The impact of noise on recreationists and wildlife in New Zealand's natural areas

A literature review

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Cover: Helicopter used to transfer 16 juvenile takahē being released into the Takahe Special Area, Murchison Mountains, Fiordland National Park, November 2009. *Photo: DOC.*

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A literature review

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ABSTRACT

This report reviews the literature about noise effects on recreationists and wildlife in New Zealand's natural areas. International literature on the nature of noise impacts, factors that influence them, responses to noise and key theoretical concepts are summarised. The range of methods available to measure noise and its effects are also critically discussed. The review of the New Zealand literature on noise impacts in natural areas then provides a synthesis of these studies and details the development and application of methodologies in New Zealand. The literature review indicates that monitoring of the impact of noise on recreationists in New Zealand has focussed on methodologies that are simple, affordable and easily carried out. Despite this, the development of the standard aircraft monitor (SAM) and its replication at a range of sites has enabled long-term changes to be recorded and for noise to be viewed in a national context. A number of other innovative approaches have also been applied in New Zealand, including limits of acceptable change (LAC) studies and the use of research diaries. In contrast, approaches used to address noise impacts on wildlife have not followed a standardised approach. Instead, studies have focussed on specific species at specific sites, using individualised methods. The focus has been on general disturbance rather than noise specifically, and studies have tended to examine short-term behavioural responses rather than long-term, cumulative effects. The report concludes with recommendations for future studies.

Keywords: recreation, tourism, wildlife, noise, sound, impacts, social impacts, aircraft, annoyance, monitoring, natural quiet, national parks, protected areas

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1. Introduction

For over 25 years, concern has been expressed about the potential impacts of mechanised noise on recreational experiences (and other values) at a variety of Department of Conservation (DOC) managed locations. More recently, the possibility of noise impacts on wildlife, particularly on marine mammals, has added further impetus to consideration of this issue. Interest in the impacts of noise on visitors to protected areas was heightened in the United States by the passing of the 1987 National Parks Overflight Act, and it has subsequently become an active area of research. The early work from the United States was, in turn, influential in guiding thinking in New Zealand around the effects of noise on recreationists in protected areas and on the value of natural quiet. At the same time, a period of rapid growth in tourism numbers in New Zealand through the 1990s led to concerns about the impacts of tourism generally (PCE 1997) and, in particular, to heightened interest in the effects of noise from aircraft overflying sensitive environments (McElymont 2000). This interest has continued to the present day.

This report presents a review of the New Zealand research literature on noise impacts in natural areas, with particular emphasis on public conservation lands and waters. It provides a synthesis of New Zealand-based studies, including unpublished grey literature, and traces the development of research and monitoring to measure noise effects in New Zealand. A particular focus of this work has been aircraft noise and, therefore, much of the report pertains to this topic. A review of relevant international literature is also included. This provides an introduction to the topic, discusses various approaches to measuring the effects of noise and gives contextual information to explain noise and its impacts.

The primary purpose of this review is to inform future management of noise-generating activities. This includes understanding the range of methods that are available to measure the impact of noise and understanding the factors that contribute to noise impacts, which, in turn, assists managers in seeking or implementing appropriate responses. This review does not address management responses to the findings of individual studies. While further work is needed to document the success of efforts to manage noise and its impacts on conservation values in New Zealand, this report provides managers, policy makers and other interested parties with an account of efforts made by the DOC to date to understand the extent of noise impacts.

Following a description of general concepts about noise and its perception, the report is structured by topic, first discussing noise effects on recreationists, then reviewing noise effects on wildlife. Specifically, the report:

1. Defines the characteristics of noise and the factors that influence its impact, and discusses various techniques to measure the impacts of noise on both recreationists and wildlife (section 2).
2. Provides a theoretical basis for understanding the effects of noise on recreationists (section 3).
3. Outlines the research and monitoring of noise effects on recreationists that has been undertaken on public conservation lands and waters in New Zealand (section 4).

4. Provides a review of the effects of noise on wildlife (section 5).
5. Outlines the research and monitoring of noise effects on wildlife that has been undertaken in New Zealand (section 6).
6. Concludes with observations on the current state of research in New Zealand and future research prospects (section 7).

2. Defining sound and noise, and the factors that influence noise impacts

This section defines 'sound' and 'noise', and describes the factors that influence the impact of noise on recreationists and wildlife. A number of techniques for measuring the effects of noise are discussed with examples of their practical application to management.

2.1 DEFINING SOUND AND NOISE, AND MEASURING NOISE IMPACTS

2.1.1 Defining sound and noise

The distinction between sound and noise is ambiguous. Sound is the aural sensory stimulus that results from pressure waves travelling through the air (or through water) caused by the vibration of a solid object (Smith 2001) such as an engine, propeller or human vocal chord. There are several definitions of noise that are relevant to its impact in natural settings. Noise can refer to a 'psychological evaluation of sound' or more simply to 'unwanted sound' (Gramann 1999: 2). Another useful definition of noise is '… sound having amplitude, frequency content, situational or temporal qualities that are inappropriate to the particular setting' (Hartmann et al. 1992: Chapter 2.1). Berglund et al. (1999: 23) likewise suggested that noise 'is a sensory perception evoked by physiological processes in the auditory brain', which makes it impossible to define 'exclusively on the basis of the physical parameters of sound'. All of these definitions emphasise the important point that noise is a subjective judgement of sound.

Noise can also refer to what is known as signal noise or extraneous sound (Pilcher et al. 2009). This refers to sound that itself carries no information but which can mask other sounds in the environment. For humans this can mean that the sounds of nature are blocked out, potentially reducing the benefits of visiting natural areas. The consequences of this sort of noise for animals may be more serious because they may rely on hearing to receive information about their environment (including the presence of predators) and for inter- and intraspecific communication.

The amount of sound to which an individual is exposed is the most obvious factor influencing human and wildlife response. Although sound can be quantified in a number of different ways (e.g. loudness, frequency and sound energy level), it is commonly measured in decibels (dB). The decibel scale is based on the change in ambient pressure (i.e. air pressure) caused by a sound wave. The decibel scale is logarithmic rather than linear—an increase of 10 dB will result in a sound that is twice as loud; a decrease of 10 dB will halve a sound's loudness.

To put this in context, the sound of normal human breathing is around 10 dB. Sound at this low level is barely audible to humans although the ears of many animals are much more sensitive. The sound of some jet aircraft taking off is around 150 dB and will likely rupture a listener's eardrums (Pepper et al. 2003) while a single dose of 70 dB(A)[1] is known to be enough to trigger the human body's 'fight or flight' response. This reaction is automatic and occurs irrespective of the listener's opinion of the sound, as the physiological response is activated by nerve impulses travelling between the listener's inner ear and brain (Björk 1986). Sound intensity levels for some common sounds are listed in Table 1.

For New Zealand airports, a noise limit of L_{dn} 65 dB(A)[2] is commonly set for an 'air noise boundary'[3] to reduce annoyance and protect local residents from sleep deprivation and related health effects from chronic noise exposure. A second boundary is commonly set at L_{dn} 55 dB(A) to protect 'amenity values'[4] (Standards Association of New Zealand 1992; Gill 1996; Hunt 1999). World Health Organisation guidelines for protecting public health in urban areas are set at a level at which health effects are thought to be negligible and range from 45 to 55 L_{Aeq} (dB)[5] (Kihlman 2006). Guideline levels of between 30 and 45 dB(A) have been suggested as being appropriate for New Zealand national parks (Hunt 1999). Animals can be much more sensitive to sound than humans, with some mammals sensitive to sound levels as low as –20 dB (Bowles 1995). Guidelines that minimise annoyance and/or health effects in humans may not be sufficient to protect animals.

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[1] A-weighting is an international standard weighting built into many commercially available sound meters and is commonly used for measuring industrial and environmental noise. When sound levels are 'A-weighted' (denoted as dB(A)) the sound energy at all frequencies is added together in a manner that corresponds to the way the human ear perceives sound. Low and high frequency sound energy is de-emphasised while more weight is given to sounds in the 500–5000 Hz frequency range, which is important for understanding human speech (Anderson et al. 1993).

[2] L_{dn} is another way of expressing noise measurements and is used in the relevant New Zealand Standard (NZS6805: 1992 Airport Noise Management and Land Use Planning). In this noise metric, noise events occurring between 10 p.m. and 7 a.m. are given a 10 dB penalty to reflect their greater potential for sleep disturbance. Sound levels are averaged over a 3-month period (Gill 1996; Hunt 1999).

[3] An 'air noise boundary' is a contour around an airport at which the noise generated is not permitted to exceed Ldn 65 dB(A) and within which the development of noise-sensitive land uses is prohibited (Standards Association of New Zealand 1992).

[4] 'Amenity values' are defined in New Zealand legislation as 'those natural or physical qualities and characteristics of an area that contribute to peoples' appreciation of its pleasantness, aesthetic coherence, and cultural and recreational attributes' (Resource Management Act 1991: section 2).

[5] L_{Aeq} is effectively an average A-weighted sound level over a set period of time. In World Health Organization guidelines, the chosen period is 8 or 16 hours (Kihlman 2006). The United States National Park Service (NPS) has set the time period as the length of an individual's visit calculated from recorded track entry and exit times (Anderson et al. 1993).

TABLE 1. SOUND INTENSITY LEVEL ASSOCIATED WITH COMMON SOUNDS (ADAPTED FROM HEWITT (2006) AND OSH (1994)).

SOUND SOURCE	SOUND INTENSITY LEVEL (dB(A))	NUMBER OF TIMES GREATER THAN THRESHOLD OF HEARING
Threshold of hearing	0	10^0
Rustling leaves	10	10^1
Whisper	20	10^2
Quiet radio in home	40	10^4
Conversation in home	60	10^6
Busy street traffic	70	10^7
Noisy lawn mower	100	10^{10}
Club music, amplified	115	$10^{11.5}$
Air raid siren, nearby	120	10^{12}
Threshold of pain	130	10^{13}
Jet aircraft 30 m away	140	10^{14}
Instant perforation of eardrum	150	10^{15}

2.2 FACTORS INFLUENCING THE IMPACT OF NOISE ON RECREATIONISTS

Factors influencing the impact of noise on recreationists can be divided into four categories: the physical properties of the sound, the characteristics of the physical environment, the ability of the listener to detect a given sound and the listener's sensitivity to noise. The sound source and the environment together define the physical characteristics of sound and whether it is audible. The ability of the listener to detect the sound and their sensitivity to it are key determinants of whether a sound is noticed and whether it is perceived as noise. The following discussion emphasises noise impacts on people, with a particular focus on recreationists in natural settings.

2.2.1 Physical properties of the sound

Physical properties of both the sound and the listener's environment influence the way that a sound is perceived. The frequency or pitch of a sound is thought to be a factor, as some studies have shown that sounds of higher pitch or frequency tend to be perceived as being more annoying than those of a lower pitch or frequency (Björk 1986; Kariel 1990). This is likely to be due to the fact that the human ear does not perceive sound equally across the range of frequencies that it can detect. Due to differences in aural sensitivity at different frequencies, a 10 dB sound at a frequency of 1000 Hz can have the same perceived loudness as a 40 dB sound at a frequency of 60 Hz. Human aural sensitivity reaches a maximum at 4000 Hz, which is a frequency similar to the top note (C8) on a piano (Smith 2001).

Variations in the characteristics of a sound are also important. Sounds that are rhythmic, irregular or intermittent are often found to be more annoying than continuous sounds (Kariel 1990). Helicopter 'blade slap' is a good example of the effects of variation in a particular sound. Schomer & Wagner (1996) found that respondents within an urban environment were more likely to notice sound from helicopters than train and aircraft sounds with the same A-weighted sound exposure level. The personal water craft (more commonly known as a jet ski) is another example of variable noise. As these craft leave the water when they bounce over waves, they lose the muffling effect of water on the exhaust creating a variation in sound level that is typically about 15 dB(A). The difference equates to an in-water personal water craft operating eight times closer to the listener. Further noise is created each time the craft re-enters the water and hits against the water surface (Komanoff & Shaw 2001). It is likely that the variation in the volume or pitch of sound from certain sources, such as a helicopter or personal water craft, attracts the listener's attention in the same way that a flashing light on an emergency vehicle draws the attention of the human eye.

It has been suggested that sounds with a random component, such as those from wind, flowing water and other nature-related sources, tend to be considered more pleasing (Kariel 1990), while other sounds may have particular characteristics, such as abrupt changes in sound level at certain frequencies, that are more 'alert raising' (Carles et al. 1999). However, it is difficult to separate responses to the characteristics of a sound from the meaning that a listener attaches to the sound.

2.2.2 The physical environment of the sound source and the listener

The environment in which the listener is situated and the sound source originates also affects the characteristics of sound. Factors such as terrain, atmospheric conditions, distance between the listener and the sound source, and existing levels of background noise influence how far sound travels and, most importantly, how it is perceived by the listener.

The local topography of an area can either block or enhance sounds. Rocky and other hard surfaces are effective in reflecting sound waves. An extreme example is the Grand Canyon in the United States and its echo phenomena: according to one researcher, it is possible for a single aircraft to sound as if three of four separate aircraft are present (Mace et al. 2003); and it is reportedly possible for noise to echo for up to 25 km along the inner walls of the Canyon (Kanamine 1997, cited in Mace et al. 2003). Different types of vegetation may also transmit, reflect or absorb sound waves. In some North American settings, foliage has been found to reduce sound levels, but only when the source is in fairly close proximity (23–107 m) to the listener (Dailey & Redman 1975 and Harrison et al. 1980, both cited in Kariel 1990).

Sound levels also decrease with distance from the sound source as sound waves are absorbed by the atmosphere in a process known as attenuation. All other things being equal, as the distance from a sound source doubles there is a resulting reduction in sound energy of about 6 dB (Mace et al. 1999). The effect of attenuation is greater for high-frequency than low-frequency sounds (Smith 2001), resulting in low-frequency sounds potentially being able to be heard over greater distances. An example of this is the large distance and high efficiency of sound travel demonstrated by the low-frequency 'booming' of a male kākāpō (*Strigops habroptilus*) as it seeks a mate (Lindsey & Morris 2000).

Atmospheric conditions affect the degree to which attenuation occurs (Manci et al. 1988; Pepper et al. 2003). In particular, temperature inversions, which occur when layers of cold air become trapped under warmer air, can result in sound being intensified, making it travel further from the source without appreciable loss of sound energy. When sound travels from an area of cold air to an area of warmer, less dense air, the sound waves are refracted and reflected in much the same way that light waves are affected when passing through water. In some conditions, sound waves hitting the boundary between two layers of air may be reflected towards the ground (Manci et al. 1988) as if they had bounced off a solid surface. Likewise, under normal conditions when air temperature decreases with increasing altitude, the sound generated by aircraft can be deflected upwards creating areas with little or no detectable sound at ground level (Manci et al. 1988). Other conditions such as wind, precipitation, temperature and cloud can either reduce or enhance the transmission of sound waves. Wind and rain also reduce the audibility of other sounds by increasing the amount of background or ambient noise.

Background noise and audibility are important in natural settings because, in many cases, the level of background noise is very low. In such settings, a noise may be perceived as louder, lasting longer and may be audible over greater distances than it would in an urban area where the same sound may go unnoticed (Grasser & Moss 1992). In some cases, however, natural sounds such as rushing water, waves, wind, rain or animal calls can fully or partially mask artificial sounds, even those that are relatively loud at source.

2.2.3 Ability to detect a given sound

The physical characteristics of the sound source and the environment determine the intensity of a sound when it reaches the listener's ear; however, individuals vary in their physical sensitivity to sound. Sensitivity to different frequencies varies with the listener's age and previous exposure to sound. In addition, an individual must notice a sound in order to be affected by it. Noticeability is defined by Gramann (1999: 15) as 'a level of sound above the average ambient level where an inattentive listener with normal hearing will hear a specified signal'. It is affected not just by the physical characteristics of the sound (discussed above) but also by what the listener is doing at the time and their degree of involvement in what are called 'foreground tasks'. A foreground task is any mentally involving activity other than listening for intrusive sounds (Gramann 1999). The importance of involvement in foreground tasks in determining noticeability of sound is illustrated in a pair of experiments which found that sounds were, on average, noticed at 48 dB while participants were engaged in a foreground task (playing video games) but dropped to about 38 dB for participants who were not engaged in a foreground task (Fidell & Teffeteller 1979, cited in Grau 2005; Fidell & Teffeteller 1981). In an outdoor recreation context, this could mean that a listener who is engrossed in a technical task, say, pitching a tent, might be less likely to notice a sound than if they were enjoying scenery.

Noticeability is also affected by a recreationist's group size, although the exact mechanism is uncertain. Some studies have found that group size affects the likelihood of reporting annoyance or interference by aircraft, with large groups being less affected (Anderson et al. 1983; Knopf 1983, cited in Gramann 1999). One explanation could be that group situations create more background noise or that recreationists in groups are more involved in foreground tasks, such as talking to other members of the group.

2.2.4 Recreationists' sensitivity to noise

If noise is defined as 'unwanted' or 'inappropriate' sound (rather than as extraneous sound), then sound can only become noise once it has been processed and interpreted by the listener's brain. The process by which sound is perceived as 'noise', and then becomes an impact, is complex and different individuals perceiving the same sound can respond to it in different ways. Recreationists do not enter protected areas as 'blank slates' but instead bring with them characteristics such as attitudes, expectations, values and past experience. These may be articulated as 'norms', which can be defined as 'standards that individuals use for evaluating activities, environments or management proposals as good, bad, better or worse. They define what people think behaviour or social conditions should be in a given context' (Freimund et al. 2002: 350). Personal norms may exist for the presence or absence of particular noise-generating activities or the intensity, type or frequency (i.e. number of occurrences) of the sound that is produced in a particular location.

The influence of socio-psychological factors such as these may be relatively large. In United States National Park Service (NPS) studies, variables such as group size, number of previous visits, setting (e.g. scenic lookout or short hike) and the degree of importance visitors placed on natural quiet, affected visitor response to sound and resulted in variation in responses equivalent to a 20 dB increase in the loudness of aircraft (Staples 1998). In a review of urban noise studies, Job (1988) found that typically less than 20% of the variation in individual responses to noise could be explained by sound exposure. Instead, factors such as attitudes to the sound source and sensitivity to noise were far more important. It has been suggested that these intangible characteristics of noise are even more important in natural settings than they are in urban settings. Aircraft overflights, for example, could represent an undesirable sound of civilisation that could be viewed as an intrusion on a visitor's experience of natural settings, even when the actual sound level is low (Tarrant et al. 1995).

Individuals are affected differently by sound in terms of their initial tolerance to noise and their ability to adjust to it over long periods of time. Some people are more or less sensitive to noise than others—sounds that seem pleasant to some people may be irritating to others (Grau 2005). Noise effect surveys carried out in communities living near airports have found that some people living in zones with the highest noise exposure are oblivious to noise, yet some people living in areas distant from the same airport can be extremely annoyed (McKennell 1970, cited in Weinstein 1978).

Noise sensitivity has been viewed as a personal characteristic or personality trait, and some studies (e.g. Krog & Engdahl 1999; Aasvang & Engdahl 2004) have used measures of sensitivity such as the Weinstein Noise Sensitivity Scale (Weinstein 1978) to explain or predict the impact of noise. While laboratory studies and field studies of community and transport noise have found a strong correlation between self-reported noise sensitivity and annoyance (Öhrström et al. 1988; Miedema & Vos 1999), it is less clear that this is the case in recreational settings where a number of studies have found no correlation (Aasvang & Engdahl 2004; Grau 2005). An Outdoor Recreation Sensitivity Scale has been developed as a way of investigating setting-specific sensitivity to noise (Grau 2005).

2.3 FACTORS INFLUENCING THE IMPACT OF NOISE ON WILDLIFE

The physical properties of the sound and the environment in which the sound is generated and perceived are also important factors controlling the responses of wildlife to noise. However, the sensitivity of animals to sound differs from that of humans in both the level of sound and the range of frequencies that they can detect. Cats, for example, are 15–20 dB more sensitive than humans, while snakes, turtles and tortoises hear very poorly (Bowles 1995). Humans can perceive sounds within a range between 20 and 20 000 Hz (OSH 1994) while the hearing of mammals overall varies within a range from less than 10 to more than 150 000 Hz (Bowles 1995). Like humans, animals can hear some frequencies better than others across the range that they are able to perceive. Baleen whales hear best at low frequencies, while dolphins, porpoises, bats and rodents hear best at high frequencies (Bowles 1995). This means that animals can potentially be sensitive to and impacted by sounds that seem quiet to human ears or to which humans are unaware. Other factors influencing the impact of noise on wildlife include the threat-response characteristics of the species and situational factors such as habitat type, lifecycle stage and previous exposure to noise or disturbance (NPS 1994). The range of potential impacts of noise on wildlife and their responses are discussed in more detail in section 5.

2.4 APPROACHES TO MEASURING THE IMPACT OF NOISE

Various approaches have been used internationally to assess the impact of noise on both recreationists and wildlife. The methods fall into five broad categories: sound measures with no response measures, dose-response studies, simulation experiments, noise modelling and response measures with no sound measures. Each of these methods is critically discussed below and examples of their practical application to management are provided. Monitoring the effects of noise on recreationists and wildlife in a New Zealand context is discussed separately in sections 4 and 6, respectively.

2.4.1 Sound measures with no response measures

These methods, which are also known as 'accoustical approaches' (Gramann 1999), involve using scientific instruments or trained observers to measure the physical properties of particular sounds. Measurement of sound intensity using scientific instruments is common in environmental and workplace monitoring. Such measurement is a comparatively recent development in recreational settings where the area of concern usually relates to short-term exposure and reduction in the quality of visitor experience, rather than health effects from ongoing sound exposure.

In natural settings, the most basic approach has been simply to count the number of discrete noise events such as aircraft overflights or vehicle movements. Other common metrics include the maximum or average intensity of sound, its duration or the percentage of time that a particular sound source is audible. Percentage of time audible has been the most widely investigated of these (Miller 2008) and is easier for people to relate to than meaures of sound intensity. Miller (2008: 83) stated that 'it is a useful metric for describing how long sources are heard, particularly at the extremes of duration. For example, if human-produced sounds are audible for 5% of the time, it is likely that most people will judge such a soundscape as relatively pristine or natural. Conversley, if human-produced sounds are audible 50–90% of the time at some location, then we would probably decide that it is not a place to expect solitude or escape from the sounds of civilization. The median noise-free interval and the decibel difference between human and ambient sounds have also been proposed as useful metrics (Miller 2008) but have not been widely used. The median noise-free interval appears to be a particularly promising way of describing soundscapes that overcomes a key disadvantage with using the percentage of time audible, whereby the same statistic for the percentage of time audible could describe soundscapes that are quite different. For example, a particular sound could be audible for 20% of the time, but this statistic could describe a situation where a sound can be heard for 1 minute in every 5 or where the same sound could be experienced continously for almost 5 hours in a 24-hour period. The human response to these scenarios could be quite different. The best approach could be to use more than one metric, as is the case with many environmental noise standards.

Irrespective of the particular metrics used, accoustical approaches have three main advantages over other methods: they provide a more objective measure of conditions at a particular location, the results can be compared with pre-defined standards of acceptability to determine whether the sound falls within a tolerable range (Gramann 1999), and some types of equipment can be automated and therefore be left unattended for long periods of time. The latter is an important consideration where effects on wildlife are being considered and where more invasive methods may alter the behaviour of animals of interest. It is also useful for monitoring in remote areas where it may not be practical to base people in the field or where other approaches, such as on-site surveys, may be ineffective due to low visitor numbers.

The principle disadvantage of accoustical approaches is that for all but the most simple approaches there is a requirement for specialist knowledge and equipment that, in the past, have been relatively expensive. Further, while there are widely accepted noise standards for protecting human health, standards for preserving recreational experiences or the well-being of wildlife are much less common. There are also technical issues around measuring sound in natural areas. Levels of background noise are often very low, meaning that sounds can be detectable and identifiable from great distances and at very low levels. These low levels of noise may not register on a sound meter but could still be considered intrusive by some listeners (Kariel 1990). Measurements made with instruments may also fail to discriminate between natural and non-natural sounds. Wind can also interfere with sound measurements, creating false readings on the microphone, even at relatively low wind speeds. This problem is exacerbated by the low levels of background noise (Miller 2008). Conversely, in some locations, natural sounds, such as birds, frogs, insects, waterfalls, wind and rain, may be relatively loud and this can add complexity to monitoring. Some human sounds may be acceptable in certain locations but not in others (e.g. vehicle noise and people talking in front-country locations), so it may be necessary to discriminate between sounds that are deemed 'undesirable' and those that are not. This is achievable, but adds complexity to monitoring. Portability of equipment, power requirements, data storage and the vulnerability of electronic equipment to weather all provide further challenges, especially in more remote locations (Miller 2008). As discussed earlier, the physical characteristics of a sound when it reaches the listener are only part of a wide range of factors that influence the response of humans or wildlife to that sound. A further weakness of accoustical approaches is that they do not consider human socio-psychological factors, value judgements, perceptions or the individual responses of humans and wildlife to particular sounds. In some cases, these factors have been shown to be far more important in determining human response than the physical properties of the sound (Job 1988; Staples 1998).

However, some of these problems can be overcome. Measurements of the audibility of sound, for example, can be carried out quite simply. Rather than requiring expensive monitoring equipment, it may require little more than a trained observer with a watch and notebook (Miller 2008). Furthermore, the price and portability of equipment is decreasing over time, while data capacity, battery life and the ability to use solar cells in place of or to supplement batteries are increasing. Many devices can also be 'ruggedised' to improve their durability in the field. Human socio-psychological factors can inform the setting of standards of acceptability that results may be measured against, or accoustical approaches can be used alongside response measures to combine the strengths of both approaches (see section 2.4.2 dose-response studies, below).

Examples from Australia and the USA show where accoustical approaches have been used to inform management of protected areas. In Australia, the Great Barrier Reef Marine Park Authority carried out sound monitoring at Whitehaven Beach, Whitsunday Island, to proof the area's Recreation Opportunity Spectrum (ROS)[6], zoning and to determine whether ambient and aircraft noise levels matched the management objectives of those settings (Hamilton 2003). The study found that the highest levels of aircraft use and noise occurred in the moderate and natural-use zones, while there was little activity in the designated high-use zone. This was found to be inconsistent with the Authority's management objectives, and a number of recommendations were given for further monitoring and management of the area.

The NPS has undertaken sound measurement studies in a number of locations. In Yellowstone National Park, accoustic monitoring was carried out during four consecutive winter seasons from 2002/03 to 2005/06. The most recent study published in 2006 found that at five study sites the percentage of time that snow mobiles and snow coaches were audible during the day ranged from 34% to 67%. The maximum sound level of snow mobiles was found to exceed 70 dB(A) at three of the five locations monitored. This information was able to be compared with existing impact thresholds developed for the Park and it was

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[6] ROS is a planning tool that is used to assign recreational areas into zones, which typically range along a continuum from developed to undeveloped or urban through to wilderness. ROS zoning of a particular area is based on a combination of its biophysical (the degree of naturalness or human modification), social (the location, type and amount of contact or interaction with others) and managerial (the amount, type and intrusivness of rules and regulations, and the presence of management staff) characteristics. ROS zones are typically depicted on a map and provide a means of describing the range and extent of recreation opportunities that are available within a given area. Developed in the United States from the 1970s onwards, ROS has been widely adopted around the world by various agencies in a variety of settings (McCool et al. 2007).

determined that there were moderate or major adverse effects on the natural soundscape or its potential for enjoyment at all five sites. Although both the sound level of oversnow vehicles and the percentage of time that they were audible was substantially lower than during the initial season of monitoring, further reductions in these metrics were recommended (Burson 2006).

In Denali National Park, Alaska, a programme is underway to systematically sample the soundscape of the entire 2.4 million hectares it encompasses (Withers & Adema 2009). The Park is divided into 60 grids and automated monitoring stations are deployed in six of these grids each summer. This information is supplemented by two further monitoring stations that are deployed at sites where more intensive monitoring is required, while a separate monitoring programme is carried out over winter focussing on areas of traditional winter use. These results can be compared with standards for the various management settings that are defined in the Park's back-country management plan. These standards are 'the percentage of any hour when motorised noise is audible', 'the number of motorised intrusions per day that exceed natural ambient sound' and 'the maximum motorised noise level'. More importantly, the programme allows park authorities to describe the values and the nature of the soundscape as a resource and to document any changes in the quality of the resource over time.

2.4.2 Dose-response studies

Dose-response studies combine a quantitative measure of the amount of activity or noise (the dose) with a response variable such as the behavioural response of an animal or the level of annoyance reported by recreational users. Dose-response studies on human subjects are also known as 'psycho-accoustical' approaches (Gramann 1999).

Dose-response methods have commonly been used in studies of communities around airports (Gramann 1999). More recently, government agencies in the USA have undertaken dose-response studies to assess the impact of aircraft noise on recreational users of protected areas. Since 1992, the NPS and United States Federal Aviation Administration (FAA) have carried out studies at Grand Canyon, Haleakala, Hawai'i Volcanoes and Bryce Canyon National Parks (Anderson et al. 1993; Fleming et al. 1998; Rapoza et al. 2001, cited in Rapoza et al. 2005). In these studies, sound exposure was measured while visitors were simultaneously surveyed to assess their responses to aircraft noise. In one study, Anderson et al. (1993) collected data from six locations in three national parks (Grand Canyon, Haleakala and Hawai'i Volcanoes National Parks) that provided different recreational opportunities ranging from front-country viewpoints to back-country trails. Two dose variables ('aircraft L_{eq}' and 'percent time aircraft were audible') and two response variables ('percent of visitors annoyed' and 'percent of visitors who judged that the sound from aircraft interfered with their appreciation of natural quiet') were chosen for the study, which surveyed almost 800 visitors. From the data, researchers were able to plot dose-response curves for each study site to describe the mathematical relationship between aircraft noise and visitor response to the noise. The difference between visitors in different recreational settings was readily apparent. For example, at the two 'short hike' sites, approximately 22% of visitors were annoyed when aircraft were audible 20% of the time, while at the two front-country viewpoints the same noise dose resulted in only 5% of visitors reporting annoyance. The study not only allowed park managers to identify sites that experience impacts from aircraft noise, it also allowed them to predict the impact resulting from any future change in aircraft flight paths and frequency.

Dose-response methods have also been applied to studies of wildife, although this is less common. Goudie & Jones (2004) found a highly significant dose-response relationship between alert behaviour in Canadian harlequin ducks (*Histrionicus histrionicus*) and low-altitude military jet overflights at Fig River, Labrador. The response was found to intensify when the sound of jets exceeded 80 dB(A). As a result, it was recommended that military overflights in Labrador be modified to reduce the exposure of habitats used by harlequin ducks to sound levels < 80 dB(A). It was proposed that this could be achieved by avoiding river valleys or by defining minimum altitudes for overflights in these areas. Other wildlife studies have investigated the relationship between behavioural response and the physical distance from ground-based sound sources such as chainsaws. This metric is potentially vulnerable to being influenced by local environmental conditions (e.g. vegetation and weather), which could affect the propagation of sound (Goudie & Jones 2004), but is easily visualised and lends itself well to certain management responses, such as the creation of buffer zones.

Overall, dose-response studies combine the strengths of acoustical approaches with those of other methodologies such as surveys and behavioural studies. They allow researchers to predict the likely responses of wildlife or recreationists over a range of noise levels. This is extremely useful in determining thresholds of acceptable activity, in setting defendable limits and for predicting the likely effects of future scenarios or management actions. A disadvantage of dose-response methods is that the results derived from these studies can be very site specific. Furthermore, like acoustical approaches, dose-response studies can be relatively expensive to carry out (Gramann 1999). A larger potential problem with dose-response studies is a lack of clarity around the relationship between sound intensity and annoyance. Kariel (1990), for example, found no relationship between sound intensity and the level of annoyance in a study encompassing a wide variety of human and mechanical sounds ranging from 22 to 83 dB(A). Although sound exposure is an important variable, it is not the sole determinant of the impact of noise on visitors (NPS 1994). Instead, a wide variety of factors, as described above, play a role in the annoyance response. There are also technical issues with carrying out dose-response studies in certain locations. In some locations, such as multi-day tramping tracks, measurements taken at a single point are unlikely to accurately reflect the noise dose that has been received by visitors. For remote or wilderness areas, it may also be extremely difficult to measure responses because of low visitor numbers. For dose-response studies on wildlife, the ability of animals to rapidly habituate (see section 5.2.2) to sounds that they learn do not pose a threat can complicate the collection and interpretation of data (Pater et al. 2009). As with studies on recreationists, it may be difficult to generalise results from dose-response studies carried out on wildlife, as dose-response models are likely to differ for each combination of noise type and animal species (Pater et al. 2009).

2.4.3 Simulation experiments

Simulation experiments enable researchers to examine responses to controlled doses of sound while potentially allowing other variables that could affect the response to be controlled. Some experiments are similar in approach to the dose-response studies described above, while others use different approaches. Simulation experiments are usually carried out off-site, which is particularly useful when the subject or area in question is difficult to study on-site (e.g. remote or wilderness areas). Laboratory research on animals is, of course, commonplace (see Bowles 1995), but researchers have also used photographs, projected slides and video footage, along with pre-recorded sounds, to assess the effect of various sounds on a range of human response variables (Anderson et al. 1983; Carles et al. 1999; Mace et al. 1999, 2003; Freimund et al. 2002; Benfield et al. 2010). A comparatively smaller number of studies have involved playing pre-recorded sounds to participants on-site (Anderson et al. 1983; Pilcher et al. 2009).

Experiments relating to recreational settings have not focussed so much on measuring impacts, but have, instead, helped park managers understand the relationship between sound and the visitor experience. In some cases, such experiments have yielded information on the level of sound that is likely to be acceptable, information that lends itself well to the setting of limits or standards. In one study, Pilcher et al. (2009) carried out an on-site experiment at Muir Woods National Monument, California, to help formulate standards for visitor-created sounds in the park. Using a sound booth in a room adjacent to the park visitor centre, researchers played a series of five 30-second audio clips to visitors, through noise-cancelling headphones. The clips included natural sounds, such as running water, squirrels and ravens, and varying levels of visitor-created sound. Respondents were asked to rate the acceptability of each clip on a scale from −4 (very unacceptable) to +4 (very acceptable). Respondents' results for each of the five audio clips were averaged and graphed against the intensity of visitor-created sound in each clip. The resulting 'social norm curve' was found to cross the neutral point of the acceptability scale at 37 dB, meaning that, on average, respondents found that visitor-created sound at levels above 37 dB was unacceptable. Respondents were also asked which of the five audio clips was most similar to their actual experience; 14.6% of respondents chose audio clips 3 or 4, which had sound levels of 39 and 46 dB respectively—both above the acceptability threshold of 37 dB. This impression was confirmed by actual measurements taken during the study period, which suggested that the level of visitor-created sound sometimes exceeded the acceptability threshold, potentially affecting the quality of visitor experience.

For recreationists, simulation experiments have the advantage that, depending on the methodology chosen, respondents do not have to be intercepted in the field. This eliminates the potential for disruption to their experience, and is particularly useful for remote and wilderness areas where visitors may only be present in low numbers and dispersed over a wide area, making it impractical to capture them on-site. It is potentially a cost-effective way of assessing the likely impact of different sounds. In front-country settings, it may be practical and cost-effective to carry out experiments on-site.

The question of whether the simulated conditions accurately recreate conditions on-site is a potential pitfall of this methodology. However, there is evidence that this may not be a significant problem, at least for respondents with prior knowledge of the site in question. Aasvang & Engdahl (2004) found similar responses from subjects who were exposed to aircraft overflights on-site and subsequently to the same sounds in an experiment simulating outdoor exposure. Freimund et al (2002) found that more than 75% of respondents in their study indicated that video simulations had served as useful reminders of their visit and helped them to articulate their norms for varying numbers of watercraft, noise from aircraft and motorised boats, and levels of facility development. The standards developed were also consistent with other studies conducted in back-country areas (Freimund et al. 2002).

The usefulness of such approaches for wildlife is less clear-cut, although there is a long history of studies examining the behavioural and physiological responses of animals to sound. Pater et al. (2009: 792) cautioned that 'sound reproduction systems are limited in their ability to produce the full frequency spectrum and temporal aspects of a noise source, particularly low frequency sound and rapid-onset transient sound events'. This may mean that animals do not respond to recorded sounds in the same way they would respond to the actual sound in the wild. Further, recorded sounds may not reproduce the effect of a moving sound source and they do not include visual cues such as the shape of an aircraft in the sky (Pater et al. 2009).

2.4.4 Noise modelling

The use of noise-modelling software to predict the likely amount of sound present at a given location and time is widespread in the management of noise from commercial airports. One such tool, the FAA's Integrated Noise Model (INM), was reported as having over 800 users in more than 40 countries in 2005 (Fleming et al. 2005). However, the application of such techniques to monitoring the effects of noise on either recreationists or wildlife is comparatively rare. Limiting factors are high cost, the requirement for specialist skills, and technical issues with modelling sound propagation from moving sources over large areas containing vegetation and complex terrain. Despite this, noise modelling techniques are potentially useful, as it may only be possible to employ other methods (such as on-site monitoring of sound levels) at a small number of sites within an area of interest. Noise modelling is especially useful when linked with geographic information systems (GIS).

One place where noise modelling has been undertaken is Grand Canyon National Park, where noise from air tours has been a long-standing issue (Hatch & Fristrup 2009). Visitor experience has been the key driver for this work, although there are specific locations within the park where there are concerns about impacts on birdlife and where acoustic monitoring of overflights has been carried out to quantify the level of exposure to sound (Rodgers 2009). Legislation in the USA requires the NPS and FAA to develop a plan to manage air tours above the Park that will succeed in 'substantially restoring the natural quiet of the park' (Miller et al. 2003: v). This is defined by the NPS as '50% of more of the park achieving natural quiet (no aircraft audible) for 75–100% of the day' (NPS 1994: 9.3). Noise modelling is seen as the only practical means of determining whether this has been achieved (Miller et al. 2003).

Initial efforts to measure the impact of overflights involved the NPS sponsoring development of a computer model: the NPS Overflight Decision Support System (NODSS) (Reddingius 1994, cited in NPS 1994). Using information on the numbers, routes, altitudes and equipment types of flights, the NODSS modelling software indicated that in 1989 just under 35% of the area of Grand Canyon National Park could be categorised as either having 'natural quiet' (0.49%) or 'substantial restoration of natural quiet' (33.94%). Forecasts were also able to be made based on different management scenarios, and the model indicated that if quieter aircraft were not introduced, and operations continued to increase as forecast, by 2010 the area categorised as having either 'natural quiet' or 'substantial restoration of natural quiet' would be reduced to approximately 10% of the Park (NPS 1994). Further work since then, including the development of an overflight management plan for the Park, has been hampered by disagreement and litigation over appropriate models and the legal definition of 'substantial restoration of natural quiet'. However, extensive modelling carried out using the INM, and confirmed by on-site acoustic monitoring at more that 40 sites in the Park, has found that aircraft noise is audible throughout the Park for > 30% of daylight hours (Hatch & Fristrup 2009).

Elsewhere, modelling and mapping of visitors' exposure to sound has been carried out along the Bear Lake Road corridor in Rocky Mountain National Park, Colorado (Park et al. 2009). For this study, four types of data were collected during the peak visitation period of the 2008 northern summer. The volume and type of road traffic was collected using automated traffic counters at three locations in the Park, while sound level data were collected at seven locations over 8 days. With the exception of one sound level meter that was located close to the road, measurement points were chosen to represent a range of environments within a typical day's hike from the trail heads. Information on visitor use was collected through mechanical visitor counters and by issuing global positioning system (GPS) units to a randomly selected sample of visitors over a 13-day period.

These data enabled researchers to graphically depict the average daytime sound levels across the Park alongside the intensity of use of particular trails within the Park's trail network. The study also provided information relating to the likely visitor experience in relation to various sound level thresholds ranging from 25 to 65 dB(A). Useful data included the average length of time and distance that it would take a hiker on each track to reach the nearest area that was within a particular noise threshold, the percentage of each track that was within a particular noise threshold and the percentage of hikers on each track who would experience at least 15 minutes of sound within a given threshold. While no specific standards for soundscape quality had been developed for Rocky Mountain National Park at the time the study was carried out, this information was considered to be useful for determining the effects of future management scenarios, such as changes to vehicle access or shuttle services within the area.

2.4.5 Response measures with no sound measures

Other measurement techniques can be grouped under the broad category of 'response measures with no sound measures'. Many observational studies of wildlife behaviour would fall into this category. For recreationists, typical approaches include surveys that enquire about respondents' sensitivity to noise, general likes and dislikes, or the effect of particular noise-generating activities on their experience. These techniques, along with qualitative methods, such as the use of diaries, can be collectively called 'psychological approaches' (Gramann 1999).

A common technique used in protected areas has been to enquire about recreationists' opinions of a range of sounds that are potentially audible in protected areas to determine which sounds are likely to require management. For example, a study carried out at campsites in three national parks in Queensland, Australia, assessed respondents' levels of annoyance with ten sounds of natural and human origin (Beal 1994). Visitors' responses to these sounds were recorded on a five-point scale ranging from 1 ('very pleasant') to 5 ('very annoying'). The natural sounds of 'birds, insects and animals' and of 'wind in the trees' were rated as the most pleasant and received average scores of less than 2. Some human sounds, such as 'wood being chopped', 'people setting up camp' and 'people talking quietly', received a neutral (3) or lower rating, indicating a general acceptance among respondents of these sounds. The sounds of loud radio or televison, both at night and during the day, were found to be keenly disliked by an overwhelming majority of respondents and were a more significant source of annoyance than 'people yelling or playing games' or 'car noises at night'. Understanding the relative levels of annoyance with different sound sources allows park managers to gain an indication of the particular noise sources that may require management, and this can be achieved without the requirement of potentially expensive accoustic monitoring or other methods described above. However, Pater et al. (2009: 789) cautioned that 'reporting animal responses without meaningfully quantifying the stimulus events limits the utility of results and prevents their application for predicting animal responses to sound in other situations'. The same is no doubt true for studies of recreationists.

2.5 SUMMARY

The distinction between sound and noise is ambigious. Sound is a sensory stimulis that results from pressure waves caused by the vibration of a solid object (Smith 2001). Noise is a subjective evaluation of sound and can refer to sound that is unwanted or inappropriate. A second definition of noise refers to signal noise or extraneous sound that masks other sounds in the environment.

A number of factors influence the effect of noise on recreationists and wildlife in natural settings. The physical properties of a sound—its intensity, pitch, frequency and variation—and environmental factors such as weather, topography and levels of ambient sound, affect the characteristics of a sound when it reaches the listener's ear. Sounds are also subject to an individual's characteristics, such as their physiological hearing capability and their sensitivity to sound. For recreationists, factors such as attitudes, expectations, values and past experience can influence the response to sound either positively or negatively. Likewise, wildlife responses are influenced by species-specific responses to disturbance, habitat, lifecycle stage and previous exposure to noise disturbance.

Various methods are available to measure the impact of noise on wildlife and recreationists. These include sound measures with no responses measures, dose-response studies, simulation experiments, noise modelling and response measures with no sound measures. A variety of studies are available that detail the practical application of these techiques to the management and monitoring of noise impacts.

3. Understanding the psychology of noise impacts on recreationists

Noise is inherently psychological, since a sound must be deemed unacceptable to be considered noise. But what is considered noise by one recreationist may be music to another (Bell et al. 2009). The psychological impacts of noise on recreation experiences are usually framed as recreation conflict issues, where the actions of some people's activities affect the experiences of others (e.g. Bell et al. 2009). In the literature, the process of goal interference (Jacob & Shreyer 1980) is widely considered to be the most substantial theoretical basis for understanding recreational conflict (e.g. Ruddell & Gramann 1993; Ramthun 1995; Watson 1995). It is used here as a useful framework for discussing and understanding how noise affects recreationists and their recreational experiences.

3.1 NOISE, CONFLICT AND GOAL INTERFERENCE

Goal Interference Theory

Goal Interference Theory assumes that people undertake recreational activities to achieve certain outcomes or goals, and defines conflict as interference in achieving these goals attributed to another's behaviour (Jacob & Shreyer 1980). When noise interferes with the expected benefits of spending time in natural settings or from other aspects of the visitor's desired experience, then goal interference (i.e. conflict) occurs between the listener and the individual or group responsible for the noise. According to Goal Interference Theory, there are four factors that are usually linked in some way to the development of conflict: activity style, resource specificity, lifestyle tolerance and mode of experience. Brief exploration of each factor highlights some of the ways that conflict situations can develop from noise.

Activity style encompasses the personal meanings an individual assigns to a particular recreational activity. This includes the importance of an activity to an individual: that is, whether the activity is a central life interest or something that is only done occasionally; the status they and others give the activity, based on their skill and experience; and their ideas about the quality of an experience based on their prior experience (Jacob & Shreyer 1980). In a noise context, Goal Interference Theory would predict that an experienced kayaker who paddles every weekend may be more annoyed by the presence of a noisy jet boat than a novice because of the greater importance of the activity of kayaking and because the novice may have little prior experience of kayaking in silence and may perceive the presence of the jet boat as being normal. Similarly, it is thought that first-time visitors are generally less sensitive to noise than repeat visitors because new visitors may consider what they encounter during their visit to be normal and appropriate (Knopf 1983, cited in Gramann 1999).

Resource specificity refers to the significance an individual attaches to using a given recreation resource for a particular experience. This is based on concepts such as the visitor's perception of the quality of the resource, their feelings of place attachment, or their sense of 'ownership' of the resource and the status they impart upon themselves based on their intimate knowledge of the area (Manning 1999). For example, a climber who regularly climbs in a particular location may feel that it is the best, quietest or most scenic place to go climbing, or simply derive status from knowing the area well. According to Goal Interference Theory, such an individual would be more likely to experience negative effects from an aircraft overflight than a novice climber or someone who is new to the area. The experienced climber might have a more negative reaction to noise in this location, while being more tolerant of it in a different setting (where his or her sense of resource ownership and 'value' for the place is lower). Differences in reactions to noise, based on previous wilderness experience, also fall under the category of resource specificity. Tarrant et al. (1995) proposed that aircraft overflights would be evaluated more negatively by visitors with high levels of wilderness experience because experienced users favour environments that are primitive and natural, with minimal evidence of human impacts, and that contain fewer people.

Lifestyle tolerance refers to an individual's tendency to reject or accept lifestyles or activities different from their own preferences. It encompasses ideas such as prejudice and views about appropriate uses of resources and technology. It follows that individuals with low levels of tolerance to noise or pre-existing views of the appropriateness of mechanised activities in protected areas may react in a negative way to noise from passing aircraft, boats or vehicles. The same event may not trigger the same response from individuals who are more tolerant of such activities.

Mode of experience refers to how people experience the natural environment. Visitors' activities can be described along a continuum from focussed to unfocussed appreciation of the setting. To demonstrate, the natural surroundings are important to both a passenger in an aircraft flying over a national park and a mountain biker riding along a track within that national park. However, the attention of these individuals may be focussed on a different spatial scale to, say, a bird watcher or a hiker who stops to look at the morning dew on a spider web. The experience of the latter is more enclosed and direct, and perhaps more intimate with their immediate natural environment. As the mode of experiencing the environment becomes more focussed, it relies increasingly on complex sensory stimuli. At this point individuals tend to develop more rigid ideas about what sights and sounds are acceptable, and they become less tolerant of other external stimuli that do not conform to their ideal. Essentially, Goal Interference Theory assumes that individuals will become more conflict prone as they move from unfocussed to focussed modes of interaction with their environment (Jacob & Shreyer 1980).

It has been suggested that these four factors affect an individual's sensitivity to conflict more than the actual stimulus experienced (Manning 1999). This helps explain why different individuals perceiving the same level of sound can be more sensitive to and more annoyed by it than others.

Once goal interference occurs, it can lead to either diminished satisfaction, annoyance or the employment of various coping behaviours by the individual, such as rationalisation (cognitive adjustment to align with encountered conditions), displacement (spatial or temporal shift) or product shift (changing behaviour or activity to reflect the conditions encountered rather than the individual's prior expectations) (Manning 1999).

3.1.1 Empirical applications

The four causal factors highlighted in Goal Interference Theory are generally prominent in research on the effects of noise in recreational settings. Visitors' prior expectations and experiences relating to both the place (resource specificity) and the activity (activity style) have been found to have a large effect on sensitivity to noise. Using data from dose-response surveys undertaken for the NPS, Anderson et al. (1993) found that first-time visitors were considerably less sensitive to aircraft sound than people who had visited the site before. The researchers calculated that the sound intensity would have to be two to three times higher for sites containing only first-time visitors to produce the same percentage of annoyance responses as sites containing only repeat visitors. This is consistent with Goal Interferance Theory, which predicts that individuals who attach less significance to both the place and the activity they are undertaking are less likely to experience conflict (in this case conflict with those using aircraft).

An earlier NPS study (NPS 1994) found that back-country visitors were far more likely to hear, and be affected by, aircraft than front-country visitors. However, the difference in the amount of aircraft activity to which back-country users were exposed was only one of a number of possible factors that might explain the difference. In a later study, Miller (1999) found differences in annoyance levels between two types of front-country visitors: visitors who had committed time to walking along a 'short hike' trail (or a day tramp) reported far more annoyance or interference with natural quiet from the same level of sound than visitors who had walked only a short distance to a viewing point. Miller speculated that visitors who commit some time to a particular park experience are likely to be more sensitive to the intrusions of aircraft noise than visitors who invest less time visiting more accessible sites. Goal Interference Theory predicts that the greater the degree of importance and specificity an activity holds for an individual, the greater their susceptibility to annoyance by noise while undertaking that activity. The greater amount of time invested by back-country visitors could imply that their activity holds a greater degree of importance than it does for front-country visitors. The ROS is based on a similar premise. It predicts that back-country visitors will be more negatively affected by mechanised noise than front-country visitors because, as settings become more natural and less developed, visitors expect less contact with the sights and sounds of people.

Other studies have highlighted specific elements of the setting as being important in individual judgements of site quality. The presence of vegetation in a setting has been shown to have an effect on visitors' expectations of environmental quality to the extent that human and mechanical sounds are evaluated as being more detracting in these settings. This has been found to occur even in settings that are heavily modified by humans, such as landscaped gardens, residential streets and urban parks (Anderson et al. 1983).

Unlike activity style and resource specificity, lifestyle tolerance has attracted little attention from researchers, but mode of experience may explain many of the observed responses to noise. One of these is the reduction in reported annoyance that has been observed to occur with increasing group size, as mentioned previously. In addition to the increased level of ambient noise and involvement in foreground tasks (such as talking to other group members), visitors in larger groups may be engaged in a comparatively less-focussed mode of experience than those travelling alone or in smaller groups. As well as experiencing the natural environment, they could also be focussing on visual and aural stimuli from their immediate group. On the other hand, a number of studies have indicated that visitors seeking tranquillity, peace and quiet, and solitude are likely to be in a more focussed mode of experience than those who are not (see Anderson et al. 1993; Tarrant et al. 1995; Mace et al. 1999), and, hence, have a lower tolerence to noise.

Focussed modes of experience, and particularly the concept of tranquillity, are closely linked with the idea of 'natural quiet'—the sounds of nature. Studies have shown that people place a high value on natural quiet and that it is a key reason for people to visit protected natural areas. Driver et al. (1987) gathered data from studies of 12 gazetted and non-gazetted wilderness areas and 3 non-wilderness areas to examine the preferences respondents had given to 16 different 'preference domains'. Across the studies, escaping noise and crowds ranked fourth in importance behind enjoying nature, physical fitness and reducing tensions. An American study of 15 000 visitors to various NPS units found that 91% of respondents considered that enjoyment of natural quiet and the sounds of nature were compelling reasons for visiting national parks (McDonald et al. 1995, cited in Mace et al. 2004). Clearly, the potential for noise to intrude on these important experience preferences is high.

In both laboratory and field studies, respondents consistently prefer natural sounds to the sounds of people and technology (Kariel 1980; Beal 1994; Carles et al. 1999), and, in recreational settings, a large number of visitors actively seek natural quiet. Yet it is this experience that is put most at risk and is closely linked to visitors' levels of annoyance with noise. Extensive studies undertaken at Grand Canyon, Haleakala and Hawai'i Volcanoes National Parks (Anderson et al. 1993) found that visitors who rated natural quiet as a 'very important' or an 'extremely important' reason for visiting a site were more sensitive to aircraft noise. Visitors who did not regard natural quiet as being important required twice the sound level of those who regarded it as being important to register the same annoyance response.

3.2 OTHER RELEVANT THEORIES AND CONCEPTS

Other recreation theories and concepts can also help explain why noise may adversely affect recreationists' experiences. One concept, Attribution Theory, describes the process whereby the listener attaches meaning to a sound and attributes it to a particular source. In doing so, the listener considers whether the sound is harmful or helpful and makes inferences about its purpose and those responsible for the sound. This theory provides another means of explaining the annoyance reaction: attributing a potentially annoying event to a cause that is stable or consistent and which is controllable by a perpetrator should lead to increased annoyance, whereas attributing the same event to a cause that is rare, not controlled by a perpetrator, or that involves benevolent motives should lead to less annoyance and fewer negative evaluations (Mace et al. 2003). For example, in recreational settings, a search and rescue helicopter might be viewed differently to a sightseeing flight of equal loudness, as the former is more of a one-off event and has a benevolent purpose. Having attributed the sound to a particular source, the listener will then make a judgement about the appropriateness of the sound to the setting that they are in. Other contextual factors, such as the listener's state of mind, whether they are enjoying their trip, or are already annoyed by something else when they hear the sound, and group dynamics are all likely to play a role in influencing how the sound impacts them.

Other useful concepts relate to the way in which noise can potentially detract from the benefits that recreationists expect from their chosen place or activity. Commonly cited benefits sought by visitors to natural areas include stress reduction, natural quiet, scenic appreciation and solitude.

Stress reduction is a well-established benefit from visiting natural settings (e.g. Driver et al. 1987) that has various theoretical explanations:

- **Arousal Theory** suggests that recovery from psychological and physical stress occurs more quickly in natural compared with built environments, because natural environments contain fewer arousal-increasing stimuli such as complexity, intensity and movement (Ulrich et al. 1991). In contrast, the level of complexity and the number of stimuli found in urban environments may overtax the brain's information processing ability and may slow the recovery from stress (Gramann 1999).
- **Attention Restoration Theory** centres on the effects of natural environments on reducing mental fatigue or, more specifically, 'directed attention' fatigue caused by prolonged mental effort. An important part of the theory is the idea that attention can be either involuntary or directed. Involuntary attention describes a process where attention is captured by inherently intriguing or important stimuli and which is essentially effortless. Directed attention (also known as voluntary attention) occurs when attention is directed by cognitive control processes (Berman et al. 2008). Natural settings are thought to be restorative environments that are able to induce involuntary attention (also known as fascination), allow reflection (Kaplan 1995) and restore an individual's capacity for directed attention (Berman et al. 2008). This may occur because, unlike urban environments, natural settings are likely to have fewer stimuli that capture the attention dramatically (e.g. car horns) and which then require directed attention in order for the stimuli to be dealt with (e.g. traffic). Put simply, natural environments allow people to 'switch off', allowing the brain's capacity for directed attention to recover while it is not being used for busy day-to-day tasks.
- **Psycho-evolutionary theories** suggest that because humans originally evolved in a natural environment over a long period of time, we still have a degree of psychological and physiological adaptation to natural rather than built settings. This means that we have a predisposition to respond positively to these environments or elements of them, such as water sources, that were important for our survival and well-being in pre-modern times. This holdover from our past allows us to derive benefits from these environments, such as increased recovery from stress (Ulrich et al. 1991; Gramann 1999).

It follows that non-natural sounds could adversely affect stress reduction by adding to the complexity or number of stimuli, by directing the listener's attention towards the artificial sound and out of a state of involuntary attention or by causing the setting to be perceived as being less natural.

Natural quiet is the most obvious value associated with visiting natural areas that can be affected by noise. This is especially the case when associated with focussed modes of experience. However, **appreciating landscapes and enjoying scenery** are also major reasons why people visit natural areas, and a number of studies have shown how noise can interfere with those desired experiences. These include on- and off-site evaluations of sound. Anderson et al. (1983) found that natural sounds (including those from wildlife) enhanced evaluations of heavily wooded natural and residential sites, and that other sounds detracted from them.

Carles et al. (1999) used projected slides and pre-recorded sound to show how scenic images and sound interact in determining people's perceptions of the quality of landscapes. The emotional meaning attributed to a sound and the extent to which it matches the setting, or is congruent with the visual information visitors receive, all determine an individual's degree of liking for a particular landscape. Mace et al. (1999) simulated conditions in the Grand Canyon using slides of scenic vistas accompanied by combinations of natural sounds and helicopter noise. Respondents' ratings of the scenic beauty of the landscape as well as six other factors (preference, freedom, naturalness, solitude, annoyance and tranquillity) were significantly negatively affected by helicopter noise at both 80 dB(A) and 40 dB(A). This method was repeated in further simulations by Mace et al. (2003) with similar results. Benfield et al. (2010) repeated the same experiment with a wider range of human and natural sounds and with images from five national parks. They found that the presence of any anthropogenic sounds from air traffic, ground traffic or human voices negatively impacted environmental assessments, and more so at louder levels. These experiments illustrate that congruent or incongruent visual and acoustic information can affect the visitor's appreciation of scenery and landscape.

Solitude is another benefit that can be strongly affected by noise. Both Tarrant et al. (1995) and Mace et al. (1999) found strong correlations between noise and lower levels of perceived solitude.

Overall, although an individual's underlying sensitivity is an important factor in determining whether someone is annoyed by noise, it does not exclusively determine whether they will categorise a sound as annoying. At the moment when a sound is perceived, it is weighed against the visitor's previous experience, motivations, expectations, values, pre-existing attitudes and their activity-experience at the time.

3.3 SUMMARY

Physical and socio-psychological factors interact to affect an individual's response to sounds in recreational settings. Socio-psychological factors such as visitors' previous experiences and expectations, underlying values, and attitudes are important to consider. Annoyance with noise in natural areas can also be caused when noise interferes with benefits sought by visitors such as natural quiet, stress reduction, scenery and solitude. Understanding such factors is important for successfully managing and monitoring the effects of noise on recreationists.

The theoretical concepts discussed in this section help to provide an appreciation of the complex nature of the relationship between noise impacts and recreational experience. They reinforce the interconnection between external stimuli and recreationists' personal characteristics and values. Conceptualising noise as a driver of recreational conflict links noise to the range of factors known to affect recreational experience, and helps identify possible means by which these factors can be managed. Importantly, for managers of protected areas, these concepts help to explain why recreationists in natural settings are particularly susceptible to noise impacts, especially if the noise and its source are unexpected, and if they are visiting areas more associated with the natural and wilderness settings of the ROS.

4. Measuring the impact of noise on recreationists in New Zealand's protected areas

This section discusses the methodologies used in the New Zealand research literature that has reported noise effects on recreationists and describes their application. It focusses on noise generated by the recreation and tourism sectors (e.g. flightseeing) within protected areas because this has been the emphasis of the research, much of which has been funded by DOC. The section begins with a general overview of research and monitoring, followed by measurement methods.

4.1 AN OVERVIEW OF NOISE MONITORING AND RESEARCH

For over 25 years, researchers have studied the effect of mechanised recreational noise on visitor recreational experiences (and other values) at a variety of DOC-managed locations. These include the mountain summits of Tongariro National Park (Gibson 1992), remote back-country areas in the Tararua and Kaweka / Kaimanawa Forest Parks (Groome et al. 1983), the mountains of Aoraki/Mount Cook National Park (Gibson 1992), Milford Sound/Piopiotahi and the Milford Track in Fiordland National Park (e.g. O'Neill 1994), coastal areas of Abel Tasman National Park, and Fox Glacier/Te Moeka o Tuawe (henceforth Fox Glacier) and Franz Josef Glacier/Ka Roimata o Hine Hukatere (henceforth Franz Josef Glacier) of Westland *Tai Poutini* National Park (e.g. Sutton 1994, 1998; Oliver 1995).

Early research raised the issue of aircraft noise, leading to some basic research and monitoring and the consequent realisation of the need for consistency of measurement. This culminated in the development of a Standard Aircraft Monitor (SAM) technique in 1997 and the ensuing application of SAM at multiple sites. In tandem, site-specific research using different methods continued in some areas.

More specifically, research and monitoring focussed on noise impacts emerged in the mid-1990s as a result of four streams of work:

- A West Coast Tai Poutini Conservancy initiative to assess visitor perceptions of aircraft noise at Fox and Franz Josef Glaciers, Westland Tai Poutini National Park (see Sutton 1998).
- The inclusion of recreational noise amongst the social impact issues addressed in a large-scale social research programme for the Great Walks (see Cessford 1999, 2000).
- Initial attempts to develop a system for mapping 'natural quiet' across areas managed by DOC, with some supporting work commissioned (e.g. Kappelle 1999).
- The development of a simple monitoring tool to measure recreationists' perceptions of aircraft noise at any specific site (refer Booth et al. 1999) and its early applications at Aoraki/Mt Cook National Park. This work developed into SAM (see section 4.2).

Results from SAM applications and other research reinforced the significance of aircraft noise as an issue for many sites. The information generated through these studies fed into discussions between DOC and the broader tourism industry (including noise generators)[7], DOC's stakeholders and in various other forums (including planning hearings). More recently, some programmes monitoring the impact of noise have been embedded into certain DOC policy and planning documents (such as the Fiordland National Park Management Plan; DOC 2007), providing a basis for evaluating the effects of noise and for decision making (in relation to aircraft activity landings in particular).

Another recent approach has been the use of Limits of Acceptable Change (LAC) or similar methodologies (see Booth & Espiner (2006) for a discussion of these approaches in a New Zealand context). These programmes have brought together representative groups of stakeholders to identify values or threats to values and to generate indicators and standards of acceptability for a range of management issues including noise-generating activities. Indicators, such as the level of annoyance or number of aircraft overflights have then been monitored (e.g. through on-site surveys), the findings reported back to the stakeholder group and management options discussed. These methods have been employed in relation to aircraft at Mason Bay in Rakiura National Park (Wray et al. 2005), and to aircraft, boats and vehicle traffic at Milford Sound/Piopiotahi in Fiordland National Park (Lindis Consulting 2008; Booth 2010), although the focus of studies at both locations has been much wider.

Despite the high level of research interest over a long period, much of the work carried out in New Zealand on the effects of noise on recreationists exists as unpublished grey literature. Findings from some of the early investigations were presented as a set of papers at the International Symposium on Recreation Noise held in 1998 in Queenstown (see Holger (1999) for the published proceedings) and some were published as standalone publications (e.g. Cessford 1997a, b, 1998a–i). However, very few studies relating to noise impacts on recreationists in New Zealand have been published in the last 10 years. Overall, the focus of

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[7] 'Noise generator' means aircraft (fixed wing and helicopters), motor vessels and any other type of human-related activity that generates noise within recreational settings.

New Zealand research has been predominantly on practical applications of SAM at a variety of DOC sites (see Appendix 1 for a summary of these applications). Other research has been carried out to address questions and issues outside the scope of the simple monitoring tool (see Appendix 2). Findings from this research collective are discussed in the following sections.

4.2 NOISE MONITORING WITH SAM

Most noise monitoring undertaken by DOC has been based on the SAM questionnaire mentioned in the previous section (see Appendices 3 and 4). The purpose of SAM was to help identify those areas where aircraft noise may be compromising the quality of visitor experiences. This was achieved through a questionnaire that comprised two parts. First, open-ended[8] questions asking respondents what they liked and disliked generally were presented in order to elicit 'top of mind' responses. Second, direct, closed-ended questions probed specific issues, asking respondents to score their annoyance levels with selected social impact issues, including aircraft noise. This approach was operationalised through development of a formal standard operating procedure (SOP) that provided practical application specifications for staff to follow. By 2010, SAM had been used at more than 20 locations around New Zealand. These locations generally mirror the distribution of the scenic flight industry in New Zealand, which is based around Aoraki/Mt Cook and Westland *Tai Poutini* National Parks, Queenstown, Te Anau and, to a lesser extent, Rotorua and the Bay of Plenty (Westwood 2002).

The SOP sets a threshold at the 25% annoyance level following US National Parks Service (NPS) thinking at that time (NPS 1994) and earlier studies in New Zealand by Oliver (1995) and Sutton (1998). Responses from any user sample that recorded annoyance levels greater than this threshold were to trigger a management response. Usually this would involve consultation between park managers and noise generators to consider the issue and discuss options to address noise effects. Nine sites have exceeded the indicative threshold of 25% to date, representing less than half of the total number of locations at which SAM has been administered. They are:

- Chalet (1) and Roberts Point (2) lookouts in the Franz Josef Glacier valley in Westland *Tai Poutini* National Park
- Mueller Hut (3) and four high alpine huts (4) in Aoraki/Mount Cook National Park
- Gertrude Valley (5) in Fiordland National Park
- Hollyford Track (6) in Fiordland National Park
- Homer Hut (7) in Fiordland National Park
- Milford Foreshore (8) at Milford Sound/Piopiotahi in Fiordland National Park
- Milford Track (9) in Fiordland National Park

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[8] An open-ended question seeks a written (free) response. A closed-ended question provides response options (e.g. tick boxes or a numerical scale).

While SAM was developed for studying aircraft noise, it has been adapted for application to jet boat noise; for example, on the Dart River/Te Awa Whakatipu in Otago (Graham 1999), and the Hollyford (Kleinlangevelsloo 2005) and Wairaurahiri (Harbrow 2007b) Rivers in Southland.

The SAM questionnaire was designed to enable non-specialist staff to carry out the monitoring and analyse the results locally. In some cases, increased local understanding (as a result of SAM work) has promoted proactive changes by noise generators to reduce their noise effects. In other cases, there has been debate about the wording of questions (e.g. whether the wording leads the respondent or has inherent bias). Debate on such matters is, however, to be expected for any type of monitor, especially those used against a backdrop of politically charged planning/legal debate—such is the case with aircraft management (see Tal 2004). The commitment to repeated use of a consistent survey tool and methodology has allowed some DOC managers to track the change in levels of aircraft annoyance over periods of up to 10 years.

Although SAM has been successful in drawing problem areas to the attention of DOC and its stakeholders, it has a number of practical limitations. As a monitoring tool designed for non-specialist staff to apply consistently at a variety of sites, it can only use a simple and short question set. It focusses on a simple annoyance measure and does not probe further into why and how visitors are annoyed. Nor does it address the concept or the importance of 'natural quiet'. There have also been some practical issues of administration inconsistency where SAM has been applied to respondents in different ways at different sites, where the wording of some questions has been altered, and where key variable definitions used in data analysis have been implemented in different ways. The standard of reporting has also varied widely. Achieving commitment to standardised application of SAM without engaging in site-specific 'tweaking' has been a challenge.

Overall, this simple indicative tool has been an effective means of creating targeted dialogue between managers and stakeholders, and has resulted in some cases of positive outcome and some cases of dispute. In each case, however, using SAM has advanced dialogue and focussed the debate.

A revised version of SAM was administered in Fiordland at several sites in the late 2000s to monitor the provisions of the Fiordland National Park Management Plan relating to Milford Aerodrome (Harbrow 2007a, 2008; Oyston 2010a). The revised questionnaire was wider in its scope; aircraft noise was only one of the factors about which respondents were questioned.

4.3 DOSE-RESPONSE STUDIES

To date, dose-response assessment methods (described in section 2.4.2) using sound monitoring equipment have not been applied in New Zealand. This is because such monitoring requires specialist knowledge and equipment that, in the past, has been relatively expensive. Instead, New Zealand studies have used simpler dose measures based on estimates of the daily or hourly frequency of aircraft activity.

Since 1996, five dose-response studies have been carried out in the glacier valleys of Westland Tai Poutini National Park. These have used a variety of indices for the dose, but the response has been measured more consistently, with four of the studies having used SAM. There has been little consistency in findings between surveys, and only two of the studies have provided potential annoyance thresholds that could be used to support management actions.

In the initial study carried out at Fox and Franz Josef Glaciers, Sutton (1998) compared visitors' reported levels of annoyance with aircraft to the number of flights observed by surveyors during the hour prior to them being surveyed. The findings indicated that levels of annoyance were relatively low and unchanging up to 14 flights per hour, increased slightly between 14 and 18 flights per hour, and rapidly increased above 18 flights per hour.

The four subsequent studies were undertaken at the Chalet and Roberts Point Lookouts, and the Franz Josef and Fox Glacier valleys. These studies compared a variety of measures of dose with responses from SAM. In the 2003 survey, the mean annoyance scores of respondents who noticed aircraft were compared with the daily number of flights sourced from information provided by aircraft operators (DOC 2003). The combined average annoyance scores for Franz Josef Valley and Roberts Point Lookout were found to be only weakly correlated with aircraft activity, increasing only slightly with increasing numbers of aircraft. Surprisingly, there was a strong negative correlation for the combined Fox Valley and Chalet Lookout data, which has not been evident in more recent studies. The measure of response in this survey only included the small number of respondents who both noticed and were annoyed by aircraft. Each data point on the dose-response graph therefore only represented a small number of respondents and could be easily skewed by extremely high or extremely low annoyance scores. The 2004 study compared the average number of flights per hour for each survey day with the more reliable metric of the percentage of respondents who were annoyed (DOC 2004). However, with only three or four survey days per site, the data were extremely limited.

Further improvements were made in 2005 and 2009. These surveys used an estimate of the number of aircraft overflights experienced by each visitor based on detailed records of flights provided by operators and on the recommended track times for each site. Estimated doses (flights per hour) for individual respondents were then grouped into categories. In the 2005 survey, clear and site-specific dose-response relationships were found, and site-specific thresholds were recommended for a maximum number of hourly flights. For the glacier valleys, the recommended limits were 20 flights per hour, while, for the adjacent lookout walks, the recommended limits were 13 flights per hour (DOC 2005). In 2009, however, there was no correlation between the average number of flights per hour and the level of annoyance (DOC 2009). Despite the limitations of the data, some mitigation measures have been put in place at the glacier valleys by both aircraft operators and DOC as result of the monitoring carried out to date (DOC 2009).

Only one dose-response study has been carried out outside of Westland Tai Poutini National Park. Again using SAM, Tourism Resource Consultants (2000) explored the relationship between the mean level of annoyance at Milford Sound/Piopiotahi and on the Milford Track with the total daily number of aircraft movements at Milford Aerodrome. The dose-response relationship was very weak, but it was suggested that this may have reflected the narrow range of doses, which, for the 9 sampling days, were between 108 and 212 flights per day. Furthermore, as there are multiple flight paths into Milford Sound/Piopiotahi, the number of movements observed at the aerodrome may not have been an accurate indicator of the dose over the Milford Track.

The various dose-response studies carried out to date have yielded useful results, although there have been challenges around choosing appropriate methodologies and metrics for both dose and response, and challenges in applying them consistently. Importantly, both methods of obtaining information on the frequency of overflights, on-site counts by observers and self reports by aircraft operators have potential limitations. In surveys in Fiordland National Park, it has proven difficult at times for surveyors to count aircraft while administering surveys, especially when based at a busy location such as a carpark or road end. Also, some overflights that are experienced by visitors on a track may not be apparent from the locations where overflights are counted. Where studies rely on self reports by aircraft operators, there is potential for operators to understate their activity, particularly where there is a perceived advantage to them in doing so (i.e. where the results of a study could be used to limit their activity). It is important to note, however, that there is no evidence that this has occurred in any of the studies carried out to date. The strength of these studies has been that they have avoided the expensive, time consuming and technically demanding use of sound monitoring equipment in outdoor settings.

4.4 OTHER QUANTITATIVE APPROACHES

At some locations in New Zealand, rather than employing SAM, a variety of predominantly closed-ended questions have been used to measure respondents' perceptions of recreational noise from aircraft and other sources. One approach has been to use a simple yes/no question. Squires (2007) asked respondents who were climbing in the vicinity of Mt Aspiring/Tititea whether they had seen any helicopter landings at Bevan Col during their trip and whether seeing helicopter landings had negatively affected their visit. This was followed by an open-ended question asking respondents to describe how helicopter landings had impacted their visit. Overall, 27% of those who had seen landings (or 13% of all respondents) indicated that they were negatively affected by helicopter landings. This approach is likely to be easy for respondents to understand and is relatively easy to analyse; however, a limitation of using a yes/no approach is that it does not allow the degree of annoyance to be measured.

The Great Walks survey programme (Cessford 1997a, b, 1998a–i) has provided the most extensive New Zealand dataset about recreationists' perceptions of noise. It included over 5000 respondents in 11 standardised surveys on New Zealand's most popular multi-day walks, a multi-day river canoeing trip and a multi-day sea kayak trip. Respondents were asked whether they noticed, and were annoyed by, a variety of potential impacts, including noise from aircraft, boats, and other people in huts and campsites. Respondents were asked if they had noticed the impact, and, if the answer was yes, whether it bothered them and by how much (a little or a lot). This represented an awareness-annoyance question that combined awareness, tolerance and annoyance responses (see Cessford 1999, 2000). The results gave insights into the tolerance or sensitivity of different types of recreationists to noise in different settings. They also allowed for comparison with results from the Grand Canyon, USA, thus enabling issues at New Zealand sites to be viewed in a wider context.

Reported annoyance levels for noise effects exceeded 25% (the recommended management threshold) at six sites: the Milford Track (69% from aircraft and 33% from other people in huts), Abel Tasman coast (sea kayakers: 53% from boats on the water/at beaches; 33% from boats near huts/campsites), the Whanganui River (34% from boats on the river), the Routeburn Track (32% from aircraft), the Abel Tasman Coast Track (30% boats on the water/at beaches; 25% from other visitors in huts), and the Kepler Track (30% from other people in huts).

In addition to highlighting the significance of New Zealand recreational noise issues within an international context, Cessford (1999) offered options and strategies for managing noise (including managed separation, reduced noise effects and improved visitor expectations). All of the management approaches Cessford identified have been used in New Zealand (including voluntary agreements, concession conditions, management regulation, education and advocacy, incentives for quiet choices and design for quiet). Evaluation of the application of these management approaches in New Zealand warrants further investigation.

Corbett (2001) used a similar question format to the Great Walks surveys for visitors at Franz Josef Glacier. Corbett found that 22% of non-guided respondents and 25% of guided respondents showed some level of concern at hearing aircraft in general. Fewer than 1% of guided respondents showed any degree of concern with helicopters dropping off walkers on the glacier.

Two surveys have used an ‘encounter norms’ approach to gauge levels of aircraft and/or boat activity that were deemed acceptable to recreationists. At Siberia Valley in Mt Aspiring National Park, Squires (2008) asked respondents to indicate the level of daily activity (for both planes and helicopters) that would be acceptable before it had a negative effect on the enjoyment of their trip. Respondents were provided with a range of categories and more than 90% of them were able to indicate a level of acceptable activity. For both planes and helicopters, a level of 3–5 flights per day was deemed acceptable by the majority of respondents.

In Fiordland, M. Harbrow and K. Wray investigated noise acceptability levels in relation to Doubtful Sound/Patea sea-kayaker expectations of non-natural noise and encounters with various types of boats and aircraft (M. Harbrow & K. Wray, unpubl. data). The study used pre- and post-visit surveys to assess respondents’ expectations and actual experience of aircraft, surface water activity and non-natural noise. The pre-visit questionnaire results showed that many respondents did not anticipate encountering boats or aircraft during their visit: 41% did not expect to encounter motorised boats and similar numbers did not anticipate seeing fishing boats (47%), cruise ships (53%) or aircraft (46%). The post-visit survey found that 40% of respondents encountered more motorised boats than expected and 26% encountered more mechanical noise than expected. By themselves, these findings do not necessarily indicate that these noise-generating activities had a negative or unacceptable effect; however, a sizeable number of visitors made negative comments about surface water activity and motorised noise when asked to indicate the most dissatisfying aspects of their visit.

Kayakers' tolerances of aircraft and surface water activity were assessed by asking respondents to state the number of aircraft and boats/ships that they considered to be acceptable to encounter in a day. Respondents were not comfortable with the idea of seeing or hearing aircraft. Just one aircraft was deemed unacceptable by almost two-thirds of overnight kayakers and almost 40% of day kayakers. Tolerances for boats were higher: for overnight kayakers, the median value was two boats per day, and, for day kayakers, three boats per day. Similar to findings from the Siberia Valley study, over 90% of respondents, when prompted, were able to specify the number of encounters that they deemed to be acceptable (M. Harbrow & K. Wray, unpubl. data).

There are some criticisms of the encounter norms approach in the international literature. Norm prevalence (i.e. the percentage of respondents giving a norm) has been found to differ between front-country and back-country, the type of encounter (conflict v. non-conflict situations) and between different question formats (Donnelly et al. 2000). This could have implications for the utility of the approach in some settings. Furthermore, the approach only works if respondents can realistically visualise the hypothetical situations that they are being asked to comment on. For the Doubtful Sound/Patea study, surveys were distributed by commercial guides, who may have had strong opinions about boat activity in the area, creating the potential for respondents' answers to be influenced.

4.5 OTHER QUALITATIVE APPROACHES

In some New Zealand visitor surveys (including SAM), general and open-ended satisfaction/dissatisfaction questions have been used to complement the assessment of noise impacts. These types of questions have served to provide voluntary responses from visitors about issues of specific concern to them. This method has been suggested as an alternative to SAM by some stakeholders who have concerns about what they believe to be potential question bias.

In response to an open-ended question in Corbett's (2001) study of visitors to Fox and Franz Josef Glaciers, 1% of respondents mentioned aircraft as an aspect of their visit that they disliked. Most respondents either indicated that there was nothing that they disliked or left the question blank. However, responses to direct questioning about aircraft in the survey indicated a much higher level of concern (over 20%). Similarly, surveys undertaken in Fiordland National Park found that the percentage of respondents reporting annoyance with aircraft in SAM questions was as much as 7–8 times higher than the percentage indicating dissatisfaction with aircraft in an unprompted, open-ended question. Non-response rates were much higher for the open-ended question, especially for day-visitor sites, where they ranged between 21% and 35% (Harbrow 2007a). Analysis of results for open-ended and closed-ended questions from SAM applications at Aoraki/Mount Cook was inconclusive with respect to any correlation between levels of response and the question style.

Response rates for open-ended questions have typically been lower than those for closed-ended questions in New Zealand noise research, and it could be concluded that general/open-ended questions are an unsuitable method for investigating specific impact issues. In terms of their suitability for evaluating the significance of noise impacts, open-ended approaches suffer from several short comings. The requirement to code[9] responses introduces a degree of subjectivity, which is compounded when different people undertake coding from year to year, as is likely to be the case in a long-term monitoring programme. Open-ended questions are more difficult for respondents to answer and are more likely to be skipped than closed-ended questions, which, for example, only require a respondent to tick a box (Hall & Roggenbuck 2002). Some common open-ended formats (e.g. 'What did you like the least about your visit?') are designed to elicit either a single response or a limited range of responses and are not sensitive enough to register all of the issues that might negatively impact the visitor's experience. Finally, by not prompting a respondent to consider any particular issue in detail, responses to open-ended questions may be superficial in that they may reflect more recent events or events that were on the respondent's mind at the time they were surveyed. In the benchmark report by the NPS (NPS 1994), the authors noted that, in order to understand visitor reactions to aircraft, visitors must be questioned specifically about aircraft, and that this needs to be done close to the time of the experience.

One New Zealand study has used an open-ended question format, but directly asked respondents about noise. Parr (2003) asked recreational users of the Abel Tasman National Park coast to list any noises that intruded on their experience. Overall, 34% of respondents reported some intrusive noise sources, most of which (29% of all respondents) were from power boats. These results indicate a much higher response rate than has been obtained through more general question formats and the approach may reduce some, but not all, of the limitations of open-ended questionning mentioned above.

A range of more complex open-ended approaches (e.g. interviews and focus groups) are possible and these are potentially very useful where more in-depth information is required or where survey methods are impractical. However, to date, the use of such techniques for noise research in New Zealand has been extremely limited. One in-depth qualitative study was carried out in Fiordland National Park in 2005. As part of a wider study looking at the importance and meaning of wilderness to wilderness users, Wray (2009) used a combination of qualitative research diaries and in-depth interviews to explore the effects that aircraft overflights and landings had on visitor experience in remote and wilderness settings. Respondents were given diaries to complete during their trip and asked to keep a daily log of their experiences and observations. They were also asked to make a note of anything that contributed positively to their experience or, conversely, anything that had a negative impact. A number of respondents also participated in follow-up interviews.

The responses provide valuable insight into the complex nature of recreationists' responses to noise-generating activities. They provide a number of concrete examples of the theories detailed earlier in this report (see sections 2 and 3).

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[9] Coding refers to the grouping of responses into like categories during analysis.

Although a small number of respondents highlighted positive aspects of aircraft access to wilderness (such as allowing greater, easier or safer access, enabling access by people with limited time, allowing users (especially hunters) to carry in more equipment, and allowing search and rescue services to operate), a considerable number of the comments were against aircraft and other forms of motorised transport in wilderness. Some respondents highlighted aircraft as a source of disturbance, indicating that aircraft had, for example, taken away the feeling of isolation, jolted them out of their wilderness experience, spoiled their mood and sense of isolation or detracted from the naturalness of the setting. Other responses highlighted the importance of factors other than sound exposure. They related to judgements about the aircrafts' occupants, the purpose of the flights or the appropriateness of aircraft in that setting. For example, some respondents felt that aircraft undermined the concept of wilderness and the values that it embodied, encouraged increased use, thereby raising the potential for social and biophysical impacts, enabled less-experienced people to access risky and dangerous areas, or allowed people to access wilderness with little effort when self reliance and challenge were aspects that were clearly valued by wilderness users. Importantly, the study revealed a number of situations where aircraft use could potentially be viewed more favourably by wilderness users. These included aircraft that passed through quickly, infrequently or at high altitude, aircraft involved in conservation management (including deer control and facilities management), search and rescue, and aircraft being used by people akin to and engaged in similar activities to those on the ground (Wray 2009). This information is potentially extremely valuable for managing the effects of aircraft in remote and wilderness areas. Overall, this study allowed a level of understanding of visitors' responses to aircraft that was difficult to obtain through other methods.

4.6 MODELLING NOISE PROFILES

Modelling noise in outdoor settings has also not been common in New Zealand. The only two attempts made to date looked at aircraft noise on the Milford Track and around Milford Sound/Piopiotahi. For both the Milford Track and Milford Sound/Piopiotahi, Hunt (1999) modelled likely noise doses based on terrain, known flight paths and typical aircraft noise levels. This information was plotted onto a map, allowing predictions to be made about areas most likely to receive higher doses of aircraft noise. On the track, those areas generally corresponded with the higher altitude sections where walkers were physically closer to the aircraft. This information was useful in encouraging voluntary changes in flight paths that were subsequently adopted by aircraft operators. At Milford Sound/Piopiotahi, a L_{dn} 65 dB noise contour was recommended around Milford Aerodrome, Fiordland National Park for land use planning purposes (Hunt 1999). For the second study in 2006, an acoustics consultant was contracted by DOC to model the arrival/departure sound intensity levels of nine commonly used aircraft types at a number of points along the main flight paths (N. Hegley, Hegley Acoustic Consultants, unpubl. data). This information was subsequently used in policy development for the Fiordland National Park Management Plan (DOC 2007).

4.7 SUMMARY

A number of studies have explored noise impacts on recreationists in New Zealand. Most of this research has been funded by DOC, and has used different techniques to address noise effects on recreationists in specific locations within protected areas. SAM, which is perhaps the longest running visitor-based social monitoring tool used by DOC, has been the most widely used tool. Other approaches have included a variety of open- and closed-ended survey questions, encounter norms, simple dose-response studies using SAM alongside counts of aircraft and noise profiling. New methods of response measurement have also been explored via qualitative approaches in remote sites where direct survey-based approaches are impractical. One aim of this research and monitoring has been to improve managers' abilities to understand and set limits on noise-generating activity, but decisions have been highly contested, particularly those relating to aircraft. Some recent monitoring programmes have seen a greater emphasis on stakeholder engagement, including the use of LAC and similar approaches. It is hoped that such approaches will result in a better understanding of the values of individual sites and greater stakeholder buy-in to both the measurement tools and DOC's management decisions.

5. Understanding the impact of noise on wildlife

This section summarises the international literature on wildlife responses to noise-related disturbance. Noise from human activities has become increasingly pervasive. For example, in 2009 more than ten million scheduled passenger flights arrived in or departed from the United States alone (Bureau of Transportation Statistics 2010) and there are large areas of the lower 48 states that are potentially affected by noise from aircraft flight paths (Miller 2003). Because noise knows no boundaries, protected areas do not necessarily guarantee animals or recreationists refuge from its effects. A 1994 NPS report suggested that approximately 30% of all National Park System units (excluding those in Alaska) have aircraft overflight problems (NPS 1994), while acoustical monitoring has revealed chronic noise exposure even in remote wilderness sites (Barber et al. 2009). Artificial noise also affects the marine environment. Ambient noise levels at frequencies below 100 Hz in the deep ocean have increased by an estimated 15 dB since 1950 due to motorised shipping (Aguilar Soto et al. 2006) and the global commercial shipping fleet almost tripled from 30 000 vessels in 1950 to 85 000 vessels in 1998 (Hatch & Fristrup 2009).

There are now numerous published and unpublished reports addressing disturbance of wildlife from aircraft and boat noise, and a much larger number of publications related to general disturbance issues within which noise is a component. These range in scientific validity from well-designed, rigorous studies to observational reports and anecdotal evidence from natural resource managers and aircraft pilots (NPS 1994). Despite this body of work, the adverse effects of noise and disturbance generally on wildlife is difficult to assess. While it is possible to measure short-term responses, even when there are obvious sub-lethal effects, such as changes in behaviour, it is not possible to say that the observed responses are detrimental to the population, without being able to link them to long-term changes in breeding success, mortality, population size or fitness. Even then, it may be difficult to isolate the effects of noise disturbance from other contemporaneous environmental factors (e.g. changes in the availability of food, presence of disease and level of predation). The literature described below reflects this problem, with many studies describing short-term responses to noise but only a handful describing the long-term impacts.

5.1 NOISE AS A FORM OF WILDLIFE DISTURBANCE

Noise is one component of visitor or vehicle presence that could disturb wildlife in their natural habitats. For example, wildlife may respond to the size, speed or sudden appearance of aircraft rather than only to the noise it creates. Visitor activities differ in their potential to generate noise and related disturbance. Walkers, bicycles and vehicles on tracks, roads and rivers have spatially-confined noise-related disturbance effects. Species that are dependent on the marginal zones around such tracks, roads and rivers have greater potential to be affected by such activities. However, noise from aircraft overflights and boat or ship activity has the potential to affect far wider ranges of habitat.

The most comprehensive overview of wildlife disturbance is provided in Knight & Gutzwiller (1995), which includes an account of wildlife responses to disturbance from recreationists. In the same volume, Bowles (1995) discusses noise issues. There are several other reviews relating to effects of specific noise sources such as aircraft (Manci et al. 1988; Pepper et al. 2003) and road noise (Kaseloo & Tyson 2004) or to the effects of noise in particular environments, such as underwater noise (Richardson et al. 1995).

The following discussion of these impacts focusses primarily on the behavioural responses of wildlife to noise-related disturbances, and the potential consequences of these responses for both the well-being of the affected animal and wider species sustainability.

5.2 IMPACTS OF NOISE ON WILDLIFE

The impacts of noise-related disturbance on wildlife are determined by the threat-response characteristics of the species and situational factors such as wildlife habitat type, life cycle stage and previous exposure to and disturbance from noise (NPS 1994). In addition, the variation in characteristics, duration and frequency of noise adds complexity to any impact relationships. Variations in both noise and species characteristics can result in a range of effects on wildlife—the most extreme resulting in major impacts. These include effects ranging from direct physical damage (e.g. to hearing), increased physiological stresses (e.g. from increased energy expenditure or reduced energy accumulation) or from the consequences of their behavioural responses (e.g. attraction, tolerance, aversion and flight) (NPS 1994). Noise can also have an indirect effect; for example, through changes to the quality of an animal's habitat. These effects are discussed below.

5.2.1 Direct physical damage

As in humans, the auditory systems of animals are susceptible to physical damage from noise (Bowles 1995). Although aircraft noise and its effects on animal hearing have not been tested, and there are no data on permanent noise-induced hearing loss for marine mammals (Erbe 2002), it has been found that motorcycle noise has caused hearing loss in desert species such as the desert iguana (Bondello 1976) and kangaroo rat (Bondello & Brattstrom 1979). Noise-induced hearing loss typically occurs as a result of hair-cell loss in the inner ear, although the relationship between hair-cell loss and hearing loss is complex. Intense noise can also damage underlying membranes, supportive tissue and nervous tissue (Bowles 1995). Hearing loss can be either temporary or permanent, depending on the level of exposure and the fragility of the animal's hearing system. In mammals, including humans, loss of hair cells in the inner ear is permanent, but other animals (including birds and amphibians) can regenerate hair cells (Bowles 1995). Chronic exposure to noise is rare for wildlife because of animals' threat-avoidance mechanisms and because high levels of human-made noise are uncommon in natural areas. Most acute exposures are, at worst, brief or occasional.

5.2.2 Behavioural responses

The main wildlife responses to noise-related disturbances fall under either tolerance or aversion/flight behaviours.

Tolerance

The ability for species to habituate is thought to be the most important determinant of their success in the presence of noise disturbance. Habituation refers to a reduction in the strength of a response to a stimulus over time after repeated exposure, where the consequences of the stimulus are neither adverse nor beneficial (Bejder et al. 2009). Although the process can be slow (Marsh et al. 1991), some birds, for example, can adjust to noise disturbances. In the long term, it has been found that some nesting birds become less responsive to the presence of human disturbance if they are not deliberately harassed (Burger & Gochfeld 1981; Knight et al. 1987). Motivation to find food can also make animals tolerant of even deliberately generated noise. Some authors (Shaughnessy et al. 1981; Bomford & O'Brien 1990; Marsh et al. 1991) have concluded that human attempts to use noise to drive wildlife away from attractive sites (e.g. crops) do not succeed in the long term due to habituation. Some animals are even attracted to noise through curiosity or its association with food opportunities, a process known as food conditioning. Attraction and food conditioning can have negative consequences for an animal. Individual animals can put themselves in danger from human activities such as hunting or accidental hazards such as collisions with vehicles. Apparent tolerance and an absence of an obvious behavioural response, however, do not necessarily indicate that there is no impact on a particular individual or species. Many animals cease activity (at least initially), freeze or feign death in response to disturbance, and some have shown dramatic increases in heart rate and other physiological changes while at the same time showing no outward changes in behaviour (Nimon & Stonehouse 1995).

Aversion/flight

Studies have identified the following types of aversion/flight behavioural responses to noise: collisions with aircraft (Burger 1985; Dolbeer et al. 1993), flushing of birds from nests or feeding areas (Owens 1977; Kushlan 1979; Burger 1981; Andersen & Rongstad 1989; Belanger & Bedard 1989; Cook & Anderson 1990; Conomy et al. 1998), alteration in movement and activity patterns of mountain sheep (Bleich et al. 1990; Weisenberger et al. 1996; Krausman et al. 1998), swimming behaviour change in whales (Erbe 2002; Patenaude et al. 2002), overproduction of adrenalin in feral house mice (Chesser et al. 1975), and habitat displacements from activities such as aircraft overflights, snowmobiles, traffic on logging roads, construction noise, military training activity and walking visitors (Richens & Lavigne 1978; Eckstein et al. 1979; Edge et al. 1985; Krausman et al. 1986). An additional complexity is the clear difference between species' responses, with some research showing certain species are more overtly responsive than others (e.g. Thiessen et al. 1957; Edwards et al. 1979).

In general, the mildest responses of mammals cannot be distinguished from simple signs of noise detection such as ear twitching or increased vigilance. But, as the intensity of their response increases, animals may alter their activity by walking slowly away, freezing, crouching, making an intention to run, engaging in mild aggression, or increasing their flocking or herding behaviour. The most intense responses are often associated with more extreme behaviours, such as panicking, urinating or defecating, and running at high speed. Birds show a similar range of responses to mammals from being alert at the mildest level, to showing an intention to fly, pecking at each other, broken-wing displays (to act as a distraction in the hope of protecting nestlings) and walking, swimming or flying short distances. Marine mammals demonstrate reactions including changes in behavioural state, short surfacings, immediate dives or turns, vigorous swimming and breaching (Patenaude et al. 2002). In contrast, many species of reptiles and amphibians freeze in response to noise (Bowles 1995).

Just as they can become habituated to noise, animals can also become sensitised to disturbance where it becomes associated with negative consequences for the animal (Bejder et al. 2009). Animals that are sensitised develop a stronger response to noise with repeated disturbance; for example, fleeing further and faster each time or responding to noise at progressively lower levels.

At the more extreme range of responses, individual animals or flocks will respond with panic flights or running. Such panic flights are often stated as the most directly dangerous of startled responses to human-made noise. Panic induced by the approach of noisy disturbances is known to cause egg loss in some colonial birds (Bunnell et al. 1981; Hunt 1985) or to frighten some birds into colliding with human-made structures such as power-lines (Blokpoel & Hatch 1976). Anecdotal evidence suggests that mammals sometimes abandon newborn young when frightened by the close approach of a noisy disturbance, or that birds such as penguins stampede in panic, although reports are rare and such incidents are difficult to observe (Bowles 1995; Harris 2005). Studies have, however, shown that animals rarely display uncontrolled flight, and that species that normally run or fly away in response to being frightened do not usually injure themselves when carrying out such a normal behaviour (Bowles 1995). While such panic responses may not be as serious for wildlife as they might appear to the human eye, the indirect effects (such as cumulative habitat displacement) from sustained disturbance may cause longer term problems for individuals and overall populations.

The process through which short-term avoidance can change to long-term displacement from a disturbed area is complex. It is ultimately determined by a variety of factors in addition to the strength of the stimulus and the history of exposure. These factors include the physical quality of the site that the animal is occupying, the distance to and quality of alternative sites, the relative risk of predation or density of competitors, and the investment (e.g. establishing a territory) that an individual animal has already made in that site (Gill et al. 2001). There is also an energetic cost to relocating to another area. Some animals may stay in an area despite repeated disturbance if they lack sufficient body condition and cannot expend energy to shift to another location (Bejder et al. 2009). To an observer, however, they may appear relatively unaffected by noise disturbance.

5.2.3 Physiological effects

The sudden sight and/or sound of aircraft and other human disturbances can trigger an animal's 'fight or flight' response. Several studies have documented an increase in heart rate occurring in species exposed to low-altitude overflights (MacArthur et al. 1982; Weisenberger et al 1996; Krausman et al. 1998). The fight or flight response is characterised by a number of physiological changes brought on by the release of stress hormones into the blood stream. The animal's metabolism, heart rate and respiration rate all increase, blood flow is diverted away from the digestive system and skin to the muscles, brain and heart, while blood temperature and blood sugar levels also increase. These changes improve the animal's chances of survival in situations where prolonged strenuous activity may be required, such as fighting or running away (Gabrielson & Smith 1995).

Repeated exposure to noise and triggering of this response can lead to chronic stress and this may have negative consequences for affected animals (NPS 1994). Bowles (1995: 126) suggested that 'prolonged physiological stress and energy expenditure would eventually compromise the health of animals by suppressing immune function, making them more susceptible to infection and parasites, altering growth, and by slowing recovery from food shortages'. Stockwell et al. (1991) suggested that aircraft overflights affected the food intake of bighorn sheep while Harris (2005) reviewed a number of examples of physiological stress outcomes from aircraft interactions with birds in the extreme environment of Antarctica.

Laboratory experiments on rats have linked noise exposure to hypertension, elevated levels of cholesterol, increased atherosclerosis, reductions in body weight, changes in immune response, disruption of cells in the lining of the intestine, all potentially leading to an increased susceptibility to disease (Baldwin et al. 2006) and decreased thyroid activity (Manci et al. 1988). Likewise, lactation has been shown to decrease or cease altogether in dairy cows in response to noise exposure (Manci et al. 1988) and this would result in offspring having decreased body mass and disease resistance. Other studies have implicated noise in increased miscarriage rates in mice and caribou and decreased pregnancy rates in mice (Manci et al. 1988). However, some caution is needed in applying results from experimental studies, as noise doses used in the laboratory may not relate to levels experienced by animals in the wild.

Some concerns have been expressed that animals that are disturbed by noise may suffer from energy losses at times when it is important for them to be storing energy critical for their survival. In the winter months, for example, animals may have greater energy requirements for daily activities, such as keeping warm and feeding. They may have little extra energy available for threat avoidance. During other seasons, energy is required for basic activities such as breeding, migration or raising young. It is possible, therefore, that some species may require special protection during certain life-stages or periods of the year (NPS 1994).

Stress responses such as increased heart rate or energy consumption are, however, an everyday occurrence for wildlife facing a variety of threats and other environmental stimuli. The question of whether the added stresses from noise-related disturbances significantly harm animals is difficult to assess. This is because it is not easy to comprehensively measure the energy balance of animals to determine precisely whether the added energy burdens of noise-related threat avoidance are sufficient to significantly harm wildlife. While noise is suspected to be associated with stress-related illness in both humans and animals, it has been difficult to prove a causal link (National Research Council 1981; Federal Interagency Committee on Noise 1992; Bowles 1995). Physiological stress on its own is difficult to assess. When stress is expressed through related behavioural responses by wildlife, the significance of noise impacts is more pronounced and its consequences more clearly understood. Where stress occurs in the absence of an obvious behavioural response, the significance of noise disturbance may be overlooked.

5.2.4 Indirect effects

Animals can be affected indirectly by noise through changes to the acoustic environment. Many animals rely on their hearing to provide them with information about their surroundings, and an animal's vocalisations can be used to coordinate a wide range of activities including feeding, mating and courtship, care of young, predator avoidance, and maintenance of territories. Animals that use echolocation, such as bats and some marine mammals, may be particularly vulnerable to changes in their acoustic environment, as could social animals that rely on vocal communication for the cohesiveness of their group. Animals may be negatively affected if noise drowns out these important sounds, a process known as 'masking'.

Masking occurs when noise interferes with the perception of a sound of interest (Bowles 1995: 119). Among the effects of masking are increases in signal detection thresholds, impaired recognition of signals and decreases in the ability of a listener to differentiate between different types of signal (Bee & Swanson 2007). Masking is not limited to human sounds and can occur as a result of the normal range of biotic and abiotic sounds encountered within an animal's natural environment, such as wind, rain, waterfalls or the vocalisations of other animals (Brumm 2004). Many species have developed adaptations to compensate for the masking effect of noise in their natural environment (Brumm & Slabbekoorn 2005). Birds, for example, compensate for attenuation of sound caused by terrain and vegetation by choosing a spot to listen and sing from that minimises its effects (Bowles 1995), and it is likely that this adaptation also reduces the effects of masking. Some animals have calls that have a dominant frequency higher than that of the predominant background noise in their environment, enabling their vocalisations to stand out more (Brumm & Slabbekoorn 2005). Despite their adaptations, however, animals may be naive to human-produced sounds or they may be unable to cope with their particular characteristics (e.g. frequency, duration and intensity). This may have consequences for animals if they are unable to detect predators, warn off competitors or find a mate.

Animals can also show a number of short-term behavioural responses to compensate for a degraded acoustic environment. Some animals will simply practice avoidance and will leave the area entirely (Bowles 1995). Alternatively, they may shift to a location, within their immediate area, where they are better able to hear or be heard or which offers better protection from predators. Another option is to increase their level of vigilance or the degree to which they rely on other senses to compensate for the reduction in or lack of auditory cues. A number of examples of these responses are described in the literature. Quinn et al. (2006) found that foraging chaffinches (*Fringilla coelebs*) increased their level of vigilance in response to controlled doses of background white noise by decreasing the period of time between head-up scanning bouts. They effectively spent more time looking for visual cues and less time feeding. This was believed to be due to the birds perceiving themselves to be at increased risk from predation rather than being a reaction to the noise stimulus itself. Rabin et al. (2006) studied the behavioural response of California ground squirrels (*Spermophilus beecheyi*) to played back alarm calls at two sites in the Altamont Pass Wind Resource Area in Northern California. The sound of wind turbines was found to at least partially mask the animals' alarm calls, blocking out the lower frequencies and reducing the distance over which the calls were effective. Squirrels at the turbine site were found to be more vigilant than those at the control site and this occurred even before playback of alarm calls commenced. They also had a tendency to return to the area immediately around their burrow, presumably to be closer to a safe refuge. They appeared to perceive a higher level of predation risk than animals at the control site and adjusted their behaviour accordingly. This was despite the study recording no difference in the actual number of predators at the two study sites.

Several studies have demonstrated how animals can change the strength, nature or frequency of their calls in response to artificial noise. Brumm (2004) studied the calls of common nightingales (*Luscinia megarhynchos*) in Berlin, Germany, and found that males in noisier territories sang louder than those in quieter localities. This was not related to the size or weight of birds. Slabbekoorn & Peet (2003) measured the song characteristics of 32 male great tits (*Parus major*) in an urban environment in The Netherlands and found that birds sung with a higher minimum frequency in noisier territories, compared with birds in quieter territories. In the noisier territories this had the effect of reducing the degree to which their song was masked by the predominantly low-frequency noise that was present. Likewise, a study of three populations of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in Japanese waters suggested that dolphins inhabiting an area with higher ambient noise (including noise from boats) produced whistles of a lower frequency and with less variation in frequency. The dolphins were thought to be selecting communication signals that were not likely to be masked by background noise (Morisaka et al. 2005). Brumm et al. (2004) found that common marmosets (*Callithrix jacchus*) increased both the sound level and the duration of their call syllables in response to increasing levels of background white noise. Increasing the signal duration is thought to increase the likelihood of the signal being detected by other birds. Some birds have also been found to increase the number of syllables and therefore the level of redundancy within calls in response to increasing background noise, which may also increase the probability of a call being heard (Brumm et al. 2004). It is possible, however, that many animals lack the ability to change their communication signals in response to noise, as the ability to do this has only been demonstrated in a limited range of species (Barber et al. 2009).

Some studies have linked the indirect effects of noise, including masking, with outcomes for particular species. Quinn et al. (2006) found that the increased vigilance response of chaffinches to background noise resulted in fewer pecks and, therefore, reduced food intake. They suggested that this would have fitness consequences for the animals. Sun & Narins (2005) studied an assemblage of frog species in central Thailand and found that when frogs were exposed to noise from aircraft overflights and playbacks of motorcycle sounds, the calling rates of three of the most acoustically active pond-edge species decreased, while rates for one species increased. This was thought to have implications for populations because the reproductive output of individual frogs is directly proportional to calling effort in many species.

Habib et al. (2007) found differences in the pairing success of male ovenbirds (*Seiurus aurocapilla*) at two types of human-modified sites associated with oil and gas production in boreal forest in Alberta, Canada. The locations included in the study had comparable levels of habitat modification and edge effect but sound levels differed. At some sites, compressor stations produced a continuous sound level of 75–90 dB(A), while at other sites well pads produced no chronic noise. The study found a significant reduction in birds' pairing success at compressor station sites compared with birds at the quieter well pad sites. These differences occurred irrespective of the quality of either the individual males or their territories. Significantly more inexperienced birds breeding for the first time were found near compressor sites compared with well pad sites. It was suggested that noise from the compressor stations interfered with the male's song, making it audible to females over a comparatively shorter distance than for birds at well pad sites. It was proposed that this could then reduce the chance of encounters between male and female birds, reducing pairing success. The authors also suggested that females could perceive males at the noisier sites as being of lower quality due to artificial noise distorting their songs. The findings of this study were thought to have wider implications for the amount of high-quality breeding habitat available to ovenbirds and other passerines in light of the scale and predicted growth of oil and gas production in the region.

While the amount of research on the indirect effects of noise on wildlife has been relatively modest in comparison with the level of research effort focussed on direct behavioural and physiological responses, these studies illustrate that the indirect effects of noise are clearly biologically important. Masking may be detrimental because an animal's response (such as changing its vocalisations) may have an energetic cost or because it may increase an individual's exposure to predation (Brumm 2004). Alternatively, there may be impacts on animals as a result of aural cues, such as warning calls or the sound of an approaching predator, being drowned out. The overall significance of the indirect effects of noise is difficult to assess, as such effects are often subtle and difficult to measure.

5.2.5 Overall cumulative effects on wildlife populations

Persistent human or predator disturbance is known to cause decline in the productivity of colonies of birds (Anderson & Fortner 1988), although it is unclear whether noisy disturbances have the same effect. Bowles (1995) concluded that noisy disturbances may affect activity and energy consumption, but the effect is moderated by behavioural and physiological adaptation and habituation, which are thought to keep animals from expending energy and attention on responding to harmless stimuli.

Projections using population models probably offer the best opportunity to determine what, if any, population effects are occurring. However, such work needs to be comprehensive and include various population parameters such as age, productivity and mortality, as well as addressing other situational factors such as changes in animal density, effect exposure characteristics, long-term adaptation to disturbance, and the effects of general environmental changes.

5.3 APPROACHES TO MITIGATE THE IMPACTS OF NOISE ON WILDLIFE

Some precautionary management actions are noted in the literature as a means to mitigate effects of noise-related disturbances to wildlife. While this report does not address management responses per se, the management actions are listed here because they have been generated by the researchers addressing this topic (see, in particular, Bowles 1995; Knight & Gutzwiller 1995; Harris 2005). The mitigation methods are directed at limiting the negative behavioural effects or limiting the cumulative physiological effects on wildlife (research interest in the indirect effects of noise on wildlife is a comparatively recent development).

Procedures to limit negative behavioural effects include:

- Keeping sources of noise from approaching animals on direct courses. This method could allow approach limits to be reduced.
- Making noise sources predictable. For example, vehicles could be limited to roadways, boat ways, and specified flight paths at predictable times; aircraft could fly at constant distances without rapid changes in direction.
- Stopping approaches if animals react with avoidance, defensive behaviours or aggression.
- Gradually habituating animals to noise. In areas where animals will be exposed frequently, some active effort to habituate naive individuals could protect them from panic. This will not help animals made skittish by predators.
- Altering noise to make it less annoying. A meaningless masking noise might help mitigate effects of meaningful noise.
- Altering noise to make it less attractive. A particularly attractive noise could be removed altogether, or it could be masked by broadband noise.

Procedures to limit cumulative physiological effects include:

- Limiting cumulative exposure to noise to protect animal hearing.
- Limiting the cycle and duration of noise to allow recovery between exposures.
- Eliminating or reducing meaningful threat noises. For example, silencing boat motors in areas where hunters shoot birds from boats.

- Limiting cumulative exposure to harassment. For example, restricting aircraft approaches during periods when animals are under greatest predator pressure.
- Providing safe cover in areas where noisy human activities are common. Cover will increase the sense of control over disturbance.

5.4 SUMMARY

The literature on noise-related disturbance to wildlife suggests that there is no simple or generalisable relationship between noise and its effect on wildlife. Assessments of impacts from noise-related disturbance are specific to individual species and settings and, therefore, require considerable research. It is apparent that the behavioural responses that are the most pronounced and easiest to study may not necessarily be the ones that have the greatest consequences for the viability of populations. Unlike the previous section on noise effects on recreationists, there is no single unifying theory that helps to explain the effects of noise on wildlife.

6. Studies of noise effects on New Zealand wildlife

This section synthesises research and monitoring of noise impacts on wildlife in New Zealand's natural areas. It is not restricted to protected areas for several reasons. First, wildlife are mobile and do not recognise park boundaries. Second, research effort in New Zealand has not been focussed on protected areas (in contrast to noise-related recreation research). Third, in contrast to its mandate to foster recreation within the areas that it administers, DOC has an advocacy role for biodiversity throughout the country.

In New Zealand, most attention has focussed on the effects of boats and aircraft on cetacean species (i.e. whales and dolphins), with some attention given to aquatic birdlife. Emphasis has been on non-consumptive wildlife tourism. The focus on cetaceans may result from the attention they receive from motorised boats and aircraft engaged in the growing wildlife-watching tourism industry, and because they are particularly susceptible to noise impacts, given they rely on sound for navigation, communication and prey detection. This focus also reflects the unusual characteristics of the New Zealand native fauna. While many of the international studies described above have examined the effects of noise on terrestrial mammals, New Zealand has no native land mammals apart from two rare bat species.

6.1 EFFECTS OF NOISE ON CETACEANS

A large amount of New Zealand cetacean research has been sponsored by DOC. Much has specifically addressed issues of boat and aircraft disturbance, with some studies having focussed specifically on noise.

Comprehensive reviews of international literature on cetaceans' responses to anthropogenic noise have been carried out (Reeves 1992; Richter et al. 2001; Richter et al. 2003). These include details of noise effects on a number of whale and dolphin species that are also found in New Zealand. While a variety of different behavioural responses to noise have been documented, ranging from avoidance to attraction, it is difficult to generalise about the effects because the response varies within species and between individuals. Complicating factors include the physical characteristics of the noise, the local environment and its effect on sound and audibility, differences in sensitivity between individual animals, the animal's age and sex, degree of habituation, and the activity the animal is undertaking at the time of measurement (e.g. calving, resting or feeding).

Richter et al. (2001) concluded that most studies had focussed exclusively on short-term impacts of boat interactions, while long-term effects were not understood. Effects such as changes in behaviour, blow interval or vocalisation rate were identified, but studies did not link them to important parameters at the population level, such as reproductive output or population growth. Although it is clearly established that cetaceans will often avoid noise from sources such as boats and aircraft, it is difficult to tell whether the noise from those sources results in harm to these animals.

6.1.1 Studies of underwater noise levels

Four New Zealand studies have measured underwater noise directly to determine what levels cetaceans may be exposed to from different sources. Using a hydrophone, Baker & MacGibbon (1991) found that, even when a helicopter was flying directly above the instrument at an altitude of 150 m, it was not detectable to humans listening from underwater. In contrast, the noise of a tour boat 100 m from the hydrophone drowned out the vocalisations of a whale that had just dived, and was extremely loud to human ears.

Marrett (1992) placed a hydrophone at a depth of 75 m to measure the intensity of the noise produced by boats, aeroplanes and helicopters passing directly overhead and to assess the noise levels likely to be experienced by whales. It was concluded that these sources were not likely to produce noise levels that cetaceans would find problematic in most cases. Among the exceptions discussed were situations where sudden noises, such as those generated by an aircraft 'buzzing' a pod of surfaced whales, could trigger avoidance behaviour. It was recommended that to reduce the potential for noise disturbance, aircraft should distance themselves from the pod and circle around it rather than fly directly overhead.

These findings were reinforced by Gordon et al. (1992) who, using a hydrophone placed 1 m below the surface, concluded that sound waves travelling through air (e.g. from an aircraft) and intercepting the sea surface at an angle less than about 45° would be almost completely reflected. On the other hand, aircraft noise underwater would be at a maximum level when an aircraft was directly overhead.

Helweg (1993) studied dolphins, which are thought to be sensitive to a different range of sound frequencies than whales. A hydrophone was used to measure the acoustic profiles of boats involved in commercial 'swim with dolphin' tour operations. The measurements showed that starting a vessel's engine or increasing its speed shifted sound into the frequency range that dolphins are able to hear, potentially having an impact on dolphins' communication and echolocation.

6.1.2 Studies of whale and dolphin behaviour

Some New Zealand studies have examined the behavioural effects of boats, aircraft or tourism generally on particular species. Noise is likely to be a component in many of these interactions but, in most cases, it has not been isolated from other potential sources of disturbance such as visual effects, movement, boat wake or the risk of physical injury from collisions with vessels. While behavioural responses to boats and aircraft have been documented, they have been found to be species, individual and context specific.

*Sperm whales (*Physeter macrocephalus*)*

Studies have concentrated on the interactions between sperm whales and whale-watching boats at Kaikoura. Findings have documented various behavioural changes amongst the whales in the presence of boats and, to a lesser extent, aircraft. These changes include alterations to breathing patterns (Baker & MacGibbon 1991; Gordon et al. 1992; Richter et al. 2003), time spent on the surface (Baker & MacGibbon 1991; Gordon et al. 1992), directional swimming behaviour (Baker & MacGibbon 1991; Richter et al. 2003), acoustic behaviour (Gordon et al. 1992; Richter et al. 2003), aerial behaviour (Richter et al. 2003), and the duration of dives and types of pre-dive behaviour (Baker & MacGibbon 1991).

There is no consensus on the importance of these behavioural changes. Richter et al. (2003) concluded that the changes in behaviour were probably not biologically important and did not constitute an impact. Baker & MacGibbon (1991) found that there was no evidence that the short-term changes in behaviour would affect an individual's chance for survival or reproduction, although they did suggest that the cumulative effects could be more serious, as a whale could spend a great part of its day avoiding boats and may be forced out of important feeding areas. Gordon et al. (1992) were concerned that a reduction in surface time would lead to a decline in the length of subsequent dives and would affect feeding. They thought that feeding could also have been affected by increases in the amount of background noise, as it could interfere with the echolocation used to detect prey. Overall assessment of the effects was complicated by the fact that the responses of whales varied individually, seasonally, and between resident and transient whales. The resident whales at Kaikoura are exposed to the greatest concentration of whale-watching activity and are thought to be habituated to some degree.

*Dusky dolphins (*Lagenorhynchus obscurus*)*

The effects of boat-based tourist activity on dusky dolphins at Kaikoura have been studied extensively (Barr 1997; Barr & Slooten 1999; Würsig et al. 2007; Markowitz et al. 2009). Barr & Slooten (1999) found that the number of leaps and direction changes was significantly higher after mid-morning when different types of boats were present. The highest degree of disturbance occurred when commercial, fishing and/or private boats were present at the same time. An increase in aerial behaviour and changes in the dispersion of dolphins within pods was also observed as pods tended to become more tightly packed in the presence of boats, although this was not statistically significant.

More recent work by Markowitz et al. (2009) found a general pattern of increased activity and decreased resting during interactions with tour vessels. Changes in leaping rate, speed, group heading and dispersion (general tightening of groups) were also observed. Short-term behavioural responses were influenced by the number of vessels, the type of vessels, and the number and manner of approaches by vessels. These responses were considered unlikely to have a biologically significant impact on the dusky dolphin population but caution was recommended regarding further expansion of dolphin tourism at Kaikoura.

Studies on dusky dolphins in the Bay of Islands (Constantine & Baker 1997; Constantine et al. 2004) also found significant behavioural changes as the number of boats increased. On 32% of approaches by 'swim with dolphin' boats, the dolphins changed their behaviour (Constantine & Baker 1997). Resting behaviour was affected in particular, and resting times decreased further when boat departure times were changed and the number of permitted trips increased from 49 to 70 trips per week (Constantine et al. 2004).

Barr & Slooten (1999) suggested that dolphins could become accustomed to the sound and behaviour of particular vessels, but when multiple types of vessels are present they receive mixed signals and are unable to predict the way that boats will move. Barr & Slooten proposed that the observed changes in aerial behaviour and pod density could aid communication between members of the pod when their normal methods were disrupted by boat noise. They found the reduction in resting behaviour, particularly concerning the presence or noise of boats, could mean that the dolphins might have less energy for feeding at night. Ongoing research and monitoring identified a midday 'rest period' behaviour by dolphins and, as a result, some boat operators now specifically avoid that time (Würsig et al. 2007).

*Bottlenose dolphins (*Tursiops *sp.)*

Bottlenose dolphins studied in Fiordland tended to avoid boats (including kayaks), especially when boat behaviour was particularly intrusive and violated the 1992 New Zealand Marine Mammal Protection Regulations (Lusseau 2002, 2006). Dolphins' behavioural responses included horizontal and vertical avoidance (diving) and swimming more erratically (a behaviour that is associated with the avoidance of predators). In Doubtful Sound/Patea, socialising and resting behaviours were reduced by two-thirds and one-third, respectively, and dolphins were more likely to move away from sites after boat interactions (horizontal avoidance). Most importantly, it was concluded that heavier levels of boat traffic restricted the use of Milford Sound/Piopiotahi by dolphins. The authors concluded that, by avoiding Milford Sound/Piopiotahi, the animals had a smaller home range, an increased risk of predation and less access to food. It was thought that this could lead to the area having a lower effective carrying capacity for dolphins and result in a lower population in the long term. In Doubtful Sound/Patea, the authors thought that, unlike Milford Sound/Piopiotahi, the level of boat interactions was low enough for the dolphin population to be sustained.

The strongest influences on dolphin response appeared to be the operational behaviour and predictability of boats, and also the sex of individual dolphins. Noise was also a factor, and dolphins reacted by increasing their dive interval well before boats were in visual contact or any interaction between boats and dolphins began. Likewise, the effect of boat interactions declined slowly afterwards, suggesting that the zone of effect went beyond physical exposure to the vessel, and most likely matched the vessel's acoustic footprint. This did not necessarily indicate that the sound of boats was disturbing, as the authors found that a kayak could trigger a similar response to a large boat if it was handled in a way that was intrusive. They proposed instead that the dolphins associated the sound of different boats with different levels of threat, especially if they had past experience of disturbing behaviour associated with a particular vessel.

There were some specific instances where noise itself influenced behaviour. Dolphins tended to turn to non-vocal signalling in some situations while interacting with fast-moving power boats, probably because the noise drowned out their vocalisations. During resting behaviour, dolphins tended to make steep dives in response to power boats, but not to kayaks. This was thought to be an effective strategy for avoiding noise in places such as Milford Sound/Piopiotahi and Doubtful Sound/Patea, because the stratification of the water into freshwater and marine layers may make it possible for dolphins to avoid boat noise by staying in the deeper marine layer. Finally, the study proposed that the impact of interaction with boats could be minimised if the vessels respected the guidelines in place, and if vessels generally made efforts to minimise the exposure of dolphins to their engine noise.

*Common dolphins (*Delphinus delphis*)*

Constantine & Baker (1997) looked at common dolphin interactions with 'swim with dolphin' boats and found that they changed their behaviour on 52% of occasions. However, Neumann & Orams (2005) found that common dolphins at Mercury Bay were tolerant of vessels being in close proximity, and reported few impacts from tourism. In some cases boat traffic was observed to alter the behaviour of some groups, especially those groups containing fewer individuals, but the differences observed were not statistically significant. Stockin et al. (2008) found that common dolphins specifically targeted for tourism in the Hauraki Gulf were significantly less likely to continue foraging and less likely to continue resting after the approach of a tour boat. The authors proposed two methods for mitigating these effects: prohibiting tour boat operators from approaching common dolphins while they are actively foraging or feeding (a policy that would require boat skippers to be trained to identify such behaviour from a distance); and identifying times and/or locations where dolphins are more likely to be foraging, and preventing tour boat interactions during these periods and/or at these locations.

*Hector's dolphins (*Cephalorhynchus hectori*)*

When studying Hector's dolphins at Akaroa, Nichols et al. (2001) found that dolphin density and group size appeared to be independent of boat presence. When the researchers examined boat-dolphin interactions, dolphins were most often associated with kayaks, sailing yachts and dinghies. Kayaks were involved in almost 40% of interactions but comprised only about 5% of the boat traffic. Although power boats made up the majority of boat traffic in the study area, only 1–2% of dolphin interactions involved these craft.

While it would appear that boat noise could be the differentiating factor, the authors cited a previous study (Bejder et al. 1999) that suggested Hector's dolphins were attracted to slow-moving boats. As they were attracted to boats at distances of up to 2–3 km—well beyond the typical range of underwater visibility in the area—it is likely that noise played a part in the apparent attraction. However, in contrast to this attraction to boat noise, the study also found that dolphins formed significantly tighter pods when a boat was present. This response is often observed among dolphins as a response to surprise, threat or danger, indicating that Hector's dolphins may still find the noise of boats stressful despite the apparent attraction (Bejder et al. 1999).

Hector's dolphins are particularly vulnerable to being entangled in gill nets and, for this reason, research has been carried out to assess the effectiveness of noise as a deterrent to animals approaching nets. Stone et al. (1999) studied the responses of Hector's dolphins to three different 'acoustic pingers'. Out of the three pingers, dolphins showed the strongest response to one with a fundamental frequency of 10 000 Hz with harmonics up to 160 Hz. The authors recommended that a higher frequency pinger with harmonics up to 200 000 Hz would be best for deterring Hector's dolphins from nets.

6.2 EFFECTS OF NOISE ON BIRDS

From a review of visitor impacts on New Zealand's freshwater avifauna, Walls (1999) found that activities involving loud noise, and sudden and rapid movement, were the most disruptive. These included the use of power boats, jet boats, off-road vehicles and aircraft. While only a handful of studies have directly addressed these issues in New Zealand, the results indicate that behavioural responses do occur, and that they appear to be species specific.

Montgomery (1991) carried out a study of the effects of disturbance on water birds at Lake Rotoiti/Te Roto kite ā Ihenga i ariki ai Kahu (hereafter Lake Rotoiti) near Rotorua. A subjective assessment of boat noise was used along with three other factors (number of boats, water-skiers and shore parties) to assign a disturbance level to each study site. In addition, the distances were measured at which four species of birds became visibly alarmed by a slow-moving motor boat, and at which they eventually fled. It was noted that the diversity and number of species present was reduced in times of high disturbance. Shags (particularly black shags, *Phalacrocorax carbo*) were identified as being especially sensitive to recreational activity. The responses of individual birds depended to a degree on the nature of the study area. At larger sites where refuge areas were available, birds tended to aggregate, while in smaller bays the birds tended to fly away when disturbed.

Observations of the behavioural effects of power boating and water-skiing on birds at Lake Rotokare in Taranaki (Hartley & Medway 2001) were similar to the results of Montgomery (1991). Black shags were noted as being most affected by the presence of boats and were observed to take flight and not return until boats left. Mallards (*Anas platyrhynchos*) and New Zealand scaup (*Aythya novaeseelandiae*) were unaffected, and no effect was noted on the singing or calling of birds in the swamp or bush margins adjacent to the lake. This study carried out 'before and after' bird population surveys in a part of the lake that was closed off to power boats and water-skiing. While no significant population differences were found over 2 years, the authors considered that any observable change may require a longer period to appear.

Bright et al. (2003) conducted controlled experiments to determine the effect of boat passes of different speeds and frequencies on the behaviour of New Zealand dabchicks (*Poliocephalus rufopectus*) at Lakes Rotoiti and Okareka. They found that a single boat pass caused significant changes in dabchick behaviour and that changes were more pronounced when the frequency of boat passes increased. Increasing boat speed from 5 to 10 knots had no significant effect on dabchick behaviour. The changes observed included increases in periods when the birds were hiding or displaying an alert posture relative to other behaviours. The changes were relatively short-lived differences and were no longer apparent 15–20 minutes after boats had passed. However, Bright et al. (2005) believed that this sort of disturbance could affect the birds' energy balance, as less time would be spent feeding and more time would be spent in energetically expensive behaviours. Birds could also be displaced into the territories of neighbouring birds. Despite this, the researchers concluded that dabchicks were probably less likely to be affected than other bird species, as they did not generally take flight or move long distances in response to disturbance. There was some evidence that dabchicks habituated to boat traffic in high-use recreational areas.

Using a multi-disciplinary and management-oriented approach, Kazmierow et al. (2000) combined ecological and social science methods to measure and evaluate the acceptability of tourism boat disturbances to kōtuku (white heron, *Egretta alba modesta*) and other birds in the Waitangiroto Nature Reserve in South Westland. The first stage was an interview-based qualitative assessment of stakeholder concerns, the most prominent of which was the impact of boat traffic on birdlife. The variety of stakeholder opinions encompassed beliefs that kōtuku flew away in response to boat disturbance through to the belief that they were resilient and seldom altered their behaviour. To assess actual bird behaviour, a hidden camera and time-lapse video recorder were used to monitor a potential feeding site for kōtuku that was subject to passes from boats, and supplementary bird counts were made by an observer in a boat. The observations showed that the main human use of the reserve was movement of boats along the river.

Most herons changed their behaviour in response to boat-related disturbance, with the most common response being to fly away, irrespective of boat type. Observations showed that kōtuku chicks preferred to use an unaffected river section to develop their feeding and flying skills, and that they generally avoided the boat-affected river section. The study site was also home to a number of other species, such as royal spoonbills (*Platalea leucorodia*) and little shags (*Phalacrocorax melanoleucos*) and boat traffic was found to significantly reduce the presence of a number of these species.

The final stage of the research was to gauge the stakeholder group's opinions of various hypothetical disturbance scenarios. This was done prior to revealing the outcomes of the ecological research. Once the results had been revealed, stakeholders altered and reprioritised their concerns. The absence of chicks in the area affected by boating was viewed as 'very unacceptable', while the effect on the adult herons was viewed as 'unacceptable'. The use of mixed methodology in this study was seen as valuable in that it avoided researcher bias in two key stages: diagnosis of the wildlife problem and evaluating the acceptability of the observed wildlife disturbance. This approach was also thought to achieve greater opportunity to enhance stakeholder 'buy-in' to the eventual management regime for that site.

Aircraft and noise impact research has also been carried out on Adélie penguins (*Pygoscelis adeliae*) at Cape Royds in New Zealand's Ross Dependency in Antarctica, including a substantial review of aircraft impact research and management guidelines (Harris 2005). Anecdotal evidence in the 1960s about major stampedes in penguin colonies had prompted interest in assessing noise and aircraft impacts, and led to prohibitions on flights over colonies, shifting helicopter landing sites, and visitor restrictions. Since then, the responses of various Antarctic species to aircraft overflights have been well studied and the resulting overflight guidelines adopted by a number of Antarctic nations (Harris 2005). Harris also noted that while many behavioural responses to aircraft disturbance were identified, any links to wider population sustainability were difficult to attribute. Resolving this issue would require a specific and extensive research approach.

6.3 SUMMARY

Current New Zealand research supports the argument that aircraft overflights and motorised boats can negatively impact some wildlife species. However, the significance of these impacts for other species or locations is not clear because research findings indicate that species and site-specific factors influence the response of wildlife to noise disturbance. Few studies have investigated noise in isolation from other stimuli. Instead, a common approach has been to link the behavioural responses of animals to the presence, absence or behaviour of boats and aircraft.

A small amount of New Zealand research has matched ecological study of wildlife responses with measurement of the social acceptability of the disturbance to humans, who may be the recreational participants involved in the activity causing noise disturbance (e.g. Barton et al. 1998; Kazmierow et al. 2000). The human dimension to such wildlife management problems should be recognised. Studies undertaken on wildlife in New Zealand have demonstrated practical application of the human dimension of wildlife disturbance and, in particular, means through which social acceptability of wildlife disturbance can be researched (e.g. Kazmierow et al. 2000) and applied in both wildlife and visitor management contexts.

7. Conclusions

From this literature review of noise effects on recreationists and wildlife in New Zealand's natural areas, conclusions can be drawn about the current state and future prospects for noise monitoring and research in New Zealand.

7.1 THE IMPACT OF NOISE ON RECREATIONISTS

Observations from a review of almost two decades of work on this topic show that, in New Zealand, monitoring of the impact of noise on recreationists has generally focussed on methodologies that are relatively simple, affordable and easily carried out by non-specialist staff. In contrast, some of the more complex approaches used internationally, such as simulation experiments, noise mapping and acoustical or dose-response studies using sound measuring equipment have either not been used or have had only limited use. Although such methods are more complex and potentially more expensive than those employed currently, their utilisation would provide an opportunity to model or simulate alternative scenarios. For example, the use of techniques such as audio-visual computerised simulations or dose-response curves would allow managers to better predict the likely impacts of different management policies. The outlay of resources required for this type of approach may be worthwhile for particular locations that are both high use and high impact. Alternative approaches may also assist in identifying people's values, expectations and preferences associated with different places and situations.

A limitation of much of the work carried out in New Zealand is the context in which results from studies feed into management decision-making processes—and the absence, in most cases, of a broader framework for decision making about limits and other management responses. The work carried out for the Fiordland Integrated Coastal Management Programme at Milford Sound/Piopiotahi (Booth 2010) and the LAC study carried out at Mason Bay (Wray et al. 2005) are notable exceptions. Although not implemented, the inclusion of defined management standards for aircraft noise in the Fiordland National Park Management Plan (DOC 2007) is likewise an exception to the overall pattern. Noise monitoring is likely to be most effective when it contributes to a limits of acceptable change (or similar) planning process. Such processes incorporate stakeholders in determining acceptable limits. Opportunities exist for more research in this area, particularly with regard to people's noise expectations and preferences for different places and situations.

Despite these limitations, the work carried out to date has been successful in identifying areas where noise is a concern and the significance of noise as an issue nationally. The development of SAM and, despite some tinkering, its application at a range of sites over a number of years has enabled long-term changes to be recorded. The glacier valleys in Westland Tai Poutini National Park provide the best example of this. In some cases, ongoing monitoring with SAM has also allowed the effects of management actions to be assessed (e.g. DOC 2009). An opportunity for minor improvement exists in relation to the use of SAM in terms of the standard of survey administration, reporting and analysis. Some basic improvements could be applied to aid interpretation of results (such as detailed information about survey administration methods and any resulting limitations, and the reporting of response rates and margins of error).

In other locations, a variety of innovative approaches have been used. Wray's (2009) study of users of remote and wilderness areas, which used diaries and key informant interviews, has increased understanding of the complex nature of the response of recreationists to noise. It has enabled an assessment of the effects of noise to be carried out in a location where it is usually not possible to employ traditional survey methods. Other studies assessing recreationists' encounter norms (e.g. Squires 2008) or using more inclusive, public participatory methods, such as LAC, have provided managers with more robust information to manage noise issues and to set limits where this approach is desirable.

Given the value of the work carried out to date, ongoing monitoring of the impacts of noise at individual sites, particularly where there is public interest or where managers consider there may be a problem, is warranted. Further, monitoring provides the greatest value when it is regularly repeated over a long time span using consistent methods, as has generally been the case at the West Coast glaciers, at Aoraki/Mount Cook and in Fiordland National Park. There is also a place for one-off studies where more detailed research is required. The continuation of research and monitoring, greater stakeholder participation and the integration of monitoring into policy and planning documents is a positive step towards more consistent and reliable noise management. Overall, there is a need to develop better understanding and specification of people's values, expectations and preferences associated with different places. Such understandings, and any related site-specific specifications of standards that may ensue, will add considerably to the value and relevance of any noise impact monitoring tools, as well as to managing any other visitor management issues. While beyond the scope of this report, evaluation of the outcomes of different noise monitoring and management approaches used in New Zealand warrants further investigation.

7.2 THE IMPACT OF NOISE ON WILDLIFE

Unlike noise-related research on recreationists in New Zealand (with the development of SAM), research associated with noise impacts on wildlife has not followed any coordinated or standardised approach. Instead, wildlife noise research in New Zealand has focussed on specific species at specific places, using individualised methods for each study. Studies have tended to focus on general disturbance rather than a specific focus on noise and have tended to examine short-term behavioural responses rather than the long-term, cumulative effects of human activity. Research drivers in this area appear to be associated with environmental and regulatory approval processes (such as applications for resource consents or concessions), which encourage one-off studies, rather than long-term and nationally consistent research and monitoring programmes.

The opportunity to develop or adopt a simple standard method for monitoring noise impacts on wildlife is unlikely to be fruitful, given species variability in noise perception and response behaviours, and the varying significance of disturbance at different times and places. However, the opportunity exists to facilitate a programme of research and monitoring for noise effects on individual species in New Zealand.

The development and application of this monitoring should be driven by species priority at different places, accompanied by some indicative research regarding the presence of any meaningful impact issue. Research would be required to identify key features of response behaviours for target species, which could act as indicators of the potential for long-term or cumulative impacts. This suggests that a case-by-case approach will continue for respective species. However, scope exists for tools developed for a species in one location to be applied across the spectrum of sites where that species occurs.

As with noise impacts on recreationists, there are also opportunities to explore the social acceptability of disturbance to wildlife through the use of LAC studies (e.g. Kazmierow et al. 2000) and similar approaches. Such approaches may be useful in setting defendable limits for noise-generating activities, particularly where long-term or cumulative impacts are suspected but not easily measured.

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Appendix 1

SUMMARY OF APPLICATIONS OF THE STANDARD AIRCRAFT MONITOR (SAM)

Table A1.1 summarises applications of the standard aircraft monitor in field studies. Data are ordered alphabetically by site name.

TABLE A1.1. APPLICATIONS OF THE STANDARD AIRCRAFT MONITOR IN NEW ZEALAND.

SITE NAME	YEAR	ANNOYANCE LEVEL*	SOURCE	SAMPLE SIZE	COMMENT
Blue Lakes, Aoraki/Mount Cook National Park, Canterbury Conservancy (Aircraft 1998–2003)	2003	9%	Brown (2003)	400	Self-completed on-site with assistance from surveyor as required. Survey carried out during March as opposed to earlier surveys, which were carried out in January and February. Structure of some questions changed. Carried out only when aircraft were flying.
	2000	12%	Ladd (2000)	360	Self-completed on-site with assistance from surveyor as required. Surveyed during January and February during periods of aircraft activity.
	1999	13%	Toxward (1999)	400	Self-completed on-site with assistance from surveyor as required. Surveyed during January and February during periods of aircraft activity. Minor changes to this and subsequent surveys from previous year. When asked to indicate acceptable threshold of aircraft activity, 'impair' substituted for 'spoil' and 'Aircraft would not impair my visit' added to list of possible responses for question relating to tolerance.
	1998	15%	Ladd (1998)	400	Self-completed on-site with assistance from surveyor as required.
Chalet Lookout, Westland Tai Poutini National Park, West Coast Tai Poutini Conservancy (Aircraft 2000–2009)	2009	32%	DOC (2009)	126	Interviewer-administered survey during January and February. Surveying was undertaken across the full range of levels of aircraft activity including days with little or no activity. The published annoyance figure is for the full dataset.
	2005	52% / 52%	DOC (2005)	155	Interviewer-administered survey during January and February. Unlike previous years, surveying was taken across the full range of levels of aircraft activity including days with little or no activity. To allow comparison with previous surveys, the annoyance figure excluding surveys taken where the flight frequency was below 2.5 flights per hour is presented first followed by the figure for the full survey. Other minor changes to survey form compared with previous years.
	2004	21%	DOC (2004)	100	Interviewer-administered questionnaire. Carried out during December and January during periods of aircraft activity.
	2003	18%	DOC (2003)	86	Interviewer-administered questionnaire. Carried out during January and February during periods of aircraft activity.

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* Annoyance levels calculated under the SAM are typically reported as a percentage of respondents who noticed aircraft. The modified SAM used in Fiordland National Park and at Siberia Hut from 2007 onwards, along with earlier studies undertaken at Doubtful Sound, Mason Bay and on the Kepler Track (2006), calculated annoyance as a percentage of all respondents. Caution is advised when comparing figures between sites.

Continued on next page

Table A1.1 continued

SITE NAME	YEAR	ANNOYANCE LEVEL*	SOURCE	SAMPLE SIZE	COMMENT
	2002	28%	DOC (2002)	52	Self-completed on-site with assistance from surveyor as required. Surveying was undertaken in January and only during periods of aircraft activity when it was not raining or heavily overcast.
	2001	29%	Hegarty (2001)	60	Self-completed on-site with assistance from surveyor as required. Undertaken in January during periods of aircraft activity when it was not raining.
	2000	33%	Batchelor (2000)	49	Self-completed on-site with assistance from surveyor as required. Undertaken in January and February. Only during periods of aircraft activity when it was not raining.
Doubtful Sound/Patea, Fiordland National Park, Southland Conservancy (Aircraft 2005)	2005	13%	M. Harbrow & K. Wray (unpubl. data)	104	Self-completion survey handed out by guided kayak operators to clients prior to trip and returned to guides, DOC visitor centre or via freepost envelope. Survey was undertaken during January and February.
Empress, Kelman, Plateau and Tasman Saddle Huts, Aoraki/ Mount Cook National Park, Canterbury Conservancy (Aircraft 2002)	2002	32%	McManaway & Bellringer (2002)	78	Surveys left in huts over summer to be self-administered. Problems with the form being seen as 'political' may have reduced the response rate. Questionnaire also designed for use in front-country sites. Although results for the four huts were combined, there was a marked difference in attitudes between visitors at Empress Hut compared with other huts, probably due to different means of access (people have to walk in to Empress Hut but most fly in to other huts).
Fox Valley, Westland Tai Poutini National Park, West Coast Tai Poutini Conservancy (Aircraft 2000–2009)	2009	21%	DOC (2009)	324	Interviewer-administered survey during January and February. Surveying was undertaken across the full range of levels of aircraft activity including days with little or no activity. The published annoyance figure is for the full dataset.
	2005	21% / 20%	DOC (2005)	338	Interviewer-administered survey during January and February. Unlike previous years, surveying was taken across the full range of levels of aircraft activity, including days with little or no activity. To allow comparison with previous surveys, the annoyance figure excluding surveys taken where the flight frequency was below 2.5 flights per hour is presented first followed by the figure for the full survey. Other minor changes to survey form compared with previous years.
	2004	15%	DOC (2004)	200	Interviewer-administered questionnaire. Carried out during December and January during periods of aircraft activity.
	2003	24%	DOC (2003)	212	Interviewer-administered questionnaire. Carried out during January and February during periods of aircraft activity.

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Table A1.1 continued

SITE NAME	YEAR	ANNOYANCE LEVEL*	SOURCE	SAMPLE SIZE	COMMENT
	2002	15%	DOC (2002)	225	Self-completed on-site with assistance from surveyor as required. Surveying was undertaken in January and only during periods of aircraft activity when it was not raining or heavily overcast.
	2001	19%	Hegarty (2001)	307	Self-completed on-site with assistance from surveyor as required. Undertaken in January during periods of aircraft activity when it was not raining.
	2000	14%	Batchelor (2000)	257	Self-completed on-site with assistance from surveyor as required. Undertaken in January and February. Only during periods of aircraft activity when it was not raining.
Franz Josef Valley, Westland Tai Poutini National Park, West Coast Tai Poutini Conservancy (Aircraft 2000–2009)	2009	17%	DOC (2009)	348	Interviewer-administered survey during January and February. Surveying was undertaken across the full range of levels of aircraft activity including days with little or no activity. The published annoyance figure is for the full dataset.
	2005	23% / 20%	DOC (2005)	380	Interviewer-administered survey during January and February. Unlike previous years, surveying was taken across the full range of levels of aircraft activity including days with little or no activity. To allow comparison with previous surveys, the annoyance figure excluding surveys taken where the flight frequency was below 2.5 flights per hour is presented first followed by the figure for the full survey. Other minor changes to survey form compared to previous years.
	2004	14%	DOC (2004)	200	Interviewer-administered questionnaire. Carried out during December and January during periods of aircraft activity.
	2003	14%	DOC (2003)	206	Interviewer-administered questionnaire. Carried out during January and February during periods of aircraft activity.
	2002	25%	DOC (2002)	210	Self-completed on-site with assistance from surveyor as required. Surveying was undertaken in January and only during periods of aircraft activity when it was not raining or heavily overcast.
	2001	19%	Hegarty (2001)	284	Self-completed on-site with assistance from surveyor as required. Undertaken in January during periods of aircraft activity when it was not raining.
	2000	13%	Batchelor (2000)	260	Self-completed on-site with assistance from surveyor as required. Undertaken in January and February. Only during periods of aircraft activity when it was not raining.
Gertrude Valley, Fiordland National Park, Southland Conservancy (Aircraft 2006/07–2009/10)	2009/10	16% helicopters, 24% planes	Oyston (2010a)	176	Self-completion questionnaire handed out on-site or left with respondents' vehicles. Surveying ran from January through to March. Surveys returned on-site or via postal return.

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Table A1.1 continued

SITE NAME	YEAR	ANNOYANCE LEVEL*	SOURCE	SAMPLE SIZE	COMMENT
					Questionnaire included modified SAM along with more general questions on visit and visitor characteristics, expectations, experience and crowding. Surveying was not undertaken on rainy days because track is not generally used.
	2008/09	33% helicopters 30% planes	Oyston (2010a)	210	Self-completion questionnaire handed out on-site or left with respondents' vehicles. Surveying ran from January through to March. Surveys returned on-site or via postal return. Questionnaire included modified SAM along with more general questions on visit and visitor characteristics, expectations, experience and crowding. Surveying was not undertaken on rainy days because track is not generally used.
	2007/08	45% helicopters, 35% planes	Harbrow (2008)	142	Self-completion questionnaire handed out on-site or left with respondents' vehicles. Undertaken during December, January and March. Surveys returned on-site or via postal return. Questionnaire included modified SAM along with more general questions on visit and visitor characteristics, expectations, experience and crowding. Surveying was not undertaken on rainy days because track is not generally used.
	2006/07	37% helicopters, 30% planes	Harbrow (2007a)	199	Self-completion questionnaire handed out on-site or left with respondents' vehicles. Surveying ran from January through to March. Surveys returned on-site or via postal return. Questionnaire included modified SAM along with more general questions on visit and visitor characteristics, expectations, experience and crowding. Surveying was not undertaken on rainy days because track is not generally used.
Hollyford Track, Fiordland National Park, Southland Conservancy (Aircraft 2006/07–2008/09, Jet boats 2005–2008/09).	2008/09	18% jet boats, 34% helicopters, 28% planes	Visser & Harbrow (2009)	88	Self-completion questionnaire handed out on-site or left with respondents' vehicles. Surveys returned on-site or via postal return. Surveying ran from January through to April. Questionnaire included modified SAM along with more general questions on visit and visitor characteristics, expectations, experience and crowding.
	2007/08	26% jet boats, 36% helicopters, 37% planes	Harbrow & Mitchell (2008)	70	Self-completion questionnaire handed out on-site or left with respondents' vehicles. Undertaken during December, January and March. Surveys returned on-site or via postal return. Questionnaire included modified AM along with more general questions on visit and visitor characteristics, expectations, experience and crowding.
	2006/07	21% jet boats, 30% helicopters, 28% planes	Squires & Harbrow (2008)	153	Self-completion questionnaire handed out on-site or left with respondents' vehicles. Surveying ran from January through to March.

Continued on next page

Table A1.1 continued

SITE NAME	YEAR	ANNOYANCE LEVEL*	SOURCE	SAMPLE SIZE	COMMENT
					Surveys returned on-site or via postal return. Questionnaire included modified SAM along with more general questions on visit and visitor characteristics, expectations, experience and crowding.
	2005	19% jet boats	Kleinlangevelsloo (2005)	117	Surveys were self completion. Most were administered over Easter by the researcher at Hidden Falls Hut. Others were left in the hut, distributed by concessionaires and clubs or posted out with hunting permits. Freepost envelopes were provided.
Homer Hut, Fiordland National Park, Southland Conservancy (Aircraft 2006/07–2007/08)	2007/08	56% helicopters, 56% planes	Harbrow (2008)	43	Self-completion questionnaire handed out on-site or left with respondents' gear. Surveying carried out in December, January and March. Questionnaire included modified SAM along with more general questions on visit and visitor characteristics, expectations, experience and crowding. Questionnaires returned on-site, collected by hut warden or returned via freepost envelope.
	2006/07	68% helicopters, 70% planes	Harbrow (2007a)	59	Self-completion questionnaire handed out on-site or left with respondents' gear. Surveying ran from January through to March. Questionnaire included modified SAM along with more general questions on visit and visitor characteristics, expectations, experience and crowding. Questionnaires returned on-site, collected by hut warden or returned via freepost envelope.
Hooker Valley, Aoraki/ Mount Cook National Park, Canterbury Conservancy (Aircraft 2001)	2001	17%	Horn (2001)	414	Self-completed on-site with assistance from surveyor as required. Respondents were surveyed during February at times when aircraft were flying.
Kepler Track, Fiordland National Park, Southland Conservancy (Aircraft 1999–2006)	2006	6% day visitors, 8% overnight trampers	M. Harbrow & K. Wray (unpubl. data)	538 day visitors 446 overnight trampers	Self-completed on-site with assistance from surveyor as required. Carried out during January.
	2005	13%	Snook (2005)	303	Interviewer administered survey carried out during April.
	1999	–	Herlihy (1999)	100	Surveys were completed on-site with assistance from surveyor as required. 100 visitors were surveyed at each of the three sites but 28 responses were invalid. Report does not state where these 28 forms came from. Apart from the Milford Track, most results are reported as a combined figure for 'Fiordland'.
Lake Gunn Nature Walk, Fiordland National Park, Southland Conservancy (Aircraft 2009/10)	2009/10	1% helicopters, 1% planes	Oyston (2010a)	394	Self-completion questionnaire handed out on-site. Surveying ran from January through to March. Questionnaire included modified SAM along with more general questions

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Table A1.1 continued

SITE NAME	YEAR	ANNOYANCE LEVEL*	SOURCE	SAMPLE SIZE	COMMENT
					on visit and visitor characteristics, expectations, experience and crowding.
Lake Marian Track, Fiordland National Park, Southland Conservancy (Aircraft 2007/08)	2007/08	Day visitors: 21% helicopters, 16% planes. Short stop travellers: 4% helicopters, 4% planes.	Harbrow (2008)	178 day visitors; 438 short stop travellers	Self-completion questionnaire handed out on-site or left with respondents' vehicles. Surveying undertaken in December, January and March. Surveys returned on-site or via postal return. Questionnaire included SAM along with more general questions on visit and visitor characteristics, expectations, experience and crowding.
Lake Sylvan and Dart Tracks, Mt Aspiring National Park, Otago Conservancy (Jet boats 1997/98)	1997/98	22%	Graham (1999)	198	
Mason Bay, Rakiura National Park, Southland Conservancy (Aircraft 2004)	2004	19%	Wray et al. (2005)	108	Self-completion questionnaire handed out on-site and returned after trip by freepost envelope, handed in to visitor centre, collected by aircraft operator or left in a box in Freshwater Hut. Carried out during February and March.
Milford Sound/Piopiotahi, Fiordland National Park, Southland Conservancy (Aircraft 1999–2006/07)	2006/07	28% helicopters, 27% planes	Harbrow (2007a)	671	Self-completion questionnaire handed out on Milford Sound foreshore near cafe. Surveying ran from January through to March. Questionnaire included modified SAM along with more general questions on visit and visitor characteristics, expectations, experience and crowding. Survey not representative of all visitors on-site as it excluded many commercial bus/cruise passengers.
	2000	20%	Tourism Resource Consultants (2000)	406	Interviewer-administered with a number of changes to SAM. Only during times of aircraft activity during February and March. Survey used a stratified sampling technique to gain a representative sample of users of the area.
	1999	–	Herlihy (1999)	100	Surveys were completed on-site with assistance from surveyor as required. 100 visitors were surveyed at each of the three sites but 28 responses were invalid. Report does not state where these 28 forms came from. Apart from the Milford Track, most results are reported as a combined figure for 'Fiordland'.
Milford Track Fiordland National Park, Southland Conservancy (Aircraft 1999–2008/09)	2008/09	Glade Wharf to Mintaro Hut: 19% helicopters, 18% planes. Mintaro Hut to Dumpling Hut: 22% helicopters, 22% planes. Dumpling Hut to	Oyston (2010a)	534	Self-completion questionnaire handed out on-site. Surveying undertaken from December to April. Questionnaire included modified SAM along with more general questions on visit and visitor characteristics, expectations, experience and crowding.

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Table A1.1 continued

SITE NAME	YEAR	ANNOYANCE LEVEL*	SOURCE	SAMPLE SIZE	COMMENT
		Sandfly Point: 20% helicopters, 17% planes.			
	2007/08	Glade Wharf to Mintaro Hut: 19% helicopters, 12% planes. Mintaro Hut to Dumpling Hut: 27% helicopters 23% planes. Dumpling Hut to Sandfly Point: 27% helicopters, 24% planes.	Harbrow (2008)	411	Self-completion questionnaire handed out on-site. Surveying undertaken in December, January and March. Questionnaire included modified SAM along with more general questions on visit and visitor characteristics, experience and crowding.
	2006/07	Glade Wharf to Mintaro Hut: 23% helicopters, 15% planes. Mintaro Hut to Dumpling Hut: 25% helicopters 20% planes. Dumpling Hut to Sandfly Point: 22% helicopters, 17% planes.	Harbrow (2007a)	389	Self-completion questionnaire handed out on-site. Surveying ran from January through to March. Questionnaire included modified SAM along with more general questions on visit and visitor characteristics, expectations, experience and crowding.
	2000	51%	Tourism Resource Consultants (2000)	408	Interviewer-administered with a number of changes to SAM. Only during times of aircraft activity during February and March.
	1999	52%	Herlihy (1999)	100	Surveys were completed on-site with assistance from surveyor as required. 100 visitors were surveyed at each of the three sites but 28 responses were invalid. Report does not state where these 28 forms came from. Apart from the Milford Track, most results are reported as a combined figure for 'Fiordland'.
Mueller Hut, Aoraki/ Mount Cook National Park, Canterbury Conservancy (Aircraft 1999–2005)	2005	27%	Garrard (2005)	144	Surveys were completed on-site with assistance from surveyor as required. Surveys carried out during March and April.
	2002	35%	McManaway & Bellringer (2002)	141	Surveys left in huts over January, February and March to be self-administered.
	2001	24%	Horn (2001)	151	Survey carried out from December to February. Surveys self-administered with hut wardens encouraging visitors to fill them in. Author spent one day onsite administering forms to check for any bias in the self-administered forms. No difference in responses between the two methods was noted.

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Table A1.1 continued

SITE NAME	YEAR	ANNOYANCE LEVEL*	SOURCE	SAMPLE SIZE	COMMENT
	2000	28%	Ladd (2000)	162	Self-completion surveys available on-site and participation encouraged by volunteer hut wardens. Surveying undertaken during December and January.
	1999	36%	Ladd (2000)	141	Surveys distributed on-site and forms left in hut for self completion. Surveying carried out from January to March.
Roberts Point, Westland Tai Poutini National Park, West Coast Tai Poutini Conservancy (Aircraft 2000–2009)	2009	33%	DOC (2009)	163	Interviewer-administered survey during January and February. Surveying was undertaken across the full range of levels of aircraft activity including days with little or no activity. The published annoyance figure is for the full dataset.
	2005	31%/26%	DOC (2005)	204	Interviewer-administered survey during January and February. Unlike previous years, surveying was taken across the full range of levels of aircraft activity including days with little or no activity. To allow comparison with previous surveys, the annoyance figure excluding surveys taken where the flight frequency was below 2.5 flights per hour is presented first followed by the figure for the full survey. Other minor changes to survey form compared with previous years.
	2004	50%	DOC (2004)	100	Interviewer-administered questionnaire. Carried out during December and January during periods of aircraft activity.
	2003	43%	DOC (2003)	84	Interviewer-administered questionnaire. Carried out during January and February during periods of aircraft activity.
	2002	30%	DOC (2002)	50	Self-completed on-site with assistance from surveyor as required. Surveying was undertaken in January and only during periods of aircraft activity when it was not raining or heavily overcast.
	2001	45%	Hegarty (2001)	51	Self-completed on-site with assistance from surveyor as required. Undertaken in January during periods of aircraft activity when it was not raining.
	2000	46%	Batchelor (2000)	49	Self-completed on-site with assistance from surveyor as required. Undertaken in January and February. Only during periods of aircraft activity when it was not raining.
Routeburn Track, Mt Aspiring National Park, Otago Conservancy / Fiordland National Park, Southland Conservancy (Aircraft 2006/07–2008/09)	2008/09	Day visitors, Glenorchy end: 23% helicopters, 10% planes. Overnight trampers: 23% helicopters, 18% planes.	Harbrow & Visser (2010)	119 day visitors; 456 overnight trampers	Self-completion questionnaire handed out on-site. Surveying of overnight visitors was carried out at both ends of the track and forms were also handed out by the wardens at Howden and Mackenzie Huts to visitors who were going on to the Greenstone / Caples Track. Guided overnight visitors were given forms to complete off-site. Day visitors were surveyed at the Glenorchy end of the track only. Surveying undertaken from

Continued on next page

Table A1.1 continued

SITE NAME	YEAR	ANNOYANCE LEVEL*	SOURCE	SAMPLE SIZE	COMMENT
					February to April. Questionnaire included modified SAM along with more general questions on visit and visitor characteristics, expectations, experience and crowding.
	2006/07	Day visitors, Key Summit: 15% helicopters, 14% planes	Visser & Harbrow (2007)	463	Self-completion questionnaire handed out on-site. Surveying ran from January through to March. Questionnaire included modified SAM along with more general questions on visit and visitor characteristics, expectations, experience and crowding.
Siberia Hut, Mt Aspiring National Park, Otago Conservancy (Aircraft 2004/05–2007/08)	2007/08	10% helicopters, 12% planes	Squires (2008)	199	Self-completed on-site during December, January and February. Significant change in methodology compared with 2004/05 survey. Questionnaire included modified SAM questions and annoyance figures were reported as a percentage of all respondents.
	2004/05	24%	Basingthwaighte (2006)	441	Self-completion questionnaire handed out on-site from December to March.
Waiotapu Scenic Reserve, East Coast Bay of Plenty Conservancy (Aircraft 1998/99)	1999	Pre-aircraft 13% Post-aircraft 17%	Chandler (1999)	Pre-aircraft 105, Post-aircraft 58.	Survey was carried out before and after the commencement of helicopter activity in the area. The two sampling periods were December/January and May/June. Sampling was not random as respondents who had visited previously were purposefully sampled. Survey was self completion.
Wairaurahiri River, Fiordland National Park, Southland Conservancy (Jet boats 2003/04)	2003/04	4%	Harbrow (2007b)	80	Surveys were left in huts to be self-administered or handed out by Wairaurahiri Lodge staff or by jet boat operators. Survey was not representative of users of area and most respondents had themselves travelled by jet boat.

Appendix 2

SUMMARY OF OTHER NEW ZEALAND RESEARCH ABOUT NOISE EFFECTS ON RECREATIONISTS IN PROTECTED AREAS

Table A2.1 summarises other key New Zealand research that reports on noise effects on recreationists in protected areas. This list includes a number of papers mentioned in the body of the report and illustrates the range of techniques used. Data are ordered alphabetically by site name.

TABLE A2.1. OTHER KEY NEW ZEALAND RESEARCH THAT REPORTS ON NOISE EFFECTS ON RECREATIONISTS IN PROTECTED AREAS.

SITE NAME	YEAR	SOURCE	SUMMARY
Abel Tasman National Park (Coast), Nelson/Marlborough Conservancy	2002/03	Parr (2003)	Self completion survey (n = 1156) carried out during December, January and March. In response to an open-ended question, 34% of visitors reported intrusive noises. The most commonly reported noise source was power boats (29%), followed by people (5%), wildlife and aircraft (4% each). Some respondents listed more than one source of noise.
Bevan Col, Mt Aspiring National Park, Otago Conservancy (Aircraft)	2006/07	Squires (2007)	Self-completion questionnaire (n = 135) distributed at Colin Todd Hut, French Ridge Hut, Aspiring Hut, Wanaka DOC visitor centre and through commercial guiding companies. 50% of respondents indicated that they had seen helicopter landings at Bevan Col during their trip. In two open-ended questions, 27% of those who had seen helicopters landing (or approximately 13% of all respondents) reported 'negative impacts' and 42% (28% of the total sample) reported 'positive impacts.' Helicopter access was important to a large proportion of respondents. 57% had used helicopters for access during their trip and almost half of those respondents indicated that they would not have climbed in the area if helicopter access had been unavailable. The most common reasons for using helicopters were 'convenience', 'limited time for trip', 'ability to time trip with a window of good weather', 'speed of access' and because access would be difficult without using a helicopter. The main reasons for not using helicopters were the cost, the experience of walking or seeing the area, that it was not necessary, ethical opposition to helicopters and the achievement of completing the trip 'under their own steam'.
Fiordland National Park, Southland Conservancy (Aircraft)	2005	Wray (2009)	Respondents were given diaries to complete during their trip and asked to keep a daily log of their experiences and observations. They were also asked to make a note of anything that contributed positively to their experience or,

Continued on next page

Table A2.1 continued

SITE NAME	YEAR	SOURCE	SUMMARY
			conversely, anything that had a negative impact. 67 diaries were returned and analysed and a number of respondents also participated in follow-up interviews along with commercial operators and individuals with managerial responsabilty and/or influence in wilderness management. The research yielded information on users' responses to aircraft and the range of factors that could increase or reduce their impact although the focus of the study was much wider than aircraft.
Franz Josef and Fox Glaciers, Westland Tai Poutini National Park, West Coast Tai Poutini Conservancy (Aircraft)	1994/95	Sutton (1998)	Carried out dose-response study (*n* = 3282) comparing reported annoyance to the number of overflights recorded in the hour prior to surveying. For the main valley walkers, a point was reached after 14 overflights per hour where the percentage of visitors registering annoyance changed and this became more obvious above 18 aircraft per hour. A 25% threshold was reached at 15–16 aircraft per hour and the increase in annoyance became non-linear. Corresponding results for visitors using the bush walks on the valley sides showed that users of these tracks were less tolerant than the valley walkers. Unprompted qualitative comments indicated only a small amount of annoyance with aircraft ranging from 2.5% to 10%.
Franz Josef Glacier, Westland Tai Poutini National Park, West Coast Tai Poutini Conservancy (Aircraft)	2000	Corbett (2001)	Self-completion survey (*n* = 413) carried out during February and March. 22% of guided visitors (*n* = 140) were concerned to some degree with aircraft flying overhead. 26% of non-guided visitors (*n* = 273) were concerned to some degree with aircraft flying overhead and 5% with helicopters landing while they were up on the glacier (although 75% did not notice this impact). Aircraft did not feature strongly in unprompted comments.
Kaimanawa and Kaweka Forest Parks, Tongariro Whanganui, Taranaki and Wellington Hawke's Bay Conservancies (Aircraft)	1983	Groome et al. (1983)	Assessed attitudes to aircraft access (rather than noise) for general users (through an on-site survey) and hunting permit holders. Although approximately 40% of each sample chose not to answer this question, about 30% of both groups were strongly against an increase in airstrips and helipads.
Milford Sound/Piopiotahi, Fiordland National Park, Southland Conservancy	2010	Booth (2010)	Self completion visitor (*n* = 599) and worker surveys (*n* = 234) administered during the peak use (February) and shoulder (March/April) seasons. Overall sample for the visitor survey was not proportional but provided ueful information on a range of sub groups of visitors present at Milford Sound/Piopiotahi. Negative effects from various noise-generating activities (amongst other items in the surveys) were compared to thresholds generated through consultation with stakeholders.
Milford Sound/Piopiotahi, Fiordland National Park, Southland Conservancy	2008	Lindis Consulting (2008)	Self-completion visitor surveys (*n* = 877) during peak use (February) and shoulder (April) seasons. When asked if anything about their experience at Milford was worse than expected, 19 responses related to aircraft activity and 12 to remoteness/tranquillity (mainly noise). Overall sample was non proportional. A worker survey (*n* = 246) carried out in February asked if

Continued on next page

Table A2.1 continued

SITE NAME	YEAR	SOURCE	SUMMARY
			respondents had noticed any changes that they thought were bad. 19 comments from the worker survey related to aircraft and associated noise.
Milford Sound/Piopiotahi and Milford Track, Fiordland National Park, Southland Conservancy	1997/98	Hunt (1999)	Modelled noise emitted from Milford Aerodrome and aircraft noise levels over the Milford Track as a tool to aid planning and mitigation of effects.
Milford Sound/Piopiotahi, Fiordland National Park, Southland Conservancy	1992	O'Neill (1994)	Self-completion survey of 290 visitors to Milford Sound carried out over 1 day in February made up of a representative sample of all user groups. 20% of respondents reported noise pollution. While no breakdown of what type of noise pollution is available the author noted that a number of respondents mentioned the amount of noise generated by aircraft and, to a lesser extent, buses. 6% of visitors indicated that the number noise of aircraft was one of the three worst features of their visit.
Milford Sound/Piopiotahi, Fiordland National Park, Southland Conservancy	1977	Chapman (1977)	Self completion survey of 200 visitors based on a stratified sample of car and bus users. Survey was undertaken during January and February. 7.5% of respondents perceived that there was noise pollution at Milford Sound/Piopiotahi and 2% indicated that they had experienced an extreme impact from aircraft noise.
Milford Track, Fiordland National Park, Southland Conservancy	2008	Booth et al. (2011)	Qualitative interviews with independent track walkers. Despite high levels of visitor dissatisfaction being previously recorded for aircraft noise, only 4 interviewees (out of 56) raised aircraft noise as an issue (unprompted). Aircraft activity was low during the study period but nonetheless was present. Those who raised the issue felt strongly.
'New Zealand back-country'	1995/96	Kearsley et al. (1998)	970 backcountry users were contacted in the field and invited to complete a mail-back questionnaire during the 1995/96 tramping season. Questionnaires were distributed on tramping tracks, at huts and at selected DOC offices and visitor information centres throughout the country to enable extensive extensive coverage of both tramping areas and the tramping season. Figures listed are for the percentage of visitors who reported noise impacts that largely or totally spoiled overall enjoyment. Noise in huts 55%, aircraft noise 40%, jet boats 19%.
New Zealand Great Walks and other popular locations—Milford Track, Rakiura Track, Kepler Track, Routeburn Track, Travers-Sabine Track, Abel Tasman Coast Track, Abel Tasman Coast sea kakayers, Heaphy Track, Whanganui River Journey canoeists, Tongariro Northern Circuit Track, Lake Waikaremoana Track	1998/99	Cessford (1997a, b, 1998a–i, 1999, 2000)	Almost 5000 visitors were sampled in 11 surveys from some of the most popular multi-day walking tracks and other recreational opportunities in New Zealand. Amongst the questions visitors were asked was the degree to which they experienced different physical and social impacts from various types of human effects, including some related directly to recreational noise. These were: hearing aircraft fly overhead / aircraft landing; some people being loud in the huts during the evenings; some people being loud at campsites in the evenings; motorboat disturbance at huts and campsites; and motorboat disturbance at beaches / on the water.

Continued on next page

Table A2.1 continued

SITE NAME	YEAR	SOURCE	SUMMARY
			Visitors were asked, using an awareness/annoyance response scale, to indicate the degree to which they perceived each of these recreational noise effects as impacts on their visit enjoyment. Results were published individually in generic track reports (1997–98) and then combined overall in later noise-focussed papers (Cessford 1999, 2000). These papers summarised the largest noise impact analyses undertaken in NZ, and highlighted a range of significant noise issues from 38 different noise type/location cases, featuring high noise annoyance on the Milford Track (69%) amongst many other specific results.

Appendix 3

STANDARD AIRCRAFT MONITOR (SAM) QUESTIONNAIRE

This questionnaire is from Booth et al. (1999).

Code:

Date:

VISITOR SURVEY

Thank you for your time.
These questions ask about your visit to [NAME AREA].
Please think about your current visit to [NAME AREA]
when answering all questions.

1 What have you liked the most about your visit to [NAME AREA]?

____

____

____

2 What have you liked the least about your visit to [NAME AREA]?

____

____

____

3 Have you noticed any aircraft during this visit? By aircraft we mean both helicopters and aeroplanes.

1☐ Yes

2☐ No

If NO then stop here. Thank you for your time.
If YES then please continue.

4 What number of aircraft have you noticed on this visit? Count each aircraft fly-over separately even if it was the same plane.

____

5 Has the amount of aircraft activity you've noticed on this visit been:

1☐ **Less** than what you expected on this visit

2☐ **More** than you expected

3☐ About **the same** as you expected

4☐ You didn't know what to expect

6 **What amount of aircraft activity would impair your visit to [NAME AREA]? Please tick only one box.**

- 1☐ Any aircraft activity at all would impair my visit
- 2☐ The amount I've noticed this visit (my visit has been impaired)
- 3☐ Double the amount I've noticed this visit
- 4☐ Five times the amount
- 5☐ More than five times the amount

7 **How have the aircraft affected you during this visit? Please tick only one box.**

- 1☐ I enjoyed them
- 2☐ Neutral (I neither enjoyed them nor was I annoyed by them)
- 3☐ I was annoyed by them
- 4☐ I don't know

If you ticked I WAS ANNOYED BY THEM, then please answer the rest of the questions. Otherwise please stop here. Thank you for your time.

8 **How much have the aircraft annoyed you? Please circle the number that best describes your answer.**

1	2	3	4	5	6	7
Hardly annoyed at all						Extremely annoyed

9 **How much have the aircraft detracted from your total enjoyment of this visit to [NAME AREA]? Please circle the number that best describes your answer.**

1	2	3	4	5	6	7
Didn't detract at all						Ruined my visit

Thank you
for your time!

Please hand this questionnaire back
to the person who gave it to you
[or other instructions for questionnaire return]

Appendix 4

REVISED STANDARD AIRCRAFT MONITOR (SAM)

This survey is from Harbrow (2007a).

Time ________

Department of Conservation
Te Papa Atawhai

Date

Gertrude Valley Visitor Survey 2007

This survey will help the Department of Conservation manage the Gertrude Valley. Your help in completing this form is greatly appreciated. All responses are anonymous

First please tell us a little about yourself and your group

1. Age:
- ☐ 16-19 years
- ☐ 20-29
- ☐ 30-39
- ☐ 40-49
- ☐ 50-59
- ☐ 60-69
- ☐ 70+

2. Gender
- ☐ Male
- ☐ Female

3. Where do you normally live? ____________

4. If you live in NZ, please tell us where _______________

5. a) Who are you visiting the Gertrude Valley with today? (Please tick (☑) ONE box)

- ☐ Independent
- ☐ Commercial/ guided group
- ☐ Club/ organisation
- ☐ Other____________________

b) How many people are in this group (Including yourself and any guides)? ______

6. Have you visited the Gertrude Valley before today?

☐ Yes ☐ No

If YES, how many times? __________

7. What were you looking for during your visit to the Gertrude Valley?
(circle one number on **each line)**

How important was?	**Not at all important**						**Very important**
a) Natural peace and quiet	**1**	**2**	**3**	**4**	**5**	**6**	**7**
b) Nature and scenery	**1**	**2**	**3**	**4**	**5**	**6**	**7**
c) Solitude	**1**	**2**	**3**	**4**	**5**	**6**	**7**
d) Rest and relaxation	**1**	**2**	**3**	**4**	**5**	**6**	**7**
e) Spending time with friends & family	**1**	**2**	**3**	**4**	**5**	**6**	**7**

Now we'd like you to tell us about your experiences on the track

8. How long was your visit to the Gertrude Valley? (Tick one box)

☐ Less than 1 hour
☐ 1-2 hours
☐ 3-5 hours
☐ More than 5 hours

9. What have you liked the **most** about your visit to the Gertrude Valley?

____

____

10. What have you liked the **least** about your visit to the Gertrude Valley?

____

____

11. How much do you agree or disagree that…?	**Strongly disagree**						**Strongly agree**
a) I was able to experience natural peace and quiet	**1**	**2**	**3**	**4**	**5**	**6**	**7**
b) I was able to enjoy nature and scenery	**1**	**2**	**3**	**4**	**5**	**6**	**7**
c) I was able to experience solitude	**1**	**2**	**3**	**4**	**5**	**6**	**7**
d) I was able to relax and reduce stress.	**1**	**2**	**3**	**4**	**5**	**6**	**7**
e) I was able to enjoy the experience with friends and family	**1**	**2**	**3**	**4**	**5**	**6**	**7**

12. How did the activities of other visitors affect your visit?

	Did not notice this	**Noticed this but it didn't annoy me**	**Annoyed me a little**	**Annoyed me a lot**
• Behaviour of other visitors				
• Hearing or seeing helicopters				
• Hearing or seeing planes				
• Meeting commercial/ guided groups				
• Meeting large groups				

Comment:

____

____

13. Did you feel crowded at all at during your visit to the Gertrude Valley?
(circle one number)

1	2	3	4	5	6	7	8	9
Not at all crowded		**Slightly Crowded**			**Moderately Crowded**		**Extremely Crowded**	

Comment:

____

____

14. a) Would you recommend the Gertrude Valley to other people?

☐ Yes ☐ No

b) What things would you tell them about it?

____

____

____

Thank you for your time!

If you have any feedback about this survey please contact Michael Harbrow, Southland Conservancy, Department of Conservation, PO Box 743, Invercargill. Ph. 03-211-2400. Email: mharbrow@doc.govt.nz

Does noise affect people and animals in natural areas?

This report reviews New Zealand research on noise impacts in natural areas, with particular emphasis on public conservation lands and waters. It provides a synthesis of New Zealand-based studies, including unpublished literature, and traces the development of research and monitoring to measure noise effects in New Zealand. A particular focus of this work has been aircraft noise and much of the report relates to this topic. A review of relevant international literature is also included, which provides an introduction to the topic, discusses various approaches to measuring the effects of noise, and gives contextual information to explain noise and its impacts.

Harbrow, M.A.; Cessford, G.R.; Kazmierow, B.J. 2011: The impact of noise on recreationists and wildlife in New Zealand's natural areas. *Science for Conservation 314.* 88 p.

New Zealand Government