and a median predicted tranquillity of 4.80, with a standard deviation of 1.83. These results can be compared to the average reported tranquillities that are displayed inTable 8, with a median value of 3.71, a standard deviation of 2.83, and a range of 8.10.

Table 7: 20 sound files used in the pilot study, their acoustic characteristics, and predicted tranquillities.

Note: 'original values' are those measured on site, and 'corrected' dBA refers to sound levels with the effects of background noise removed.

Sound file ID	LA_{eq} (dBA)	LAF Max (dBA)	LAF Min (dBA)	LAF10 (dBA)	LAF50 (dBA)	LAF90 (dBA)	Predicted TR (using original LA_{eq} values)	Environmental background noise level (dBA)	dB SPL values corrected for background noise levels	Predicted TR using corrected dB SPL values	Predicted TR using corrected SPLs, and a value of 26dB for sound files with only natural sounds present	Signal to noise ratio using background noise levels and adjusted LA_{eq}
M017	50.78	51.56	49.96	51.15	50.76	50.43	6.37	49.69	50.78	6.37	9.98	N/A
M025	52.39	53.68	51.51	52.98	52.33	51.88	6.13	49.69	52.39	6.13	6.13	0.95:1
M027	55.02	58.27	52.46	57.09	54.12	53.01	5.75	49.69	55.02	5.75	5.75	0.9:1
M035	70.94	74.37	67.33	72.94	70.51	68.92	3.42	49.69	70.94	3.42	3.42	0.7:1
M041	50.44	51.21	49.72	50.8	50.45	50.07	6.42	49.69	50.44	6.42	6.42	0.99:1
M043	64.14	67.05	60.51	65.81	64.08	61.28	4.42	49.69	64.14	4.42	4.42	0.77:1
M044	62.15	66.06	59.18	64.53	61.6	59.96	4.71	49.69	62.15	4.71	4.71	0.8:1
M050	57.18	60.52	53.02	59.5	56.68	54.37	5.43	49.69	57.18	5.43	5.43	0.87:1
M058	66.71	68.17	62.95	67.61	66.71	65.49	4.04	49.69	66.71	4.04	4.04	0.74:1
M059	60.94	65.16	57.31	63.24	60.42	58.21	4.88	49.69	60.94	4.88	4.88	0.82:1
M060	52.2	54.39	50.74	53.37	51.83	51.1	6.16	49.69	52.20	6.16	6.16	0.95:1
M063	65.45	70.02	59.75	67.81	64.82	61.61	4.22	49.69	65.45	4.22	4.22	0.76:1
M064	67.88	71.33	61.25	70.57	67.35	62.81	3.87	49.69	67.88	3.87	3.87	0.73:1
M066	64.58	66.1	62.52	65.52	64.61	63.18	4.35	49.69	64.58	4.35	4.35	0.77:1
M068	62.68	65.92	58.85	64.52	62.29	60.42	4.63	49.69	62.68	4.63	4.63	0.79:1
M070	49.77	51.58	48.08	50.67	49.97	48.54	6.51	48.05	44.85	7.23	7.23	1.07:1
M071	62.27	65.09	59.15	63.72	62.07	60.52	4.69	48.05	62.10	4.71	4.71	0.77:1
M073	48.98	49.76	48.05	49.34	49	48.6	6.63	48.05	41.70	7.69	9.98	N/A
M078	59.59	62	56.14	61.28	59.2	57.48	5.08	48.05	59.27	5.13	5.13	0.81:1
M079	68.31	70.28	66.16	69.43	68.28	66.99	3.81	48.05	68.27	3.81	3.81	0.7:1

3.2.3 Subjective testing

The averaged subjective responses are shown in Table 8; displaying average reported tranquillity, naturalness, remoteness, pleasantness, and calmness for each sound file.

Single sample t-tests were completed for each sound file, comparing predicted tranquillity values with averaged tranquillity ratings for each participant, as shown in Table 9. Using a conservative significance level of 0.001, there were significant differences between the predicted tranquillity and the reported tranquillity for 16 of the 20 sound files. Sound files M027 (p value .673), M044 (p value 0.002), M059 (p value .634), and M070 (p value .330) were the only recordings that were found to have no significant differences between the predicted tranquillities obtained using the TRAPT equation (using adjusted sound levels and a value of 26dB for natural sounds), and the reported tranquillities from the New Zealand population. This data is prone to bias, as not all data had normal distributions, and analysis through multiple t-tests increases the chance of type 1 (α) errors.

A spearman's correlation analysis (

Table 10) show significant correlations between all of the variables. Positive correlations are shown when comparing subjective, reported variables; this is also the case when comparing objective, acoustic variables. Negative correlations are shown when comparing subjective and objective values together (i.e. predicted tranquillity and LA_{eq} have a negative correlation of -.993).

Table 8: Pilot study, averaged subjective responses to 20 sound recordings based on tranquillity, naturalness, remoteness, pleasantness, and calmness.

Note: predicted tranquillity was obtained using the TRAPT equation with 'corrected' dBA refers or a set value of 26dBA for sound recordings with only natural sounds present.

Sound File	Predicted Tranquillity	Reported tranquillity	Reported naturalness	Reported remoteness	Reported pleasantness	Reported Calmness
M017	10	8.94	8.94	8.59	4.57	4.59
M025	6.1	8.48	8.63	8.23	4.45	4.55
M027	5.7	5.85	5.02	5.3	3.48	3.69
M035	3.4	0.98	0.94	1.29	1.69	2.04
M041	6.4	7.89	7.81	7.77	4.36	4.36
M043	4.4	2.52	1.92	2.49	2.26	2.7
M044	4.7	3.55	3.13	3.51	2.79	3.01
M050	5.4	4.07	3.45	3.95	2.78	3.13
M058	4	1.45	1.28	1.7	1.91	2.32
M059	4.9	4.73	4.38	4.62	3.23	3.47
M060	6.2	8.26	8.3	8.05	4.33	4.45
M063	4.2	2.31	2	2.29	2.21	2.49
M064	3.9	1.45	1.28	1.55	1.81	2.27
M066	4.4	2.82	2.38	2.74	2.55	2.8
M068	4.6	3.39	2.77	3.07	2.72	3
M070	7.2	7.55	7.22	7.19	4.15	4.2
M071	4.7	2.98	2.38	2.88	2.56	2.83
M073	10	9.09	9.14	8.8	4.73	4.71
M078	5.1	3.88	3.14	3.58	2.77	3.18
M079	3.8	1.18	1.05	1.38	1.86	2.23

Table 9: Single sample t-test summaries for each sound file, comparing predicted tranquillities with the averaged reported tranquillities for participants.

Note: Test values were obtained using the TRAPT equation with corrected dBA values, and a value of 26dBA for sound recordings with only natural sounds present.

Sound File						95% Confidence Interval of the Difference	
	Test Value	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
TR_REPORT_17	10	-5.708	31	.000	-1.0625	-1.442	-.683
TR_REPORT_25	6.1	9.700	31	.000	2.3766	1.877	2.876
TR_REPORT_27	5.7	.426	31	.673	.1516	-.574	.877
TR_REPORT_35	3.4	-11.706	31	.000	-2.4156	-2.836	-1.995
TR_REPORT_41	6.4	4.510	31	.000	1.4906	.817	2.165
TR_REPORT_43	4.4	-7.245	31	.000	-1.8766	-2.405	-1.348
TR_REPORT_44	4.7	-3.444	31	.002	-1.1531	-1.836	-.470
TR_REPORT_50	5.4	-4.128	31	.000	-1.3297	-1.987	-.673
TR_REPORT_58	4.0	-9.575	31	.000	-2.5469	-3.089	-2.004
TR_REPORT_59	4.9	-.480	31	.634	-.1656	-.869	.538
TR_REPORT_60	6.2	7.997	31	.000	2.0578	1.533	2.583
TR_REPORT_63	4.2	-6.590	31	.000	-1.8875	-2.472	-1.303
TR_REPORT_64	3.9	-8.978	31	.000	-2.4469	-3.003	-1.891
TR_REPORT_66	4.4	-4.975	31	.000	-1.5797	-2.227	-.932
TR_REPORT_68	4.6	-3.911	31	.000	-1.2094	-1.840	-.579
TR_REPORT_70	7.2	.990	31	.330	.3469	-.367	1.061
TR_REPORT_71	4.7	-5.522	31	.000	-1.7156	-2.349	-1.082
TR_REPORT_73	10	-5.533	31	.000	-.9141	-1.251	-.577
TR_REPORT_78	5.1	-4.248	31	.000	-1.2250	-1.813	-.637
TR_REPORT_79	3.8	-10.697	31	.000	-2.6203	-3.120	-2.121

Table 10: Spearman's correlation analysis of all acoustic and reported variables.

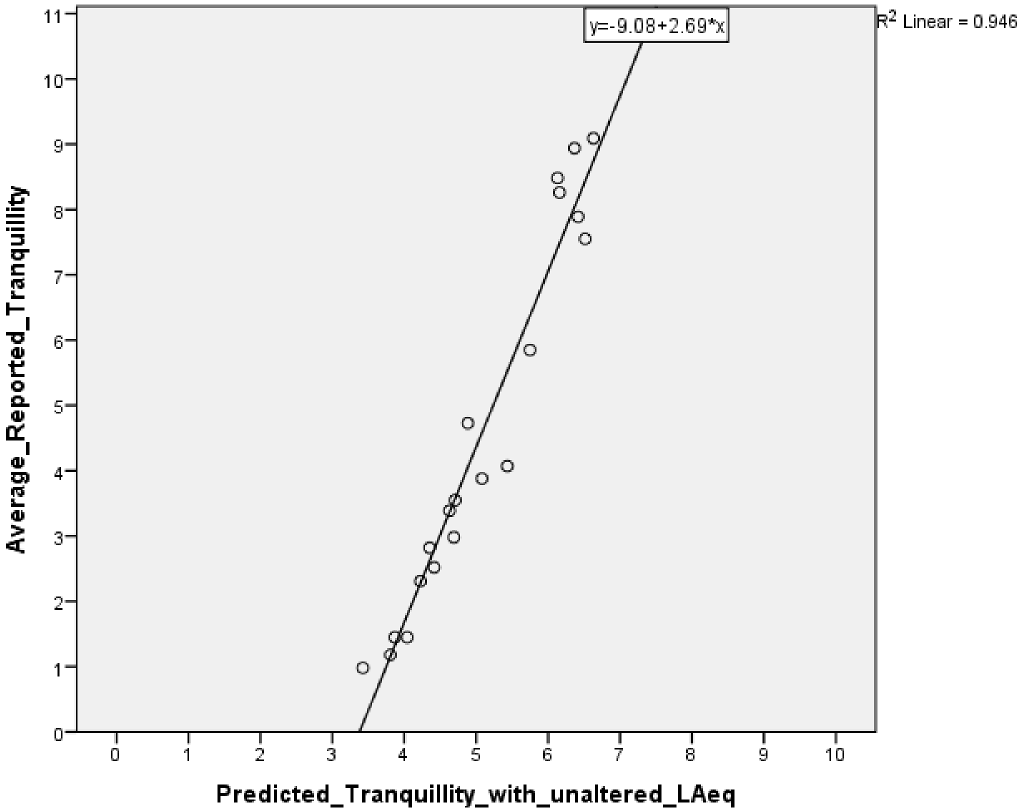
Note: 'original values' are those measured on site, and 'corrected' dBA refers to sound levels with the effects of background noise removed

Correlations															
Spearman's rho		LAeq	LAFmin	LAFmax	LA10	LA50	LA90	Predicted tranquillity (adjusted &26LA_{eq})	Predicted tranquillity (adjusted LAeq)	Predicted tranquillity (measured LA_{eq})	Reported tranquillity	Reported naturalness	Reported remoteness	Reported pleasantness	Reported calmness
LAeq	Correlation Coefficient	1.000													
	Sig. (2-tailed)	.													
LAFmin	Correlation Coefficient	.984**	1.000												
	Sig. (2-tailed)	.000	.												
LAFmax	Correlation Coefficient	.981**	.961**	1.000											
	Sig. (2-tailed)	.000	.000	.											
LA10	Correlation Coefficient	.991**	.971**	.995**	1.000										
	Sig. (2-tailed)	.000	.000	.000	.										
LA50	Correlation Coefficient	1.000**	.984**	.981**	.991**	1.000									
	Sig. (2-tailed)	.	.000	.000	.000	.									
LA90	Correlation Coefficient	.989**	.995**	.956**	.971**	.989**	1.000								
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.								
Predicted tranquillity (adjusted & 26LA_{eq})	Correlation Coefficient	-.993**	-.977**	-.982**	-.988**	-.993**	-.979**	1.000							
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.							
Predicted tranquillity (adjusted LA_{eq})	Correlation Coefficient	-.998**	-.984**	-.986**	-.994**	-.998**	-.986**	.993**	1.000						
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.						
Predicted tranquillity (measured LA_{eq})	Correlation Coefficient	-1.000**	-.984**	-.981**	-.991**	-1.000**	-.989**	.993**	.998**	1.000					
	Sig. (2-tailed)	.	.000	.000	.000	.	.000	.000	.000	.					
Reported tranquillity	Correlation Coefficient	-.967**	-.952**	-.956**	-.962**	-.967**	-.952**	.977**	.964**	.967**	1.000				
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.				
Reported naturalness	Correlation Coefficient	-.962**	-.951**	-.951**	-.957**	-.962**	-.948**	.973**	.958**	.962**	.998**	1.000			
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.			
Reported remoteness	Correlation Coefficient	-.967**	-.950**	-.958**	-.964**	-.967**	-.950**	.977**	.964**	.967**	1.000**	.998**	1.000		
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.		
Reported pleasantness	Correlation Coefficient	-.961**	-.937**	-.950**	-.958**	-.961**	-.941**	.968**	.955**	.961**	.991**	.989**	.992**	1.000	
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.	
Reported calmness	Correlation Coefficient	-.965**	-.949**	-.956**	-.962**	-.965**	-.949**	.976**	.962**	.965**	.998**	.996**	.998**	.991**	1.000
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.

**. Correlation is significant at the 0.01 level (2-tailed).

A series of four scatter graphs show the relationship between average reported tranquillity for each sound file and (A) predicted tranquillity using the TRAPT equation with unaltered LA_{eq} values; (B) predicted tranquillity using the TRAPT equation with adjusted LA_{eq} values to remove the effects of background noise levels; and (C) Predicted tranquillity using adjusted LA_{eq} values to remove the effects of background noise, as well as a set LA_{eq} value of 26 dBA for sound files where only natural sounds are present. Averaged reported (D) tranquillity was plotted against itself, created for comparison purposes only.

Figure 6 and Figure 7 depict the relationships between LA_{eq}, reported tranquillity, and predicted tranquillity for the 20 sound files used in the pilot study. As demonstrated in the scoping study, both predicted and reported tranquillity are affected by LA_{eq}; however, reported tranquillity has a steeper relationship than predicted tranquillity. This is the case for both measured LA_{eq} and adjusted LA_{eq}. Data can be extrapolating from these graphs. By using measured LA_{eq} values, it can be shown that in order to obtain a predicted tranquillity of 10, a value of 26 dBA or lower is required, while a much higher value of 46 dBA is the maximum sound level required to achieve a reported tranquillity of 10. Using adjusted sound levels, a level of 26 dBA or less is required to achieve a predicted tranquillity of 10, and a reported tranquillity can be obtained with a value of approximately 30 dBA or less. To obtain a. ‘excellent’ reported tranquillity rating of 8 or higher, helicopter sound pressure levels need to be below approximately 40 dBA for helicopter noise, or 51 dBA for overall sound levels.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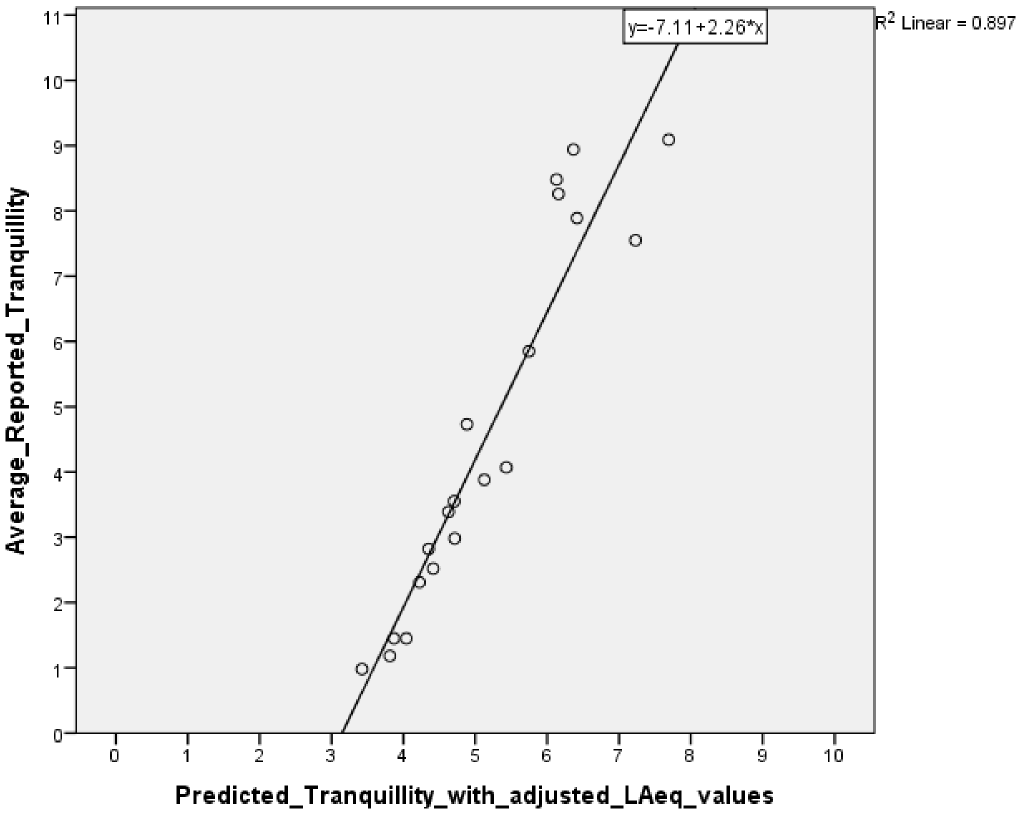
Predicted_Tranquillity_with_unaltered_LAeq

A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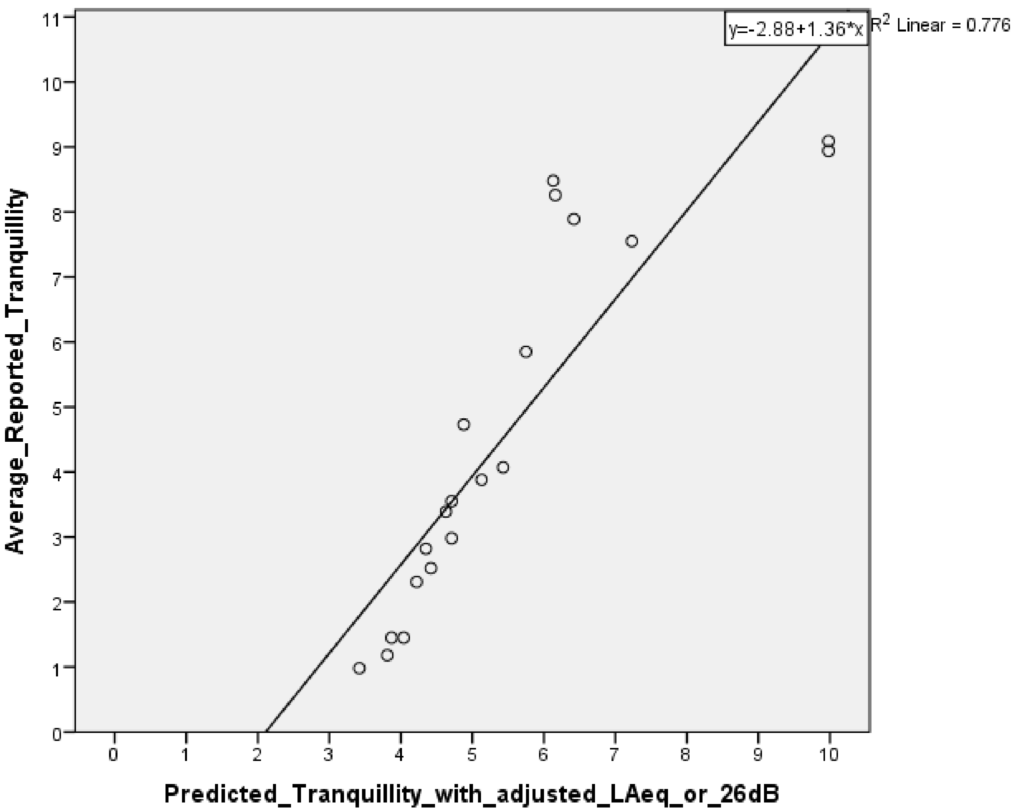
B



C

Figure 5: Three graphs depicting the relationships between reported tranquillity and (A) predicted tranquillity using the TRAPT equation with unaltered LA_{eq} values, (B) predicted tranquillity using the TRAPT equation with adjusted LA_{eq} values to remove the effects of background noise levels, and (C) Predicted tranquillity using adjusted LA_{eq} values to remove the effects of background noise, as well as a set LA_{eq} value of 26 dBA for sound files where only natural sounds are present.

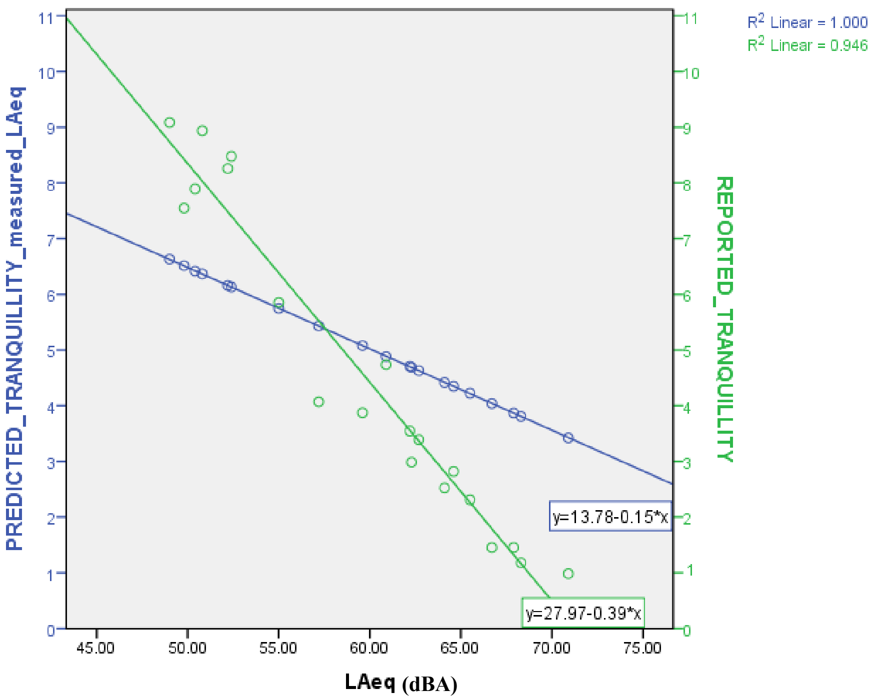


Figure 6: Graph depicting the relationships between measured LA_{eq}, predicted tranquillity (using measured LA_{eq} values in the equation) and averaged reported tranquillity for 20 sound files.

Note: Predicted tranquillity in this graph was calculated with the TRAPT equation, using Measuired LA_{eq} values.

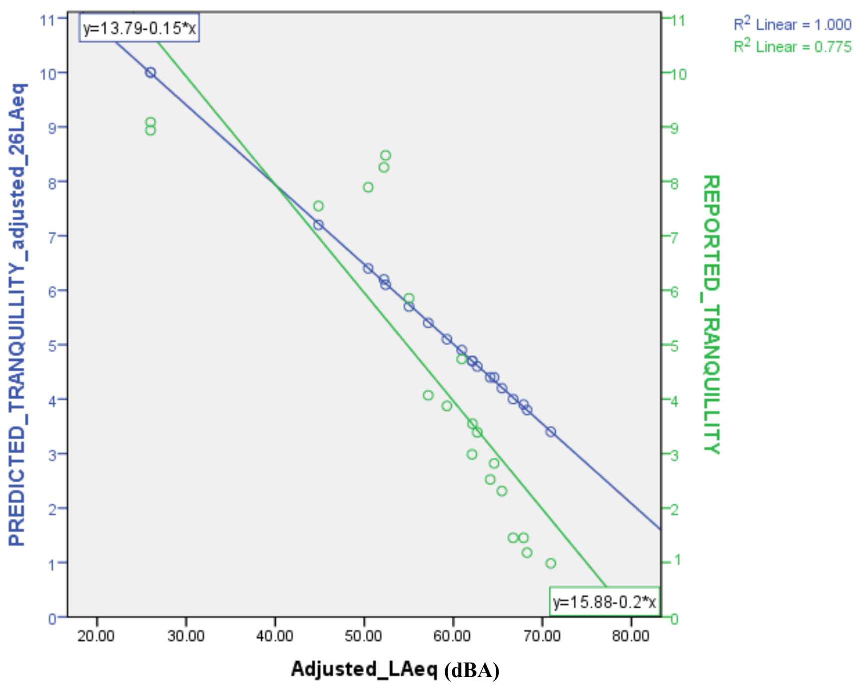


Figure 7 Graph depicting the relationships between adjusted LA_{eq} levels, predicted tranquillity and averaged reported tranquillity for 20 sound files.

Note: Predicted tranquillity in this graph was calculated with the TRAPT equation, using adjusted LA_{eq} levels to remove the effects of background noise, and using a set LA_{eq} value of 26 dBA for sound files where only natural sounds were present.

Chapter 4. Discussion

4.1 Overview

This study aimed to review methods of Subjective tranquillity testing in a New Zealand context. Following that, research was conducted to quantify the extent of the disturbance of helicopter noise on the levels of perceived tranquillity for the New Zealand population. This was then related to predicted tranquillity levels obtained using the TRAPT equation, in order to evaluate the equation's effectiveness in a New Zealand context.

As expected, this study shows that sound level is a significant predictor of tranquillity; as sound levels increase, predicted and reported tranquillity levels decrease. However, the New Zealand population's responses are in most cases, significantly different to the predicted tranquillity levels obtained through the use of the TRAPT equation. Despite initial predictions, this study indicates that the New Zealand population does not respond to noise in the same way as the British population. However, the TRAPT predictions used here were based on responses from UK urban park visitors that would have been adapted to higher noise levels than experienced in a national park. A further analysis is required that uses data collected from a study of tranquillity in UK National Parks (Watts and Pheasant, 2015). Therefore it goes to say that because the TRAPT equation was designed for use with the British population in urban parks, in its current state, it cannot accurately predict how the New Zealand population may be affected by helicopter noise.

This study is designed to emulate a previous study by G. R. Watts and Pheasant (2015). This data needs to be considered in the context of a relatively small, subjective response study with subjects that were often highly educated.

4.2 Environmental noise

Although there are standards that recommend maximum acceptable environmental noise levels in certain environments, there are no specific standards for natural environments such as conservation areas. The only recommendation that is specific to those types of areas was suggested by WHO over 15 years ago (WHO, 1999). Even then, the recommendation to keep the signal to noise ratio low is vague. In this research, signal is classified as background environmental noise, as measured at the recording location; whereas noise is considered to be any sounds above that level. Along the Franz Josef glacier valley walking track, background noise is constant, and relatively high due to the amount of running water in the area. This poses a dilemma for the TRAPT equation, as not only does background noise affect the overall sound levels used in the equation, but it also affects how the environment is perceived by the individual. For sound recordings containing helicopter noise, the most favourable signal to noise ratio that was measured and played to participants was 1.07:1 in favour of natural sound, whereas the least favourable signal to noise ratio that was measured was 0.7:1 in favour of helicopter noise. Out of the twenty sound recordings that were played to the subjects, two recordings contained only natural sounds. Each of the remaining 18 sound files contained helicopter noise, 17 of which had signal to noise ratios where the helicopter noises outweighed the levels of natural environmental sounds.

Consequently, it can be stated that when helicopters are flying over a conservation area, it is considerably difficult to maintain a ‘low’ signal to noise ratio where background natural sounds are relatively low. Therefore ideally, helicopters should not be flown over areas that are of natural importance like conservation areas or national parks.

This is an interesting result, particularly as these recordings have been taken in a location where natural environmental noise is relatively loud. If these recordings were taken in a location that did not have such high levels of background noise, a positive signal to noise ratios would be even less achievable.

These results indicate that a low signal to noise ratio is almost unattainable when helicopters are flying over national parks. This raises the question: is signal to noise ratio the best way to determine how much noise is too much in national parks? The use of more specific guidelines or possibly a cut-off point where noise is considered too loud could be investigated. The concept of looking solely at sound levels or signal to noise ratio is problematic, as context needs to be taken into consideration, rather than just a fraction of the environment such as sound. The TRAPT equation does look at various aspects of the environment, including sound and visual components, and could therefore be a more suitable alternative.

4.2.1 Sound measurements

In total, 65 sound recordings/measurements were taken on site at the Franz Josef Glacier Valley in the Westland National Park. Sound recording opportunities were restricted, due to the limited amount of flights running on the recording date, and also due to noise interference caused by national park visitors. The recordings that were collected on the date were largely unsuitable for use for testing purposes, chiefly due to undesired sounds that were present in the recordings such as talking, footsteps, and clicks. Out of the original 65 sound recordings, only 24 were deemed to be suitable for testing. To truthfully represent the environment and the variety of sounds that were observed, 20 sound files were chosen to best display the range of recorded sounds, based on their sound quality and their LA_{eq} values. With an LA_{eq} range of 21.96 dBA, the twenty selected sound files represented the whole range of average sound levels that were observed on site. Sound files that were chosen for the testing set included some recordings with only natural sounds, others with helicopters at various distances and SPLs, and even a few recordings that contained multiple helicopters. It cannot be stated that this sample represents all of the noise conditions that may occur in the specified environment; however, it can be stated that the sample does represent the sound conditions that were present while the recording session was taking place.

4.3 Scoping Study

The scoping study was completed with the aim of establishing and refining testing techniques that would later be used in the pilot study. As expected, this process resulted in a number of changes to the pilot study methodology, with the intention of increasing ease and accuracy of data collection. In an attempt to prevent unnecessary wastage of resources, time, and willing participants, subject numbers were narrowed down to seven people for the scoping study. A smaller cohort was deemed to be acceptable, as the scoping study was designed to evaluate methods, and not to draw conclusions from data. Due to this small sample size, data collected from the scoping study lacks statistical power, and therefore, reliable conclusions cannot be drawn from that data.

4.3.1 Instructions

Instructions were given to participants before testing commenced. However, some of the terminology was somewhat vague, and subjects each had their own interpretations of specific scales. For example, hearing a helicopter made some people feel less remote, as it was obvious that people were flying nearby; whilst others felt that helicopter noise made the area seem more remote, because you have to take a flight to get there. Differences in understanding can lead to different reported results. As a result, it was found that when instructing subjects for the pilot study, terms needed to be explained more specifically and consistently for each individual and each scale.

4.3.2 Reporting

In the Scoping study, multiple areas for improvement were identified, including inadequacies with the reporting process. For instance, reporting sheets were printed two to a page, on double sided paper. This printing option was not ideal for testing, as it increased confusion, and may have led to results being plotted on incorrect pages. One page was designated for each sound file containing seven reporting scales representing tranquillity, wildness, naturalness, remoteness, pleasantness, calmness, and control. Some subjects found reporting somewhat difficult due to confusion with some of the terminology, as well as the limited time frames to respond to recordings and report their feelings. Adjustments were made for the pilot study, including single sided printing with one page per sheet, increased reporting times, and reduced numbers of reporting scales. After referring to the literature, previous research had found that control and wildness were not essential for the study; therefore their scales were removed from the reporting sheets used in the pilot study. After noticing that directionality of some scales may have been confusing, reporting sheets for the scoping study were designed for consistency, with negative responses down one end of the page, and positive responses on the other end of the page. New headphones were also sourced to improve participant comfort whilst testing. No practice runs were completed by subjects in the scoping study, which in turn resulted in mistakes and confusion. This was changed for the pilot study, with a short practice set for each participant before recorded testing commenced.

4.3.3 Analysis

Data collected during the scoping study did not have enough statistical power to produce any solid conclusions through statistical analysis. Data needs to be looked at qualitatively, and can be used to give an indication as to the types of relationships or trends that a full set of data might follow.

4.3.3.1 Predicted Tranquillity

Performing the TRAPT equation with the measured LA_{eq} values for the 10 chosen sound files used in the scoping study, returned a predicted tranquillity range of approximately 3.2. The range was wider using the adjusted LA_{eq} values, with a predicted tranquillity range of 4.25; and even more so when using the adjusted LA_{eq} values and a set value of 26 dBA for natural sounds to calculate the predicted tranquillity (with a range of 6.56). On average, predicted tranquillity values were higher when using the TRAPT equation with adjusted LA_{eq} values, when compared to using the equation with the measured LA_{eq} values. Using a set value of 26 dBA for sound files where only natural sounds were present, tranquillity ratings reached a level of 9.98. This was much higher than any of the predicted values obtained using the TRAPT equation with any of the sound levels that were observed on-site. A value of 26 dBA was used as it is the value that is necessary to achieve the best possible tranquillity rating of approximately 10; this has been used in previous studies.

4.3.3.2 Reported tranquillity and other emotional responses

Tranquillity was found to be highly dependent on LA_{eq}. However, reported tranquillity is much more notably affected by LA_{eq} than predicted tranquillity is, implying that the New Zealand population may have a shorter range of noise levels that they deem to be acceptable. However, it must be remembered that the TRAPT equation used was based on UK urban park visitors.

All variables seemed to be strongly related, as shown by the correlation analysis. However, due to the small sample size, these results cannot be considered reliable. There seem to be strong positive relationships between tranquillity, wildness, naturalness, pleasantness and remoteness. This is not the case for control or calmness; however, this is likely due to confusion created by the scales on the reporting sheets. When comparing reported variables with acoustic variables, trends show that the relationships are generally negative; meaning that with an increase in noise, perceived tranquillity, pleasantness, etcetera tend to decrease.

4.3.3.3 Images and Preference

Images were shown to participants at the end of the study, and the reported preference results were analysed. Although there were not enough samples or participants to be able to draw any strong conclusions from the data, it can be stated that there is little variability in averaged reported preference values. Average reported preference values have a range of 3, with lower preference values assigned to images with less water and greenery. Results are found to be much more dependent on visibility of greenery or water, rather than actual percentage of natural features. This result relates well to previous research, indicating that people tend to prefer environments that have either water or a lot of plant life. Only one image has 100% natural features, and contains both water and greenery (Appendix 6, image H). This image was therefore used for the Pilot study, in an attempt to be able to obtain an environment that is near 'perfect,' consequently focussing primarily on the effects of the noise levels, rather than imperfections in the visual environment.

4.4 Pilot Study

The pilot study was conducted to quantify the extent of the disturbance of helicopter noise on the levels of perceived tranquillity for the New Zealand population. This was then related to predict tranquillity levels obtained using the TRAPT equation, thus comparing tranquillity response trends for New Zealand respondents virtually embedded in a national park setting and British respondents visiting urban parks.

4.4.1 Subjects

Subjects that participated in the pilot study totalled to 32, with subjects representing a wide variety of ages ranging from 23 to 71 years of age. Care was taken to ensure that a variety of ethnicities were included in the sample study, with participants belonging to European, Maori, Pacific Islander, and Asian ethnicities. Sex was represented with a 53:47 percentage split in favour of males. This participant pool does not represent the New Zealand population in terms of exact percentages of age, ethnicity, or sex. It does, however give a fair representation of the diversity that is unique to the New Zealand population.

4.4.2 Results

4.4.2.1 Sound levels and tranquillity

Results indicate that there is a very strong relationship between sound levels and tranquillity, which is implicit with the use of the TRAPT equation. A spearman's correlation was used for analysis because the collected data does not all fit into a normal distribution, and there are some outliers present in the data. Outliers have not been removed from the data set, as responses are subjective, and each one is considered to be important.

The relationship between sound levels and predicted tranquillity has been well established in articles concerned with the TRAPT equation. Research has shown that there is a negative relationship between sound level and predicted tranquillity (G. R. Watts & Pheasant, 2013). This relationship is guaranteed by the very use of the TRAPT equation; as entering a higher sound level value into the equation will always result in a lower predicted tranquillity rating. Results from this study support these findings, indicating that when sound levels increase, predicted tranquillity levels consequently decrease. However, what sound measures should be used for the TRAPT calculations? All of the acoustical indices tested had very significant, negative correlations with reported tranquillity levels. Correlations range from, -.952 to -.967, with LA_{eq} and LAF50 having the highest correlations, both with a -.967 value. Although these two values are often similar, LA_{eq} was chosen for use in these equations. This was chosen, because LA_{eq} represents the average of the whole recording, rather than just the lesser half of it. Two sound level options that can be considered for use with the TRAPT equation are the LA_{eq} levels that were measured on site, and a series of adjusted LA_{eq} levels that remove the effects of background noise, focussing purely on man-made or 'extra' noise levels.

A correlation analysis showed that the relationship between averaged reported tranquillity and predicted tranquillity obtained using the TRAPT equation using measured LA_{eq} values is significant. This analysis showed a strong correlation coefficient of .967, a coefficient of determination (R^2) of .946, and a significance level of .000. This means that there is a very strong relationship between reported tranquillity and predicted tranquillity obtained using the measured LA_{eq} values; and most of the variance of reported tranquillity is accounted for in this model. Adjusted LA_{eq} values have a correlation that is only very slightly lower (.964), which is also deemed to be highly significant (sig. 0.000), However, the R^2 value (0.897) shows that this relationship is not the only thing that governs reported tranquillity levels, and that some variance from the linear model is not accounted for in this relationship. Finally, using the adjusted LA_{eq} values and a set value of 26 dBA for sound recordings where only natural sounds are present, a significant correlation coefficient of .977 is returned. This is the highest correlation that is produced by any of these three analyses; however, it also has the most unexplained variance from the mean, with an R^2 value of .776.

The Department of Conservation has suggested that they would prefer to be able to maintain an ‘excellent’ tranquillity level of 8 or higher in the national parks. To obtain this tranquillity level using just the TRAPT equation (with 100% NCF), noise levels need to be 39.5dBA or less. However, by extrapolating data from Figure 6 and Figure 7, it can be shown that by using the fit line, a reported tranquillity of 8 can be achieved for the New Zealand population with a measured sound level of approximately 51 dBA or less, or an adjusted (manmade) sound level of approximately 40dBA or less. However, these values should be viewed with some caution as background levels of natural sounds were relatively high leading to a wide range of responses at high levels of tranquillity. To obtain more prediction precision, recordings need to be taken additionally in environments with low background noise levels.

4.4.2.2 Reported and Predicted tranquillity

Using the results obtained in this study and comparing them to results from previous research by G. R. Watts and Pheasant (2015), the research aim to "determine the relationship between reported tranquillity values from the New Zealand population, and the corresponding predicted tranquillities obtained using the TRAPT equation for national park environments; thereby answering the question: does the New Zealand population respond to helicopter noise in the same way as the British population?" can be addressed.

Reported tranquillities have the highest correlation with predicted tranquillities obtained using TRAPT with adjusted sound levels and a set value of 26dBA for natural sound files. Because this is the case, this specific relationship is further analysed, and conclusions are being drawn from this analysis.

Using multiple single sample t-tests would not normally be advised for analysis of so many conditions or variables; usually an analysis of variance would be recommended. However, due to the fact that responses are being compared to a singular value (the predicted tranquillity), this is one of the only ways to achieve this comparison. Multiple t-tests assume that the data is normally distributed, and they also increase the risk of bias in the results. Therefore in this study, differences are considered significant at the ultra-conservative level of 0.001 (p-value), to reduce the risk of false positives (alpha errors). T-tests were completed comparing the predicted tranquillity values to average responses for each participant and each sound file. Out of the twenty sound files used in the pilot study, sixteen recordings have reported and predicted tranquillity values that were considered to be significantly different from each other. Out of the four recordings that had significantly similar reported and predicted tranquillity values, no particular trends could be identified to explain why these were similar, while the others were not. Considering that the TRAPT model predicts how British populations would respond to noise levels, and that the New Zealand reported tranquillities are in 80% of cases significantly different to their predicted values, it can be stated that the New Zealand population responds differently to how the British population would. Therefore, the TRAPT model in its current state does not accurately predict New Zealand responses to helicopter noise. However, there was a statistically significant correlation between predicted tranquillity and that reported that supports the use of TRAPT once it is successfully calibrated with a wider range of sounds and in different natural environments.

This is supported by the results of a correlation analysis, comparing the predicted and reported tranquillity levels for New Zealanders. Yes, the New Zealand population and the British populations both report lower levels of tranquillity with increased levels of noise. However, the correlation is steeper and more negative for New Zealanders, implying that levels of noise have a more pronounced impact on the New Zealand population, and their reported tranquillity. There is a smaller range of noises that the New Zealand population finds tranquil, and the cut off point for ‘tranquil noise’ is likely to be lower in New Zealand, rather than the UK.

In the British population, the relationship between reported tranquillity and predicted tranquillity gives a R^2 value of 0.779. This is similar to the variance of data collected from the New Zealand population (using TRAPT with adjusted sound levels and a set value of 26dBA), with an R^2 value of 0.776. This implies that for the New Zealand population, 77.6% of response variance is explained and accounted for in this model, leaving 22.4% of the variance in responses unexplained. Variance is natural and expected in all populations. It is interesting to see that even though both populations have similar amounts of variation, their average reported tranquillity levels are often different to a significant degree.

4.4.2.3 Other emotional responses

All subjective responses including tranquillity, naturalness, remoteness, pleasantness, and calmness had very strong, positive correlations with predicted tranquillity levels. The strongest correlations were observed for reported tranquillity and reported remoteness, both of which had correlation coefficients of .977. Results indicated that the lower the noise, the higher the tranquillity, calmness, naturalness, remoteness, and pleasantness. This was the expected result.

4.5 Implications

This data shows that although there are some similarities between the reported and predicted tranquillities obtained using the TRAPT equation, they are still significantly different. The TRAPT equation may be suitable for use with British people in UK urban parks; however, it cannot accurately predict the responses of the New Zealand population in national parks. Before this equation can be applied to the New Zealand environment and population, it needs to be calibrated to match the responses obtained from that specific population. Once this tool has been calibrated, and it can accurately predict how the New Zealand population will respond to noise, it can then be applied to New Zealand environments and national parks. Data collected for this study could be used for the task of TRAPT recalibration.

Using the TRAPT equation along with noise contour maps, a predicted tranquillity rating can be produced for a specific environment/location and under specific noise circumstances. Noise contour maps can then theoretically be turned into tranquillity maps.

This data may be used in noise control or management strategies, such as the one that the Department of Conservation is currently looking into developing. For example, to achieve a reported tranquillity level of 8 or higher, helicopter sound pressure levels need to be below approximately 35 dBA for helicopter noise, or 51 dBA for overall sound levels. Such values, if confirmed by more intensive studies, could be used as a guideline, to promote tranquillity in the New Zealand national parks; acting as a ‘cut-off’ value, that helicopter noise is not allowed to exceed without consequences. Another, perhaps more practical approach that is more likely to gain acceptance is to specify the percentage of daylight hours where tranquillity should be 8 or higher.

4.6 Limitations

One of the most prominent issues with this study was the fact that it was a multidisciplinary thesis; this can have the potential to interfere with the smooth flowing of communication and consequently work. Attempting to have timetables that suited all of the parties involved was difficult, leading to delays for both on-site testing and participant testing. In turn, such delays then affected later aspects of the study such as data analysis and reporting, which may have affected quality of work.

There are very few standards or regulations that have been developed for conservation areas or national parks; this means that there are no recognised standards to compare data to. Data needs to be compared to something, and there were few articles that were comparable to this study and its data. Overall, there was not a lot of academic research that was directly related to this research topic. However, a lot of the previously published material in relation to soundscapes, predicted tranquillities and emotional responses to environmental noise has been published by only a select few academics, which is not unusual. Not only does this means that there is a limited amount of pre-existing studies that relate to, and can be compared to this research; but it also means that what material there is may have the potential to be biased because it has been created by the same set of people. To further this issue, one of those authors, Professor Greg Watts generously gave his time and input into this study; although this study was not performed by him, his input influenced how the study was performed. For example, using the value of 26 dBA for sound files that contained only natural sounds has been performed in the research previously (G. R. Watts & Pheasant, 2015), and was the recommended procedure. Mathematically it makes sense to do this, and the model fits well when 26dBA is used. However, if that had not been recommended or previously applied, actual recorded background noise levels would probably have been applied to those recordings instead, and some sort of scaling factor would have been applied.

Analysis of data in this study increases the risk of bias. This is largely due to the fact that not all of the data was normally distributed. This was an issue, as single sample t-tests were one of the only ways to determine if the reported and predicted tranquillities were significantly different. Multiple t-tests increase the risk of bias, but they also assume that the data is normally distributed, which this data was not. For correlations, this was not as much of an issue, as reported variables were averaged, and distributions were predominantly normal.

The biggest limitation for this research is that the results that are being reported by participants are subjective, open to interpretation, and very much influenced by the individual, their mood, and their state of mind. Subjective testing is always going to be difficult to analyse and report, as there is a lot of variation and there are too many factors that could influence results. If someone has a fascination with helicopters or another has a fear of helicopters, it is going to drastically affect the results. Even things such as personal interpretation of a scale or a piece of terminology can greatly affect the responses that are reported. People are impossible to predict in the best of circumstances; and that in itself is the major limitation of this study. It was also mentioned by multiple subjects that it is difficult to completely imagine yourself in an environment when it is being simulated in a laboratory setting. This may affect the results markedly. Responses also depend on what sounds were played directly before or after a recording. Tracks were block randomised to reduce the effect, but there is still a risk that responses are affected by what preceded the sound in question.

The final limitation for this study was the use of participants that were (to a large degree) closely associated with the University of Canterbury, either as staff members, workers, or students. This means that the studied population likely had quite a high level of education. This may have altered the results in some way, as subjects may have had different ways of thinking or reasoning that did not represent the whole of the New Zealand population.

Despite these limitations the study gives insights into the human responses to helicopter noise in an alpine valley in New Zealand and will be extended in further phases of research.

4.7 Further research

Tranquillity prediction is still quite a young research area, without a substantial amount of published studies. Consequently, more research is needed to grow the area and to improve overall understanding.

In terms of this research, further analysis of this data and UK data from national parks could be completed and appropriate regression analyses used. This would enable the equation to be recalibrated to match these responses, and therefore to better represent the New Zealand population.

This data has been collected in order to represent the New Zealand population's responses to helicopter noise; however, manmade noise can come from a wide variety of sources. Research into other specific noise sources would be beneficial, such as jet boat noise, chainsaws, or other man made noise, as these also have the potential to affect visitor experiences in the national parks. As this research has focussed on the use of TRAPT for the New Zealand population and national parks in respect to only helicopter noise, it cannot be stated that this equation will not work for other noise sources.

Further testing could also be performed, to determine the relationships between reported tranquillity and predicted tranquillity values for various sub groups of the population. This would enable conclusions to be drawn based on age, sex, or ethnicity.

Chapter 5. Conclusions

This research aims to determine the relationships between helicopter noise, reported tranquillity for the New Zealand population and predicted tranquillity obtained using the TRAPT equation. Results show a good and statistically significant correlation between predicted tranquillity using the TRAPT equations and reported tranquillities using helicopter noise sources at different levels. However in its current state, the TRAPT equation needs further calibration to reflect the responses of a New Zealand population. It is suggested that the following steps are taken in any further phase:

1. Collection of a wider range of stimuli with both low and high levels of background noise. This will assist in defining more precisely the coefficients in the TRAPT equation

2. Larger number of respondents drawn from society as a whole

3. Analysis of UK National Park data and comparison with existing data to assist in validation of adopted procedures

From the data analysed here and in order to meet standards that are preferred by the Department of Conservation, and to achieve a reported tranquillity rating of 8 or higher, it is tentatively suggested that helicopter noise should not exceed the value of 35 dBA However, further calibration is required before definite guidance can be given and a more practical approach might to be to put limits on the percentage of time tranquillity lies below 8.

Declarations

The researcher acknowledges that this study has been completed with support from a third party, the Department of Conservation. Financial contributions have been made by this organisation, facilitating the sound recording section of this study; however, no payments have been made to the researcher. Intellectual autonomy has been maintained, and the study has been reported in a full, honest, and accurate account, with full transparency. No important data or information has been omitted from this study.

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Appendix

Appendix 1 Human Ethics Application Approval

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

HUMAN ETHICS COMMITTEE

Secretary, Rebecca Robinson
Telephone: +64 03 364 2987, Extn 45588
Email: human-ethics@canterbury.ac.nz

Ref: HEC 2016/46/LR

22 August 2016

Holly Nicholls
Communication Disorders
UNIVERSITY OF CANTERBURY

Dear Holly

Thank you for submitting your low risk application to the Human Ethics Committee for the research proposal titled "The Effects of Helicopter Noise on Perceived Tranquility in New Zealand National Parks".

I am pleased to advise that the application has been reviewed and approved.

Please note that this approval is subject to the incorporation of the amendments you have provided in your email of 16th August 2016.

With best wishes for your project.

Yours sincerely

pp. R. Robinson

Jane Maidment
Chair, Human Ethics Committee

University of Canterbury Private Bag 4800, Christchurch 8140, New Zealand. www.canterbury.ac.nz

F E S

Appendix 2 Participant information/recruitment flyer

Experience a New Zealand National Park!

2016 Audiology Thesis research participants needed!

- Do you live in New Zealand? Do you love our natural environment? Then this is the study for you!
- The Department of Conservation has identified helicopter noise as a problem in NZ national parks. But how much is too much?
- This study aims to determine acceptable levels of helicopter noise, and its effect on national park visitors.
- All that is required from you is about 1 hour of your time, while you are presented with imagery and sound clips from a New Zealand National Park, and you tell us how they make you feel! Easy as that!
- Anyone is welcome to participate, the only requirements are the ability to hear and understand English.

If you are interested in participating in the study , or you would like to know more information, please contact either:

- Holly Nicholls: hni24@uclive.ac.nz , or call 0211149169.
- John Pearse: john.pearse@canterbury.ac.nz, or call (+64) (3) 364 2987 ext 7383

UNIVERSITY OF CANTERBURY

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Appendix 3Participant Information sheet

Research Participant Information Sheet

Telephone: 0211-149-169
Email: hni24@uclive.ac.nz

The Effects of Helicopter Noise on Perceived Tranquillity in New Zealand National Parks

UC UNIVERSITY OF CANTERBURY

Information Sheet for research participants.

My name is Holly Nicholls and I am a 2nd year Masters of Audiology student at the University of Canterbury. During the second year of the Masters of Audiology degree, students must undertake a research thesis in order to complete their studies. My thesis is concerned with the impact of helicopter noise on visitor experiences in New Zealand National Parks. During this study, I will be the primary researcher and reporter.

The Department of Conservation has identified man made noise – such as helicopter noise – as an environmental issue in New Zealand National Parks, affecting visitors and making their experiences less enjoyable. To address this, the Department of Conservation would like to establish a method of measuring noise levels, and predicting how these noise levels affect visitors, and to what extent. This research study aims to assess whether an established noise measurement and annoyance prediction tool known as the TRAPT model, can be applied in this situation.

If you choose to take part in this study, your involvement in this project will require an investment of about 1 hour of your time. During this time, you will be seated in a test environment with a television screen showing a picture of a typical New Zealand National Park. Testing will involve listening to a set of 20 ten-second sound clips of helicopter noise at various volumes, and stating how relaxing or annoying you find the noise. This will be repeated 3 times.

There will be no follow-up investigation.

Participation is voluntary and you have the right to withdraw at any stage without penalty.
You may ask for your raw data to be returned to you or destroyed at any point.
If you withdraw, I will remove information relating to you.
However, once analysis of raw data starts on the 1st of November 2016, it will become increasingly difficult to remove the influence of your data on the results.

The results of the project may be published, but you may be assured of the complete confidentiality of data gathered in this investigation: your identity will not be made public without your prior consent. To ensure anonymity and confidentiality, any information collected that contains identifiable information (such as consent forms) will be stored separately from results and data, and they will be stored in a secure lockable facility. Data will also be stored on a password protected computer that will be accessible only to those involved in this research. Data collected for this study may be used in subsequent research; however, confidentiality and anonymity will be preserved for any use of data.

Data will be stored for 5 years following the completion of the research, at which time all data and information will destroyed. The written documents that will be produced are expected to include a thesis and a paper in an academic journal. A thesis is a public document and will be available through the UC Library; academic papers vary in their availability, based on the publication.
Please indicate to the researcher on the consent form if you would like to receive a copy of the summary of results of the project.

The project is being carried out as a requirement for the Masters of Audiology degree by Holly Nicholls under the supervision of Dr. John Pearse, who can be contacted at john.pearse@canterbury.ac.nz . He will be pleased to discuss any concerns you may have about participation in the project.

This project has been reviewed and approved by the University of Canterbury Human Ethics Committee, and participants should address any complaints to The Chair, Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz).

If you agree to participate in the study, you are asked to complete the consent form and return it to Holly Nicholls at the pre-arranged meeting [details can be confirmed via email: hni24@uclive.ac.nz].

Holly Nicholls.

Appendix 4Participant consent form

Consent Form

Telephone: 0211-149-169
Email: hni24@uclive.ac.nz

The Effects of Helicopter Noise on Perceived Tranquillity in New Zealand National Parks

UNIVERSITY OF CANTERBURY

Consent Form for Research participants

I declare and fully understand the following:

□ I have been given a full explanation of this project and have had the opportunity to ask questions.
□ I understand what is required of me if I agree to take part in the research.
□ I understand that participation is voluntary and I may withdraw at any time without penalty. Withdrawal of participation will also include the withdrawal of any information I have provided should this remain practically achievable.
□ I understand that any information or opinions I provide will be kept confidential to the researcher, Holly Nicholls, and that any published or reported results will not identify the participants.
□ I understand that a thesis is a public document and will be available through the UC Library.
□ I understand that all data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after five years.
□ I understand that data collected from this study may be used in subsequent research.
□ I understand the risks associated with taking part and how they will be managed.
□ I understand that I am able to receive a report on the findings of the study by contacting the researcher at the conclusion of the project.
□ I understand that I can contact the researcher, Holly Nicholls [hni24@uclive.ac.nz; 0211149169] or supervisor, John Pearse [john.pearse@cantercury.ac.nz; (+64) (3) 364 2987 ext 7383] for further information.
□ If I have any complaints, I can contact the Chair of the University of Canterbury Human Ethics Committee, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz)
□ I would like a summary of the results of the project.
□ By signing below, I agree to participate in this research project.

Name:

Signed:

Date:

Email address (for report of findings, if applicable):

Consent forms will be collected at your scheduled testing appointment.

Holly Nicholls.

Appendix 5Scoping study participant response sheet

Sound clip 1

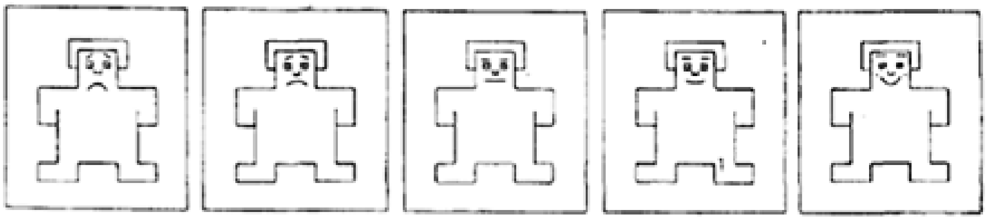
a. Tranquillity 0-----1-----2-----3-----4-----5-----6-----7-----8-----9-----10
not at all tranquil very tranquil

b. Wildness 0-----1-----2-----3-----4-----5-----6-----7-----8-----9-----10
not at all wild very wild

c. Naturalness 0-----1-----2-----3-----4-----5-----6-----7-----8-----9-----10
not at all natural very natural

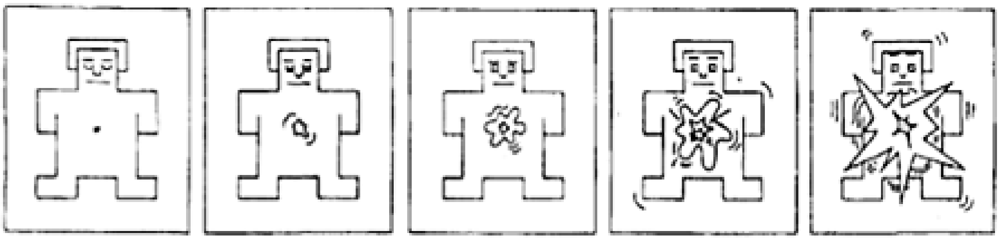
d. Remoteness 0-----1-----2-----3-----4-----5-----6-----7-----8-----9-----10
not at all remote very remote

e. Pleasantness



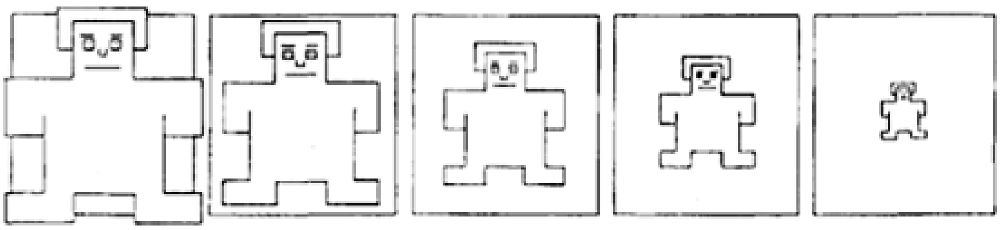
Unpleasant Pleasant

f. Calmness



Calm Excited

g. Control



In control Controlled

Appendix 6 Franz Josef national park images used in the scoping study (A-H)

A

B

C

D

E

F

G

H


Appendix 7 Pilot study subject response sheet

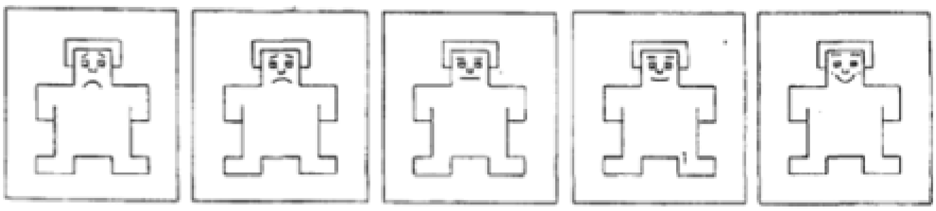
1

a. **Tranquillity** 0-----1-----2----3----4----5----6----7----8----9----10
not at all tranquil very tranquil

b. **Naturalness** 0-----1-----2----3----4----5----6----7----8----9----10
not at all natural very natural

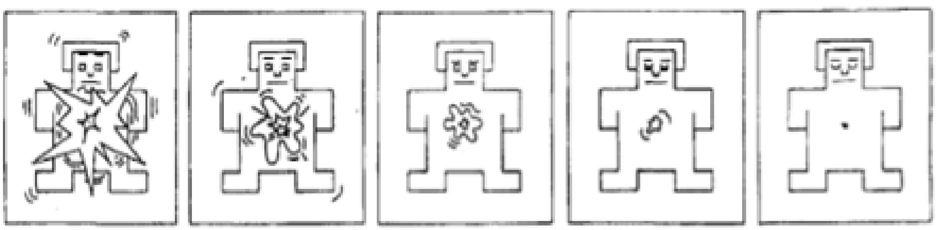
c. **Remoteness** 0-----1-----2----3----4----5----6----7----8----9----10
not at all remote very remote

d. **Pleasantness**



Unpleasant Pleasant

e. **Calmness**



Excited Calm