Recommendations for an Intervention Strategy for the Prevention of Noise Induced Hearing Loss (NIHL) in New Zealand

Based on the findings from research projects funded through the HRC OHS Joint Research Portfolio: Epidemiology of NIHL and Prevention of NIHL in New Zealand

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Contents

1. Introduction 3
1.1 Summary of findings of the two research projects 3
1.2 Identification and analysis of the strategic issues 3
1.3 Structure of the report 4
2. Summary of Research Findings 5
3. Strategic issues 12
3.1 Society/ Community issues 12
3.2 Industry sector issues 12
3.3 Compliance issues 13
4. Analysis of the strategic issues 14
4.1 Society/ Community issues 15
4.2 Industry sector issues 18
4.3 Compliance issues 22
5. Recommendations 24
5.1 The highest areas of priority for immediate intervention. 24
5.2 The most effective intervention options 24
References 30
Appendix A – Executive summaries of the two reports 32
Appendix B – SoundSafe - Agriculture 38
Appendix C – SoundSafe - Construction 40
Appendix D – SoundSafe - Manufacturing 42

1. Introduction

Two research projects were undertake over the period 2008 – 2011, to investigate aspects of the epidemiology and prevention of Noise Induced Hearing Loss (NIHL) in New Zealand industries. The projects were undertaken by research groups from the University of Auckland (Epidemiology of NIHL in NZ) and Massey University (Prevention of NIHL in NZ). The detailed findings of each of these research projects are contained in separate reports (Thorne et al, 2011; Laird et al, 2011, respectively) to the Health Research Council of New Zealand, Accident Compensation Corporation and the Department of Labour.

Two research questions from the Prevention of NIHL project Research Proposal, and involving input from both research groups were required to be addressed in this document. They were, to identify;

(a) The highest areas of priority for immediate intervention.

(b) The most effective intervention options

This document provides a unified summary of the findings of both research projects. It identifies strategic issues raised by the research and provides an analysis of the predominant NIHL prevention issues using a problem-solving risk management methodology. It concludes with recommendations for intervention strategies to prevent NIHL in New Zealand.

1.1 Summary of findings of the two research projects

The Executive Summaries of the two research projects (Thorne et al, 2011 and Laird et al, 2011 respectively) are detailed in Appendix A of this report.

The Epidemiology of NIHL report (Thorne et al, 2011) provides estimates of the incidence and prevalence of NIHL in the NZ population, sound pressure levels across industry sectors, personal noise dose estimates of workers in those industry sectors, identification of noise sources, the extent of hearing loss and details of non-work noise exposures.

The Prevention of NIHL report (Laird et al, 2011) provides information on international best practice in noise management, case study data on the nature and extent of noise controls used in industry sectors, the level of conformance to noise management standards, the nature and extent of hearing protection usage and data on safety climate and attitudes to noise and noise exposure.

1.2 Identification and analysis of the strategic issues

The strategic issues of importance to the problem of NIHL in New Zealand were identified through a series of meetings and fora with stakeholders and industry representatives, OHS practitioners and government agencies and through consultation and workshops between the research team members.

The analysis of the strategic issues that were identified utilised a systematic problem solving framework developed by Sparrow (2000), which has been successfully used in public policy development around injury prevention. As Sparrow (2000) notes in his book *The Regulatory Craft*, "For regulators, continuing in a traditional, enforcement-centred mode— given the constraints of shrinking budgets, declining public tolerance for the use of regulatory authority, and clogged judicial systems—is now simply infeasible." Sparrow suggests the need for "the capacity to identify, prioritize, and fix significant risks, problems, and patterns of noncompliance. A problem-solving strategy picks the most important tasks and then selects appropriate tools in each case, rather than deciding on the important tools and picking the tasks to fit."

A modified version of this methodology was applied to the strategic issues identified from the current research projects to assist in the formulation of recommendations.

1.3 Structure of the report

This report is in five sections;

- Section (1) is an **Introduction** that outlines the background and analytical approach used to identify and discuss the issues raised in the research,
- Section (2) is a combined **Summary of Research Findings** of the two research projects. It attempts to provide a context for the strategic issues and recommendations and to generate a useful single set of views about the NIHL problem in NZ from epidemiology to interventions.
- Section (3) identifies the **Strategic Issues** of significance,
- Section (4) provides an **Analysis of the Strategic Issues** based on the Sparrow (2000) framework, and finally,
- Section (5) provides specific **Recommendations** for the development of interventions in the prevention of NIHL.
- The **Appendices** include (A) Executive Summaries of the findings of the two research projects, and (B – D) details of some industry specific interventions recommended.

2. Summary of Research Findings

The following is a collective summary of the findings of the two NIHL research projects undertaken by groups at the University of Auckland (Epidemiology of NIHL in NZ) and Massey University (Prevention of NIHL NZ). The detailed findings are contained within separate reports (Thorne et al., 2011; Laird et al., 2011) to ACC and the Department of Labour. Here we bring the findings together in a single summary and identify the issues raised in these reports and provide some comments and recommendations on strategies to reduce NIHL in New Zealand

2.1 Epidemiology of Occupational Noise Induced Hearing Loss in New Zealand

2.1.1 Estimates of Incidence and Prevalence

Estimates of the prevalence of NIHL (≥25dBHL$_{Ave1,2,3,4kHz}$) in the *New Zealand workforce,* in 2006, range from 29,242 to 42,497. This gives an incidence in the workforce ranging from 1077 to 1537 new cases of NIHL in 2006.

Extrapolation of the workforce data gives an estimate of the prevalence of NIHL (≥25dBHL$_{Ave1,2,3,4kHz}$) in the *New Zealand population*, in 2006, of between 62,169 69,613. Since the population data reflect *Occupational NIHL*, the incidence in the *New Zealand population* would not differ from that in the workforce. Based on these population data it is estimated that between 1.54 and 1.73% of the New Zealand population had a hearing loss that is solely due to occupational noise exposure.

However, hearing loss is often multifactorial and especially can deteriorate with age Thus there will be people in the population who have a combination of age and noise related hearing loss. Including estimates of this group, the proportion of the New Zealand population who would have only NIHL or some contribution to their total hearing loss from occupational noise exposure is between 2.25% and 2.58% or 90699 to 104088 people (in 2006). . All of these estimates are for unprotected noise exposures and are therefore likely to overestimate the prevalence of NIHL.

Given the estimated prevalence of hearing loss in the New Zealand population is 10% (Greville, 2005) then we estimate that between 13.5% and 17.5% of the hearing impaired population have an occupational Noise-induced Hearing Loss and a total of 22.5-25.8% of hearing impaired people have some hearing loss from occupational noise exposure.

Retrospective estimates using Census data indicates that there has been an increase in the total number of cases of NIHL and a small increase in the incidence rates between 1986 and 2006. The model predicts this on the basis of changes in the participation rates in sectors rather than any changes in the environmental noise levels which are assumed to remain the same across this period. Although the workforce has increased substantially (approximately 500,000) in this 20yr period there has been a major shift away from noisy sectors and an increase in the white collar workforce.

Estimates of future incidence and prevalence were made under the assumption that the current trends in population growth and noisy sector participation would continue. On this basis the total number with NIHL and the number of new cases are predicted to decrease, out to 2040.

2.1.2 Noise levels in New Zealand Industries

Noise measurements were made across different economic sectors and a range of industries using static sound measuring procedures and dosimetry. The greatest proportion of workers affected by noise exposure in excess of 85dBA or 90dBA were mostly in Mining, Construction, Agriculture, and Manufacturing and these would be the key sectors to target interventions. In the remaining sectors, smaller proportions were exposed to over 85dBA or 90dBA in Transport and Services. No workers in the Finance and Administration Sectors were exposed to levels in excess of 85dB LAeq, although levels in some Early Childhood Education Centres exceeded 85dB LAeq and may need to be regarded as a special case.

Assessments were made of the current daily noise exposure levels using dosimeters worn during a single shift. Employees were grouped into production and non-production workers. There were large differences in mean noise exposure levels between these two groups (Mean 81.9dBLAeq, range 68-86.3 dBLAeq vs Mean 71dBLAeq, range 69.6-73.8dBLAeq respectively).

The proportion of males and females exposed in these sectors is similar for Agriculture and Trade, reflecting the nature of the work and participation rates in these sectors. However in all others a higher proportion of males are exposed to damaging levels of noise than females.

There is a higher proportion of Māori exposed to noise in all the High and Medium Noise Industries compared with non-Māori, except for Agriculture where the proportions are equivalent.

Some non-production workers, for example in Agriculture, Construction and Manufacturing are exposed to relatively high noise levels (approximately 74dBLAeq) which may relate to office workers and managers moving between the office and factory or workshop. Non-production workers in the Services Sector were also exposed to high noise levels, possibly for similar reasons. Thus no non-production workers were exposed over 85dBLAeq but some (6%) were exposed to peak levels over 140dBCpeak.

There was a very large range of exposures within each sector. From these data it was possible to gain an estimate of the proportion of workers exposed to noise levels of 85dB LAeq or greater or 90dB LAeq or greater. We estimate that the greatest proportion of workers affected by noise exposure in excess of 85dBA or 90dBA were mostly in Mining (75%, 50% respectively), Construction (67%, 20%), Agriculture (58%, 27%) and Manufacturing (43%, 14%). This confirmed these as “High Noise Sectors” with high risk of developing hearing loss. In the remaining sectors, smaller

proportions were exposed to over 85dB or 90dB (Transport, 24% and 12%; Services 14% and 4%; and Trade 12% and 10% respectively). These sectors could be classed as “Medium Noise Sectors”. Caution needs to be considered around these classifications: for instance, the Services sector contains noisy environments (eg panelbeating) and low noise environments (eg libraries), and this would be true to some extent in all sectors.

No workers in the Finance Sectors were exposed to levels in excess of 85dB LAeq. These could be classed as a “Low Noise Sector”.

Assuming these noise levels and proportions can be generalised within each sector (the validity of this assumption is discussed in the general discussion), these data suggest that the proportions of New Zealand workers exposed to levels in excess of 85dBLAeq and 90dBLAeq are greater in Construction, Manufacturing and Agriculture, but substantially less in Finance than predicted by the NIOSH data and the WHO model.

2.1.3. Noise sources

In the high risk industry sectors, the sources were primarily impact noise; rotational noise due to machinery, gears, conveyers and electric motors; engine noise; high frequency pneumatic noise due to hydraulic equipment and operations; pipe noise due to turbulent flow within pressurized steam lines; compressor noise and alarm noise due to operational alarm activation.

In the medium and low risk sectors, noise sources tended to be related to the task, activity and equipment being used and the interaction of other, usually external sources of noise not directly related to the workplace such as traffic noise.

Identification of noise paths in relation to the noise sources was complex as it included indoor and outdoor environments. However, airborne paths were the primary route for noise, with some cases of structure-borne and duct-borne noise/vibration transmission.

Agriculture, construction and saw milling sound sources and paths were similar in the fact that sound from many key activities, tasks and use of equipment and machinery were generated and transmitted in outdoor environments. This is opposed to the other traditional manufacturing sectors (bottling, textile, engineering) where key activities, tasks and machinery and equipment use were usually undertaken within a building structure (indoor), where structure borne sound transmission became more evident.

2.1.4 Hearing Loss

The proportion of people with hearing loss and the extent of the loss in these sectors tended to be correlated with the expected exposures, except for the construction sector where the losses tended to be worse than predicted. This may relate to the small samples size or could reflect greater impulse noise exposures in this industry.

The greatest proportions and level of hearing loss were in the Construction, Manufacturing and Transport sectors (Mining was not studied). Proportionally fewer people showed hearing losses in the Trade, Finance and Services sector, and these were only in the older age groups (51+yrs). Interestingly, there were few with significant hearing losses in the Agriculture sector, given the noise levels.

There is a difficulty in distinguishing the hearing loss from noise exposure from the effect of age purely on the basis of the audiogram because the two audiograms can overlap.

A number of algorithms which attempt to define noise-induced hearing loss by determining the presence of a “notch” at 4kHz were trialled and compared with the noise history. Of those identified by the algorithms and our criterion of average hearing loss at 1-4kHz >25 dBHL, 84% to 91% had a history of occupational noise exposure.

2.1.5 Non-work noise exposure

Non-occupational noise exposure is a significant issue and some people are exposed regularly to levels of noise in excess of the dose that would be derived from occupational settings.

Most participants (74.3%) in our studies took part in one or more non-work activities which they considered to be noisy. The most commonly reported non-work noisy activities were ”do-it-yourself“ (DIY) construction and maintenance projects at home (including lawn mowing, power tools, chain saws) and music listening (including night clubs, bars, live music events,

Participation rates for non-work related activities seem to be similar for younger (≤40 years old) and older (>40 years old) subjects, apart from DIY and music. Reflecting trends in social activity a much larger proportion of older subjects are involved in DIY activities (59.2%, compared to 36.4% of younger subjects). More males take part in noisy leisure activities than females (84% and 67% respectively). In addition, males report higher participation in DIY, motor cars, and shooting activities, whereas females take part more in music-related activities. The most commonly reported non-work noisy activities were ‘do-it-yourself’ (DIY) construction and maintenance projects at home (including lawn mowing, power tools, chain saws) and music listening (including night clubs, bars, live music events, Personal Listening Devices, home/car stereos, musical instruments, fitness classes). Other, less common, non-work activities included those involving motor vehicles (including racing cars, riding motorbikes, boating, water skiing and jet skiing) and firearms (including hunting and target shooting).

People are potentially exposed to high noise levels in many of these leisure activities. High noise levels occur (eg 100dBLAeq and 108dBLAeq) in nightclubs and live music events while PLDs can produce levels up to 100dBA using earbud headphones.

Because people spend a long continuous time in loud music (around 2-5hrs per day with a PLD; longer for nightclubs and live music events) these high noise exposures can contribute significantly to the daily noise dose for an individual (e.g., 15 minutes unprotected exposure at a nightclub with noise levels at 100dB is equivalent to 85 dBLAeq for 8 hours).

Total lifetime noise exposure contributions from both occupational and non-work related activities were calculated in these studies. Subjects who are currently less than 30 years old had a larger proportion (60%) of their lifetime noise exposure attributed to non-work related activities, compared to older subjects (41-45%). This may be due to a decrease in levels of occupational noise exposure or changes in the types of non-work related activities, possibly the introduction and popularity of PLDs, or greater access to and/or attendance at nightclubs or music concerts.

Hearing Protection Equipment (HPE) use during non-work related activities appears to be low. HPE was not used for 68.2% of all reported noisy leisure activities, but there is greater usage during DIY activities and firearms use. Not surprisingly, HPE usage is lowest when listening to music, since it is often not possible (for example using PLDs) or is socially undesirable (for example in night clubs or other live music events).

2.2 Prevention of Noise-induced Hearing Loss in New Zealand

2.2.1 International Best Practice

A systematic and comprehensive search of the peer-reviewed and non-peer reviewed literature demonstrated that effective interventions will require a combination approach, taking the best strategies from different types of intervention. In the intervention studies identified, the best of these approaches combined “high level” interventions (e.g. active management targeted with greater use of noise elimination, design and engineering noise controls). The least effective contained a lower level component (e.g. person-centred behavioural approaches with little management support to promote the wearing of personal hearing protection). The review identified five key strategies used in NIHL prevention interventions: introduction of legislation and enforcement, leadership, multifactorial interventions, implementation of engineering and design controls, and training interventions.

2.2.2. Noise controls and conformance assessment

The predominant noise control strategy in New Zealand businesses appears to be minimisation, specifically the use of personal hearing protection.

Based on the small sample (30 businesses) it appears that many businesses are concerned about noise exposure and may explore options for elimination and isolation of noise sources but few (12%) seem to undertake modifications or replacement of equipment, which resulted in a self-reported reduction of noise exposure in the workplace. Although many investigate control at source options, few pursue these options because they are (1) too expensive or (2) they do not have the

technical expertise to reduce noise further. Administrative controls were not used in any of the organisations surveyed.

Conformance values across all sectors is very low (median value 2.0 and mean 1.9, sd.1.7 with 10 being total conformance). The conformance element most commonly addressed was the provision of personal hearing protection, followed by the requirement to investigate and if practical, control noise at source.

Although some businesses (27%) undertake some form of preliminary noise survey, relatively few provide information on noise to employees as part of their hazard management programme. It was very interesting that less than 10% of the businesses undertook audiometry of employees, isolated noise sources or had notified the Department of Labour of a hearing loss case.

As a consequence very few businesses (6%) had taken all practical steps to provide a safe place of work.

Of the "high risk" industry sectors surveyed the bottling, engineering businesses and farms were the most compliant followed by construction and saw mill/ wood processing businesses. Of the remaining "high risk" industry sectors, textile manufacturing had the lowest mean conformance score of 0.33 (0.57), which was comparable with the "medium risk" hospitality sector (mean 0.33(0.57)). The "low risk" sector, education, had a mean conformance score of 1.7(1.5) indicating that at least some effort was being undertaken to address the noise exposure issue in this sector.

2.2.3 Hearing Protection Equipment Usage

Hearing Protection Equipment (HPE) seems to be used by most workers (80-100%) when the noise levels are in excess of 85dBLAeq and by all of those who worked in levels above 90dBLAeq. Where workplaces are subjectively perceived to be noisy, there is an increased use of HPD.

A large proportion of production workers do not use HPE; and this was greater in the Transport and Agriculture sectors. The use of HPE appears to be equivalent across ages, although very young workers (<30yrs) tend to have the lowest rates of use. The majority (69%) of those who used HPE preferred ear muffs to earplugs.

A high proportion of older workers did not use HPE at earlier stages of their lifetime work noise exposure. This may indicate that younger workers currently use HPE more often in noisy situations than the older workers did at the same age.

2.2.4. Safety climate and attitudes to noise and exposure to noise

Companies with higher compliance scores and higher risk of NIHL also have higher noise levels, as measured by the median value of the LAeq.8hr measures. Compliance appears to be unrelated to safety climate or to employee acceptance of noise.

NIHL risk however, coded as low, medium or high is correlated with employees' perceptions of benefits of and barriers to managing noise at work, with employees in higher risk workplaces perceiving fewer barriers to or benefits from managing noise, perhaps because noise hazards were already being addressed in these workplaces.

Employees in noisier workplaces see fewer barriers to managing noise. Only the 'personal responsibility' facet of safety climate appears to be correlated with noise levels.

Personal responsibility for safety is also correlated with stronger perceptions that there are barriers to noise management and lower self-efficacy for HPD use. The Safety Priority facet of safety climate is correlated with less acceptance of noise, and fewer perceived barriers to managing noise.

It is interesting and disappointing that the only facet of safety climate related to HPD use was personal responsibility for safety. Significant mediation was found for only one of the personal factors, perceived benefits of managing noise. Thus overall, safety climate: perceptions of safety as a workplace priority explained little variance in anything. Safety as a personal responsibility did. After decades of effort in trying to improve safety management, this is disappointing. Evidence from this study suggests that maybe perceptions of safety climate follow, rather than lead safety management efforts. Safety Climate is complicated: different facets have different correlates and implications. The implications of this study are that hazards are best managed directly rather than indirectly through attempts to change climate through marketing, training, attitude change. In focusing on psychosocial factors, it is important not to overlook the physical work environment – actual noise levels were more strongly related to HPD use and management compliance than safety climate or attitudes.

3. Strategic issues

The following are strategic issues that become apparent from the findings of the research.

3.1 Society/ Community issues

- Noise exposure, in work and leisure environments, causes substantial hearing loss and contributes to a significant proportion of the total population hearing loss burden.
- There is low compliance for hearing loss prevention strategies in industries and relatively little attention given to hearing protection in leisure activities, suggesting low awareness of noise as a hazard and poor safety practices associated with noise exposure.
- Society's perception of NIHL as a condition is relatively poor, given that the consequences of exposure noise are not directly evident. Furthermore, hearing loss per se is not universally recognised as a significant problem (the so-called "invisible handicap" and there is the perception that hearing is not considered a "treasured/valued sense".
- The artificial separation of strategies around noise exposure and NIHL prevention into occupational and non-occupational environments.
- The importance of reducing acoustic risk-taking behaviour and noise exposures with children (primary and secondary school children) and youth
- The importance of community driven design and redesign strategies in controlling/ eliminating noise exposures at its source.

3.2 Industry sector issues

- Production workers in Agriculture, Mining, Construction and Manufacturing are exposed to the highest noise levels and have the highest risk of developing hearing loss.
- Workers in some sub-sectors of other economic sectors have high risk of hearing loss but overall those in Transport, Services and Trade, have lower risk of NIHL
- Non-production workers and workers in "white-collar" occupations (i.e. professionals, administrators, clerks, and sales and service staff) have a relatively low risk of developing NIHL.
- Traditional noise control at source solutions in the high risk industry sectors (agriculture, construction and manufacturing) may be perceived difficult to implement.
- A majority of the enterprises in the high risk industry sectors employ fewer than 20 staff and there are difficulties (a) identifying and (b) engaging small enterprises in these industry sectors.
- National resources are currently limited to adequately engage the high risk industry sectors.
- Intervention strategies need to be specific to the industry sector.

3.3 Compliance issues

- Prevention of NIHL is not identified specifically as a priority in national strategies.
- Business owners and managers do not generally pursue noise control at source as a noise management option.
- There is a lack of appropriate technical advice, support and incentives for effective noise management strategies in the “high” risk industry sectors.
- There is a lack of surveillance for NIHL and noise exposure generally in industry.
- Few noise control interventions at national, industry sector or organisational levels have been adequately evaluated.

4. Analysis of the strategic issues

Our current challenge in promoting evidence-based practice and policy development is to build on the systematic collection and synthesis of evidence to develop tools that will assist decision-makers in choosing interventions to implement. Verma et al (2011) suggest, however, that in the individual/clinical and population health fields, the risk reductions which have been identified from systematic reviews are rarely if ever applied locally and presented as impacts on local populations.

The opportunity provided from the current research is to apply the evidence collected directly to the development of a strategy for preventing NIHL and the design and development of specific or targeted interventions. Identifying the key issues and problems will enable more effective and targeted approaches.

A variety of techniques have been developed to assist with the development of interventions. One technique, utilising a problem-solving risk management methodology, is promoted by Professor Malcolm Sparrow, Kennedy School of Government, Harvard University (Sparrow, 2000). The methodology has the following generic features;

1. Nominate potential problem of attention
2. Define the problem precisely
3. Determine how to measure impact
4. Develop solutions/intervention
5. a. Implement the plan
   b. Periodic monitoring/review/adjustment
6. Project closure, and long-term monitoring, maintenance.

A modified version of this methodology has been applied to the strategic issues identified from the current research projects and to assist in formulating recommendations.

4.1 Society/ Community issues

The problem(s)

- Noise exposure, in work and leisure environments, causes substantial hearing loss and contributes to a significant proportion of the total population hearing loss burden.
- There is low compliance for hearing loss prevention strategies in industries and relatively little attention given to hearing protection in leisure activities, suggesting low awareness of noise as a hazard and poor safety practices associated with noise exposure.
- Society's perception of NIHL as a condition is relatively poor, given that the consequences of exposure noise are not directly evident. Furthermore, hearing loss per se is not universally recognised as a significant problem (the so-called "invisible handicap") and there is the perception that hearing is not considered a "treasured/valued sense".
- The artificial separation of strategies around noise exposure and NIHL into occupational and non-occupational environments.
- The importance of reducing acoustic risk-taking behaviour and noise exposures with children (primary and secondary school children) and youth.
- The importance of community driven design and redesign strategies in controlling/ eliminating noise exposures at its source.

Solutions/intervention

The following four part multifactorial/ multilevel intervention strategy (*eg SoundSafe*) could be implemented at the community level. This would be a community education and awareness programme.

1. To become of national significance to New Zealand society, industry and other government agencies the Prevention of NIHL needs to be identified and resourced as a priority. This should be promoted through a community development/action approach to hearing loss prevention (SoundSafe). This could be achieved by;

   (a). Establishing a National Forum on NIHL to raise commitment and motivation for improved noise management and hearing loss prevention among government and non-government organisations, the wider community and for specific settings such as workplaces, public places, marae, schools, homes, roads and sport and recreational environments.

   (b). Establishing a SoundSafe website which would provide easily accessible information, resources and data for the prevention of NIHL for government agencies, research and community organisations.

   (c). Establishing a National NIHL Expert Advisory Panel (including leading international experts) to provide advice and guidance on the implementation of the intervention strategy to government and non-government organisations and the wider community.

2. Integrate the vision and objectives of the SoundSafe strategy with other national strategies including the New Zealand Injury Prevention Strategy (NZIPS), the Workplace Health and Safety Strategy (WHSS) and the National Foundation for the Deaf, Noise Induced Hearing Loss Strategy (NFD NIHLS). Integrate the Strategy with other hearing loss prevention initiatives and programmes.

3. A key component of the SoundSafe strategy could be the implementation of the Prevention through Design (PtD) initiative developed by NIOSH (2010) to reduce the noise exposure of equipment and machinery used in the community and in "high" risk industry sectors. Through utilizing the four functional areas (research, policy, practice, and education) of the PtD process, the PtD approach consists of developing collaborations or partnerships, procedures, resources, implementation plans, design strategies, case studies, and research to practice (r2p) initiatives from identification of the problem to implementation. This would involve developing collaborations with equipment and machinery manufacturers and distributors, government and community agencies and groups.

4. Another key component of the community wide strategy would be the implementation of an educational intervention designed for primary and secondary school children aimed at reducing acoustic risk-taking behaviour in children. The implementation of the "Dangerous Decibels" programme should be supported and maintained.

Measure impact

Whilst evaluation of community-based interventions is complex, several outcomes can be assessed by either asking participants in the community about the programme (i.e. self-report measures) or by obtaining data on health measures (i.e. objective measures). Even with the limitations of these approaches, the capability of self-report measures to collect health information from a large number of individuals can make them useful tools for evaluating large-scale community-based interventions. In comparison, the demands and costs of gathering nonverbal information can limit the number of individuals in the community that can be assessed. To offset concerns about the use of self-report measures, it can be beneficial to empirically demonstrate the reliability and validity of such measures. However, strategies of providing community-wide education (termed the "top-down" approach) may be less effective in changing health than interventions that also target collaborative community involvement and infrastructure development (termed the "bottom-up" approach).

A longitudinal ecologic case-referent study design could be utilised. This would assess a sample of the population's awareness, attitudes, perceptions and self-report behaviour in relation to noise and NIHL, prior to, and after, implementation of the proposed intervention. It is important to note that a PhD student at the University of Auckland, Ravi Reddy, funded through a ACC/HRC doctoral award is currently exploring this model for NIHL.

Implement the plan and periodic monitoring/review/adjustment

The strategy would be required to be implemented in a number of stages.

1. The establishment of a National Forum and NIHL Expert Advisory Panel with the identification of the Prevention of NIHL as a national priority.

2. Development of a plan for the integration of the vision and objectives of the Sound-safe strategy with other national strategies.

3.Develop collaborations and partnerships with equipment and machinery manufacturers and distributors, government and community agencies and groups to implement the Prevention through Design (PtD) initiative.

4. Develop and implement the primary and secondary school educational intervention (Dangerous Decibels/ Sound Sense).

5. Develop a community-wide evaluation strategy for the SoundSafe intervention.

4.2 Industry sector issues

The problem(s)

- Production workers in Agriculture, Mining, Construction and Manufacturing are exposed to the highest noise levels and have the highest risk of developing hearing loss.
- Workers in some sub-sectors of other economic sectors have high risk of hearing loss but overall those in Transport, Services and Trade, have lower risk of NIHL
- Non-production workers and workers in "white-collar" occupations (i.e. professionals, administrators, clerks, and sales and service staff) have a relatively low risk of developing NIHL.
- Traditional noise control at source solutions in the high risk industry sectors (agriculture, construction and manufacturing) may be perceived difficult to implement.
- A majority of the enterprises in the high risk industry sectors employ fewer than 20 staff and there are difficulties (a) identifying and (b) engaging small enterprises in these industry sectors.
- National resources are currently limited to adequately engage the high risk industry sectors.
- Intervention strategies need to be specific to the industry sector.

Solutions/interventions

An eight part multifactorial/ multilevel intervention strategy (SoundSafe) would be required. This would be an industry specific intervention programme. Components would include;

1. Identification of Prevention of NIHL as a priority under the Workplace Health and Safety Strategy 2015 and the WHSS National Action Agenda (2010) and the Draft Occupational Health Action Plan (2011). Utilise the proposed National Forum on NIHL to gain commitment and motivation for improved noise management and hearing loss prevention among industry sectors.

2. Through the National Forum on NIHL, develop industry specific intervention strategies for "high" risk industry sectors (agriculture, construction and manufacturing). Base these on intervention strategies designed for small businesses, including the recognition of the key role of intermediaries and external stakeholders.

3. Developing collaborations and partnerships with equipment and machinery manufacturers and distributors, government and industry sectors associations to implement the Prevention through Design (PtD) initiative in the agriculture, construction and manufacturing sectors. Support and promote of national and international standards for equipment and machinery noise emissions, including a manufacturers declaration of conformity to prescribed standards and labelling of sound power levels generated by the equipment.

4. Designing intervention programmes that focus on increased awareness, prominence, self-efficacy, economic and regulatory incentives and managerial commitment. This may be achieved by visits from the Department of Labour, the

influence of peers, role-models and industry champions and by other social marketing strategies. Raising the awareness of the potential benefits of effective noise control by developing easily accessible and useable noise control cost-benefit models and templates is also suggested. Business owners and managers could access these templates from government or industry websites.

5. Developing and promoting “best” or “good” practice models for effective noise control management within the industry sector. These include noise control measures that actually improve productivity and reduce costs - in contrast to reliance on conventional enclosures and acoustic guarding. In addition, the introduction and continued promotion of “buy quiet” purchasing policies by industry sectors and business owners, is seen as an important component of these best practice models.

6.Development, promotion and maintenance of surveillance schemes for occupational hearing loss and workplace noise exposure within the “high” risk industry sectors.

7. Providing technical advice and support for small enterprises within the industry sectors through Industry Associations, Department of Labour, ACC and other community agencies (e.g. local authorities).

8. Developing industry specific evaluation strategies for the SoundSafe intervention.

Measure impact

1. The impact of the proposal to engage industry associations and community groups through the proposed National Forum on NIHL could be assessed by reference to national strategy documents from the Department of Labour, ACC and industry sector associations, where a commitment to the prevention of NIHL is detailed, and where industry specific interventions are proposed and developed.

2. The Prevention through Design initiative in the agriculture, construction and manufacturing sectors, could be evaluated by the development and distribution of case studies of the successful application of Prevention through Design (PtD) initiatives; case studies and recommendations for the “buy quiet” approach to equipment and machinery purchase and renewal and the development of practical engineering solution exemplars specific to the industry sector. The impact of the initiative could be assessed by surveying the nature and extent of adoption of the PtD principles within the industry sectors.

3. Industry specific interventions for the prevention of NIHL would be developed in collaboration and partnership with industry associations, Government agencies and other community groups. It is recommended that the intervention strategy for the Prevention of NIHL (SoundSafe) be based on the conceptual model for intervention research initially developed by Goldenhar et al, (2001) and enhanced by LaMontagne et al (2003) and LaMontagne and Shaw (2004).

4. Evaluation of the SoundSafe intervention can be done at different times of the intervention and provide different sorts of information. The best types of evaluation provide information that helps improvement – information for action.

   Process evaluation can be done during the intervention or after its completion. Formative evaluation can also be done while the intervention is happening – the distinction here is that whatever is learned is applied in an on-going way to help fine-tune the intervention and to ensure reliable data. Process and formative evaluation are relatively less resource-intensive than effectiveness evaluation (LaMontagne & Shaw, 2004). These types of evaluation will answer questions like:

   - How well did we implement the activities?
   - Did we get the right stakeholders involved?
   - How is the intervention affecting the targets?
   - How well did the intervention address the identified problem?

   Effectiveness evaluation (Outcome evaluation) requires the most time and resources and can only be finished after the intervention has been completed (LaMontagne & Shaw, 2004). This type of evaluation will answer questions like:

   - To what extent did the intervention achieve the expected outcomes?
   - Did the intervention meet the identified needs?
   - Did we get value for money from the intervention?

   The framework developed by LaMontagne et al (2003) lays out a systematic process for evaluating occupational health and safety intervention programmes. It is designed for use by practising professionals working in government OHS agencies. The intervention evaluation framework focuses on answering three questions:

   (1) What is the rationale of the intervention? (Put more simply, how is it supposed to work?)
   (2) What are the questions to be answered about this intervention?
   (3) What are the appropriate evaluation methods, designs or tools that can be used to answer these questions?

   As the implementation of the Intervention Strategy involves identifying and engaging small businesses primarily at the organisational level, recent approaches to intervention evaluation in small businesses may also offer an important framework for analysis. Legg et al (2010) applied a “programme theory” framework to interventions in small business (SB). Essentially, programme theory provides the fundamental rationale and the underlying driver(s) that makes a programme work. The construct ‘programme theory’ can be particularly useful because it is a construction of a plausible and sensible model of how a public programme is supposed to function. It is also useful in evaluating the programme and identifying moderators.

   There are, in particular, three points with important moderators which can enhance or constrain the effects of the programme theory. The first is ‘contact with

the SB': are they actually reached? The second is 'interpretation in the SB': do they actually interpret the programme as intended? The third point concerns 'the effects'; that is, whether the action is carried out as intended. It may be possible to integrate the evaluation frameworks identified to provide a comprehensive evaluation framework at the National, Industry and Organisational level.

4.3 Compliance issues

The problem(s)

- Prevention of NIHL is not identified specifically as a priority in national strategies.
- Business owners and managers do not generally pursue noise control at source as a noise management option.
- There is a lack of appropriate technical advice, support and incentives for effective noise management strategies in the “high” risk industry sectors.
- There is a lack of surveillance for noise induced hearing loss and noise exposure generally in industry.
- Few noise control interventions at national, industry sector or organisational levels have been adequately evaluated.

Solutions/interventions

1. Through the proposed National Forum on NIHL, identify Prevention of NIHL as a national priority for action, work in collaboration with Government agencies and industry sectors associations and other community agencies to integrate prevention of NIHL in national programmes and initiatives. The Draft Occupational Health Action Plan 2011 does have Noise identified as an Occupational Health priority.

2. An integrated compliance strategy is recommended (Sparrow, 2000) for the Department of Labour where there would need to be operational changes in expectations with respect to policing the requirements of the legislation and the Approved Code of Practice for the Management of Noise. They would include – much less reliance on HPD’s; much more of a risk based approach; much better compliance with the duty to reduce noise by engineering means is expected; risk assessments should identify a programme of work; less assessment and "process", more Action is expected; if solutions have been identified "stop assessing and start controlling"; health surveillance is required above 85dB(A) which can be considered to be "a tax on failure to control the risks".

3. Increased enforcement activity from the Department of Labour is recommended. The potential for introducing into New Zealand legislation a strata of action levels (lower and upper) similar to those introduced in Europe and the United Kingdom could be investigated to reinforce the current NZ standards. The aim (of the action levels) would be a mechanism to encourage business owners and managers to implement not only minimisation strategies (HPD’s), but to pursue elimination, isolation and noise reduction strategies, particularly if those strategies were able to effect productivity and reduce costs.

4. In relation to technical advice and support, a SoundSafe toolbox could be developed for specific industry sectors which could include; case studies of the successful application of Prevention through Design (PtD) initiatives; case studies and recommendations for the “buy quiet” approach to equipment and machinery purchase and renewal; practical engineering solution exemplars specific to the industry sector; accessible (web based) cost-benefit models for proposed noise management options; case studies and recommendations for use of other control

techniques including the effective use of administrative controls, work organisation and work environment modifications and equipment maintenance schedules.

5. Incentive schemes for promoting noise management initiatives at the industry and organisational level could be developed.

6. Surveillance schemes for occupational hearing loss is identified as a key strategy in effective noise management programmes. A programme of increased surveillance is recommended within the “high” risk industry sectors. Surveillance for occupational hearing loss is primarily about providing information to the employer to assist in their duty to manage risks to their employees. In addition, surveillance of workplace noise exposure is vital to prevention of NIHL because it can identify the most problematic industries, occupations, equipment and tasks and because it can be used to evaluate the effectiveness of intervention activities.

7. Design, develop and implement an evaluation plan for the SoundSafe strategy at the national and industry sector levels.

Measure impact

1. Identify and confirm that noise and the prevention of NIHL have been incorporated in subsequent action Plans and Agendas related to National strategies.

2. Monitor Department of Labour inspectorate visits to high risk industry sector enterprises regionally to assess the extent to which better compliance with the duty to reduce noise by engineering means is undertaken, and whether risk assessments have identified a programme of work and whether action in pursuing noise management options at source have been effective.

3. Process and formative evaluations of the distribution and use of the SoundSafe toolbox.

4. Monitor the Sound Safe incentive scheme (if initiated) to identify and promote innovative noise management solutions in the high risk industry sectors. Determine whether significant reduction of sound power emissions have been achieved, by pre and post intervention sound level measurements.

5. Monitor the SoundSafe surveillance scheme for increase audiometric testing and collection of sound level survey data in the high risk industry sectors

5. Recommendations

The following are **Recommendations** for an intervention strategy for the prevention of NIHL (SoundSafe) focused on the higher risk industries which have been identified from the findings of the combined research projects (Epidemiology of NIHL and Prevention of NIHL).

5.1 The highest areas of priority for immediate intervention.

> **Recommendation 1:** *The highest areas of priority for immediate intervention in relation to the prevention of NIHL are the Agriculture, Mining, Construction and Manufacturing industry sectors. We recommend that intervention strategies for the prevention of NIHL be developed for these industry sectors.*

5.2 The most effective intervention options

The most effective way to prevent NIHL is to remove the hazardous noise from the workplace or to remove the worker from the hazardous noise. Implementation of engineering and administrative controls of noise represents a top occupational health and safety priority and should be fully utilized to reduce and eliminate hazardous noise exposures. Recommendations for development of interventions at the national and industry sector level are detailed below.

5.2.1 National level interventions

The purpose of an Intervention Strategy for the Prevention of Noise Induced Hearing Loss (SoundSafe) would be to establish an integrated framework for the prevention activities of government agencies, local government, non-government organisations, industry groups, iwi, communities, businesses, families/whanau and individuals to reduce the incidence of NIHL. The Strategy should set out a vision for the prevention of hearing loss in New Zealand where;

> *"hearing is regarded as a special sense that is valued by the community in home, work and leisure environments".*

> **Recommendation 2:** *We recommend an Intervention Strategy for the Prevention of NIHL (SoundSafe) has a vision for New Zealand where hearing is regarded as a special sense that is valued by the community in home, work and leisure environments.*

This strategy could be achieved by the following;

(i) Establish a National Forum and Expert Advisory Panel on NIHL

A National Forum on NIHL would raise commitment and motivation for improved noise management and hearing loss prevention among government and non-government organisations, the wider community and for specific settings such as

workplaces, public places, marae, schools, homes, roads and sport and recreational environments.

In addition, a National NIHL Expert Advisory Panel should be established to provide advice and guidance on the implementation of the Intervention Strategy to government and non-government organisations and the wider community.

> **Recommendation 3:** *We recommend a National Forum and expert Advisory Panel on NIHL be established.*

> **Recommendation 4:** *We recommend a SoundSafe website be established to provide easily accessible information, resources and data for the prevention of NIHL for government agencies, research and community organisations.*

(ii) Prevention of NIHL should be national priority

To become of national significance to industry and other government agencies the Prevention of NIHL needs to be identified and resourced as a priority. The Prevention of NIHL is not identified as a national priority under the WHSS 2015, nor as a priority in the WHSS National Action Agenda (2010), nor as a priority in the Construction Sector Action Plan 2010 - 2013 (2011). However, it has been included as a priority in the Occupational Health Action Plan (2011).

> **Recommendation 5:** *We recommend that through the proposed National Forum on NIHL, Prevention of NIHL would be identified as a national priority for action, and work in collaboration with Government agencies, industry sectors associations and other community agencies to integrate prevention of NIHL into national programmes and initiatives.*

(iii) Community development/ action approach to hearing loss prevention

Community wide (leisure and home) intervention strategies such as the National Foundation for the Deaf (NFD) “Noise Induced Hearing Loss Project” need to be inter-related with workplace (occupational) initiatives. Unlike the consequence of other hazardous exposures, NIHL is linked to both work and leisure activities and the “administrative” separation of these components make effective prevention/ management interventions difficult. Community based non-government organisations could effectively be engaged to promote incentive schemes/ awards and other programmes that recognise and acknowledge good noise management practice at the industry and organisation level. In addition, the implementation of an educational intervention designed for primary and secondary school children aimed at reducing acoustic risk-taking behaviour in children is recommended. The implementation of the “Dangerous Decibels” programme should be supported and its role maintained.

> **Recommendation 6:** *We recommend that community wide (leisure and home) NIHL intervention strategies need to be inter-related with workplace (occupational) initiatives.*

Recommendation 7: *We recommend that community based non-government organisations could effectively be engaged to promote incentive schemes/ awards that recognise and acknowledge good noise management practice at the industry and organisation level.*

Recommendation 8: *We recommend that the implementation of the "Dangerous decibels" programme for schools should be supported and maintained.*

(iv) Adoption of Prevention through Design (PtD) principles

Evidence suggests that the Prevention through Design (PtD) initiative developed by NIOSH (2010) could be successfully applied to reduce the noise exposure of equipment and machinery used in "high" risk industry sectors. Through utilizing the four functional areas (research, policy, practice, and education) of the PtD process, the PtD approach consists of developing collaborations or partnerships, procedures, resources, implementation plans, design strategies, case studies, and research to practice (r2p) initiatives from identification of the problem to implementation.

Recommendation 9: *We recommend that collaborations and partnerships be developed with equipment and machinery manufacturers and distributors, government agencies and industry sector associations to implement the Prevention through Design (PtD) initiative in the agriculture, construction and manufacturing sectors.*

(v) Increased enforcement activity of Department of Labour and introduction of action levels for noise exposure

Increased enforcement activity from the Department of Labour is seen as an important part of a multilevel national strategy for the prevention of NIHL. In addition, the potential for introducing into New Zealand legislation a strata of action levels similar to those recently introduced in Europe and the United Kingdom could be investigated to reinforce the current NZ standards. For example a lower action level at 80dB(A) where noise assessment, training and the provision of information is required, and an upper action level at 85dB(A) where noise control measures become mandatory would similarly reinforce the existing standards.

Recommendation 10: *We recommend that the Department of Labour increase its enforcement activity in relation to noise exposure in agriculture, construction and manufacturing industry sectors. In addition, the potential for introducing into New Zealand legislation a strata of action levels (lower and upper) similar to those recently introduced in Europe and the United Kingdom could be investigated to reinforce the current NZ standards.*

(vi) Change in expectations in relation to noise management options

There have been significant changes in expectations with respect to policing the requirements of the noise regulations internationally. These could be very applicable in the New Zealand context. They include - less reliance on PPE; much more of a risk based approach; much better compliance with the duty to reduce noise by engineering means is expected; risk assessments should identify a programme of

work; less assessment and "process", more Action is expected; if solutions have been identified "stop assessing and start controlling"; health surveillance is required above 85dB(A) which can be considered to be "a tax on failure to control the risks".

> **Recommendation 11:** *We recommend that the Department of Labour changes its expectations with respect to policing the requirements of the legislation and the Approved Code of Practice for the Management of Noise. These changes would focus the duty holder of the enterprise to actively investigate and pursue noise control at source as a* ***primary*** *consideration.*

(vii) Promotion of innovative "best" or "good" practice models

A variety of "best" or "good" practice models for noise management have been identified. These include noise control measures that actually improve productivity and reduce costs - in contrast to reliance on conventional enclosures and acoustic guarding. In addition, the introduction and continued promotion of "buy quiet" purchasing policies by industry sectors and business owners, is seen as an important component of these best practice models.

> **Recommendation 12:** *We recommend that the Department of Labour in collaboration with agriculture, construction and manufacturing industry sector associations and ACC, develop and distribute industry specific, "best" or "good" practice models for noise management and continue to promote "buy quiet" purchasing policies by industry sectors and business owners.*

(viii) Development of surveillance schemes for occupational hearing loss and noise exposure

Surveillance schemes for occupational hearing loss are identified as a key strategy in effective noise management programmes. Surveillance for occupational hearing loss is primarily about providing information to the employer to assist in their duty to manage risks to their employees. In addition, surveillance of workplace noise exposure is vital to prevention of NIHL because it can identify the most problematic industries, occupations and tasks and because it can be used to evaluate the effectiveness of intervention activities.

> **Recommendation 13:** *We recommend that agriculture, construction and manufacturing industry sector associations in collaboration with the Department of Labour and ACC, develop and implement surveillance schemes for occupational hearing loss and workplace noise exposure.*

(ix) Provision of technical advice and support for noise management

A range of initiatives providing technical advice and support for primarily small enterprises have been developed and trialled in Australia, UK and Europe with varying levels of success. These have been reviewed extensively by Legg et al. (2009). Many of these initiatives could be very appropriate for the effective management of noise in New Zealand. This could include development of a "toolbox" which would contain case studies of the successful application of Prevention through Design (PtD) initiatives; case studies and recommendations for the "buy quiet" approach to equipment and machinery purchase and renewal;

practical engineering solution exemplars specific to the industry sector; accessible (web based) cost-benefit models for proposed noise management options; case studies and recommendations for use of other control techniques including the effective use of administrative controls, work organisation and work environment modifications and equipment maintenance schedules.

Recommendation 14: *We recommend that agriculture, construction and manufacturing industry sector associations in collaboration with the Department of Labour and ACC, develop a SoundSafe "toolbox" to provide technical advice and support for those industry sectors.*

(x) Intervention development, implementation and evaluation

Interventions need to be cyclical and ongoing, from needs assessment, intervention development, implementation and evaluation to renewed assessment of needs (Laird et al 2010; Legg et al., 2010). Given the risk of NIHL in NZ industry, commitment is required at national as well as organisational levels to develop strategies for noise injury prevention including those that are suitable for small businesses (Hasle & Limborg, 2006).

Recommendation 15: *We recommend that the Department of Labour, ACC and industry associations develop in collaboration, an evaluation strategy for the implementation of SoundSafe programme within industry sectors.*

5.2.2 Industry sectors level interventions

(i) Agriculture

Recommendation 16: *We recommend that;*
1. Noise management interventions in agriculture be designed, developed and implemented in collaboration with all key internal and external stakeholders and intermediaries as well as farmers and farm mangers.

2. The intervention (SoundSafe – Agriculture) should be a multifactor/ multilevel design and include the following three components; the work environment, the organisation and people at work (Appendix B).

(ii) Construction

Recommendation 17: *We recommend that;*
1. Noise management interventions in construction be designed, developed and implemented in collaboration with all key internal and external stakeholders and intermediaries as well as SiteSafe and Government agencies.

2. The intervention (SoundSafe – Construction) should be a multifactor/ multilevel design and include the following three components; the work environment, the organisation and people at work (Appendix C).

(iii) Manufacturing

Recommendation 18: *We recommend that;*
1. Noise management interventions in manufacturing be designed, developed and implemented in collaboration with all key internal and external stakeholders and intermediaries as well as manufacturing association representatives and Government agencies.

2. The intervention (SoundSafe – Manufacturing) should be a multifactor/ multilevel design and include the following three components; the work environment, the organisation and people at work (Appendix D).

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Appendix A – Executive summaries of the two reports

1. Epidemiology of NIHL in New Zealand (Thorne et al, 2011).

This study, funded by the Joint Research Partnership Programme of the Health Research Council (HRC) and the Accident Compensation Corporation (ACC), was undertaken to investigate the epidemiology of Noise-induced Hearing Loss (NIHL) in New Zealand.

- The study design was based on a modelling approach developed by the Global Burden of Disease working group of the World Health Organisation (WHO) (Concha-Barrientos, Campbell-Lendrum & Steenland, 2004). The model utilised international data, to establish the estimated *excess risk* of developing hearing loss above age-related hearing loss given the level and duration of noise exposure in an occupational setting.
- Using this we identified the proportional attributable fraction for given sectors and occupational settings and then took data from the Census over different years on the participation rates in each sector and occupation, and the prevalence of hearing loss in New Zealand to provide the background data. From these data we developed estimates of the prevalence and incidence of NIHL (hearing loss ≥25dBHL$_{Ave1,2,3,4kHz}$) in different sectors and occupational groups and across census years (1986-2006).
- We attempted to verify and assess the sensitivities of these estimates with field measurements of noise levels in the workplace and assessment of hearing levels among a sample of workers in different sectors (529 workers and 99 companies across economic sectors). These data then allowed us to refine the estimates and to place them in a New Zealand context by drawing on New Zealand data.
- Our estimates of the prevalence of NIHL (≥25dBHL$_{Ave1,2,3,4kHz}$) in the *workforce,* in 2006, range from 29,242 (based on the WHO calculations) to 42,497 (based on New Zealand data collected in this study). This gives an incidence in the workforce ranging from 1077 to 1537 new cases of NIHL in 2006.
- We extrapolated the data to estimate the prevalence of NIHL (≥25dBHL$_{Ave1,2,3,4kHz}$) in the *New Zealand population*, in 2006, giving a range from 62,169 (based on the WHO calculations) to 69,613 (based on New Zealand data collected in this study). Since the data reflect *Occupational* NIHL, the incidence in the *New Zealand population* would not differ from that in the workforce.
- Based on these population data it is estimated that between 1.54 and 1.73% of the New Zealand population had a hearing loss solely due to occupational noise exposure. Because age-related hearing loss can add to the NIHL we estimated the number of people who would have only NIHL or some contribution to their total hearing loss from occupational noise exposure at between 2.25% and 2.58% of the population. Estimates are for unprotected noise exposures and are therefore likely to overestimate the prevalence of NIHL.

- Given the estimated prevalence of hearing loss in the New Zealand population is 10% (Greville, 2005) then we estimate that between 13.5% and 17.5% of the hearing impaired population have an occupational Noise-induced Hearing Loss and a total of 22.5-25.8% of hearing impaired people have some hearing loss from occupational noise exposure.
- Retrospective estimates using Census data indicates that there has been an increase in the total number of cases of NIHL and a small increase in the incidence rates between 1986 and 2006. The model predicts this on the basis of changes in the participation rates in sectors rather than any changes in the environmental noise levels which are assumed to remain the same across this period.
- Estimates of future incidence and prevalence were made under the assumption that the current trends in population growth and noisy sector participation would continue. The longest projections, to 2040, suggest that the number of people with NIHL will fall if current workforce trends continue and the rate would be determined by the efficacy of prevention programmes.
- Based on the noise measurements production workers in Agriculture, Mining, Construction and Manufacturing were exposed to the highest average noise levels (86.3-83.9 dBLAeq in descending order). However, these average levels were lower than what was predicted by the literature or NIOSH (1998) figures.
- The greatest proportion of workers affected by noise exposure in excess of 85dBA or 90dBA were mostly in Mining, Construction, Agriculture, and Manufacturing and these would be the key industries to target interventions. In the remaining sectors, smaller proportions were exposed to over 85dBA or 90dBA in Transport and Services. No workers in the Finance and Administration Sectors were exposed to levels in excess of 85dB LAeq.
- The proportion and extent of hearing losses in these sectors tended to be correlated with the expected exposures, except for the construction sector where the losses tended to be worse than predicted. This may relate to the small samples size or could reflect greater impulse noise exposures in this industry.
- The proportion of males and females exposed in these sectors is similar for Agriculture and Trade, reflecting the nature of the work and participation rates in these sectors. However in all others a higher proportion of males are exposed to damaging levels of noise than females.
- There is a higher proportion of Māori exposed to noise in all the High and Medium Noise Industries compared with non-Māori, except for Agriculture where the proportions are equivalent.
- Hearing Protection Equipment (HPE) was used by most workers (80-100%) when the noise levels were in excess of 85dBLAeq and by 100% of those who worked in levels above 90dBLAeq.
- HPE was used at some time by 50% of all workers interviewed. A large proportion of production workers (67%) did not use HPE; this was greater in the Transport and Agriculture sectors.
- The use of HPE tended to be equivalent across ages, although very young workers (<30yrs) tended to have the lowest rates of use.

- The majority (69%) of those who used HPE preferred ear muffs to earplugs.
- A high proportion of older workers did not use HPE at earlier stages of their lifetime work noise exposure. This may indicate that younger workers currently use HPE more often in noisy situations than the older workers did at the same age.
- Non-occupational noise exposure is a significant issue and some people are exposed regularly to levels of noise in excess of the dose that would be derived from occupational settings.
- Most participants in our sample (74.3%) took part in one or more non-work activities which they considered to be noisy. The most commonly reported non-work noisy activities were 'do-it-yourself' (DIY) construction and maintenance projects at home (including lawn mowing, power tools, chain saws) and music listening (including night clubs, bars, live music events, Personal Listening Devices, home/car stereos, musical instruments, fitness classes). Other, less common, non-work activities included those involving motor vehicles (including racing cars, riding motorbikes, boating, waterskiing and jet skiing) and firearms (including hunting and target shooting).
- More males take part in noisy leisure activities than females (84% and 67% respectively).
- The modelling approach has been shown to be effective as a framework to incorporate findings from research. Gradual improvement of these estimates with continued input from future research is therefore anticipated.

2. Prevention of NIHL in New Zealand (Laird et al, 2011).

1. Study Objectives

The objective of this project was to evaluate existing work-related interventions to reduce NIHL in New Zealand, to identify critical factors in the development and implementation of such strategies, and to propose strategies/interventions where current interventions are considered ineffective. In particular, this research project was to identify barriers to implementation of known approaches for addressing noise exposure, given that the association between noise and NIHL is well established. This included the perspectives of social marketing and behavioural psychology with respect to barriers to noise control and effective marketing of noise control messages to employers and workplaces. In addition, the research was to examine those aspects of workplace culture that affect decision-making around NIHL. The first objective of the project was to develop a research strategy that addressed the key objectives of the project.

2. Review of Literature

The second objective of the research strategy was the completion of an evidence based literature review relating to the effectiveness of intervention strategies to prevent NIHL. The evidence identified and collated in the review suggests that NIHL prevention is a complex issue without simple solutions. A systematic and comprehensive search of the peer-reviewed and non-peer reviewed literature identified 71 reports of relevance. Critical evaluation of the reports included assessment of study quality, impact and quality of outcome measures, consistency of

study findings, and generalisability and applicability of study findings to the NZ industrial context. Overall intervention study quality was satisfactory to poor. Studies varied widely in intervention type (from legislative change to one-off interventions) but interventions to promote the use of personal hearing protection dominated. Most interventions were conducted in the USA amongst white, middle-aged male workers. A range of industries was represented with manufacturing, mining, construction and agriculture the top four. Effective interventions will require a combination approach, taking the best strategies from different types of intervention. In the intervention studies identified, the best of these approaches combined "high level" interventions (e.g. active management targeted with greater use of noise elimination, design and engineering noise controls). The least effective contained a lower level component (e.g. person-centred behavioural approaches with little management support to promote the wearing of personal hearing protection). The review identified five key strategies used in NIHL prevention interventions: introduction of legislation and enforcement, leadership, multifactorial interventions, implementation of engineering and design controls, and training interventions. The challenge for designing effective NIHL intervention strategies will be to integrate and build on evidence from previous international quantitative and qualitative studies, in combination with attention to optimal occupational intervention study design, and a clear understanding of the local context gained through primary research.

3. Survey of Workplaces

The third objective of the research project was the completion of a survey of workplaces. A case study design was utilised to identify, describe and evaluate noise sources, exposures and control strategies used by those "high", "moderate" and "low" risk industry sectors in relation to exposure to noise. Thirty three (33) primarily small business workplaces were assessed, which showed that generally noise sources and paths could be readily identified and that area and personal sound level exposure measurements varied considerably between the high, moderate and low risk industry sectors. It was found that of the "high risk" industry sectors surveyed, most had mean and median sound levels that were at or above $L_{Aeq.8hr}$ 85dB and mean and median noise exposures recorded in "moderate" and "low risk" industry sectors (cafes and preschools respectively) were below $L_{Aeq.8hr}$ 80dB. Saw mills, construction and engineering businesses had the greatest percentage of employees exposed to noise levels above 85dB $L_{Aeq.8hr}$ (85%, 83% and 75% respectively). For other sectors, agriculture and bottling plants had lesser percentages (40% and 30% respectively) of employees exposed to levels in excess of 1 Pa^2hr. No employees in textiles and cafes were exposed to noise above 85dB $_{LAeq.8hr}$. Two employees in preschool facilities had daily dose estimates of 1.94 and 3.16 Pa^2hr. However, these values were outliers and were excluded from the analysis.

The predominant noise control strategy used by the businesses was the use of personal hearing protection. Although many operations were complex, noise management strategies aimed at the noise source and noise paths could have been investigated further. In agriculture and construction however, prevention through either noise reduction at source or isolation of the noise, even though best practice, may not always practicable so that hearing protection could be the only control option available. Most enterprises surveyed did not conform to the specific requirements of

legislative standards for noise management. Conformance values, scored from conformance values to the Approved Code of Practice, across all sectors ranged from 0 to 6 out of 10 (with 10 being total conformance - median value 2.0 and mean 1.9 (sd.1.7)). Of the "high risk" industry sectors surveyed the bottling, engineering businesses and farms were the most compliant (mean (sd) conformance scores; 4.3(2.1), 3.3(2.3) and 3(0) respectively). Mean conformance scores for the remaining industry sectors ranged from 2.3/10 to 0.33/10.

In addition, a survey of one hundred and sixty-three (163) respondents from these enterprises also provided data on hearing protection use, safety climate and attitudes to noise at work. Factor analysis identified two facets of safety climate: personal responsibility and workplace priority. Neither was related to company compliance with the Code of Practice but objective sound levels did predict compliance. There was little evidence that safety climate, conceptualised as perceptions of workplace priorities for safety, was related to noise management. Perceptions of safety as a personal responsibility predicted HPD use, and perceptions of benefits to managing noise mediated this relationship. Attempts to address safety climate by changing attitudes, beliefs and perceptions may be less effective than changing unsafe conditions and behaviours at all organisational levels.

Evidence from this study suggests that an employee's sense of personal responsibility for safety is the main motivator for protective behaviour in the workplaces surveyed rather than management initiatives or leadership. After decades of effort in trying to promote and improve health and safety management at the organisational level, this is disappointing. It is concluded that noise hazards are best managed directly rather than indirectly through attempts to change climate through marketing, training or attitude change. Safety climate is complicated. Different facets have different correlates and implications. The findings from this study suggest that perceptions of safety climate may follow, rather than lead, safety management efforts in relation to noise control within the businesses.

The background and results of this study were presented to industry and stakeholder representatives at the Symposium on Noise-Induced Hearing Loss, School of Population Health, University of Auckland. 29th November 2010. Comments and feedback was sought on the research and key issues identified included the importance of legislation and enforcement, culture change, intervention strategies, surveillance and provision of advice and information.

Finally, proposals for intervention strategies for the prevention of NIHL are described. They include establishing noise exposure and NIHL as national health and safety priorities; community wide (leisure and home) intervention strategies inter-related with workplace (occupational) initiatives; the Prevention through Design (PtD) initiative developed by NIOSH (2010) could be successfully applied to reduce the noise exposure of equipment and machinery used in "high" risk industry sectors; changes in expectations with respect to policing the requirements of noise regulations; increased enforcement activity from the Department of Labour is seen as an important part of a multilevel national strategy for the prevention of NIHL; the potential for introducing into New Zealand legislation a strata of action levels (lower

and upper) similar to those recently introduced in Europe and the United Kingdom could be investigated to reinforce the current NZ standards; adoption of “best” or “good” practice models for noise control, including noise control measures that actually improve productivity and reduce costs; development and maintenance of surveillance schemes for occupational hearing loss and surveillance of workplace noise exposure; adoption of interventions designed for small businesses within the “high” risk industry sectors (agriculture, construction and manufacturing) identified in this report, over 90% of enterprises within these sectors have less than 20 employees; initiatives providing technical advice and support for enterprises have been developed and trialled in Australia, UK and Europe with varying levels of success; interventions need to be cyclical and on-going, from needs assessment, intervention development, implementation and evaluation to renewed assessment of needs (Laird, et al., 2010).

4. Development of an Intervention Strategy for the Prevention of NIHL

A final and fourth outcome of the research project was the development of Recommendations for an Intervention Strategy for the Prevention of NIHL. This has been undertaken as a collaboration between the two research project teams. These recommendations are detailed in the companion document to this Report - “*Recommendations for the Development of an Intervention Strategy in the Prevention of NIHL”*.

Appendix B – SoundSafe - Agriculture

Work environment

The focus of intervention in the work environment involve changes to equipment, machinery, tasks and structures where noise is generated and transmitted. The source of noise on farms is site and situation specific, but can usually be readily identified. Farm work environment interventions involve 6 areas;

1. Identification of the specific noise source on the farm is the first step.
2. Working with agriculture equipment and machinery distributers and manufactures to determine whether the sound power emissions for the equipment can be reduced, if so how and whether new equipment to the market has lower emissions. This can be influenced by the development and outcome of the Prevention through Design (PtD) proposal if implemented (national strategy).
3. Design modification solutions for equipment and machinery can be implemented where appropriate, through the proposed SoundSafe “toolbox” resources involving practical engineering solution exemplars specific to farms and access to (web based) cost-benefit models for proposed noise management options.
4. Implementation of a “buy quiet” programme for equipment and machinery purchase and renewal. Case studies and recommendations for these would be available through the proposed SoundSafe “toolbox” resources.
5. The promotion and implementation of equipment and machinery maintenance schedules can be effective for significant sound level reductions.
6. Design modification solutions for farm structures (sheds, enclosures, workshops) can be implemented where appropriate, through the proposed SoundSafe “toolbox” resources involving practical engineering solution exemplars specific to farms and access to (web based) cost-benefit models for proposed noise management options.

Organisation

The focus of intervention in the farm organisation involves;

1. Assessing the nature and extent of general OHS management within the business, and noise management in particular. This can be achieved by completion of a modified health and safety management systems assessment (Department of Labour or ACC templates).

2. The adoption and implementation of “best” or “good” practice models for noise management. These include implementation of noise control measures that actually improve productivity and reduce costs - in contrast to reliance on conventional enclosures and acoustic guarding.
3. The development of a noise management plan linked to equipment and machinery purchase and renewal; equipment and machinery maintenance schedules and personal HPD programme. The potential for the implementation of effective administration controls and other control options (work organisation) for noise exposure should be included.

People at work

The focus of the intervention for people at work would involve;

1. An education based, targeted, social marketing strategy aimed at control of noise at source on the farm. This would target not only the farm owner/ manager but family members and other external stakeholders and intermediaries in the supply chain. The primary focus would move from promotion of wearing hearing protection to practical and cost effective control at source solutions.
2. The education strategy would include an assessment of the opportunities for changes in the organisation of work and tasks on the farm to reduce noise exposure, in addition to the promotion of efficient personal hearing protection selection, use and maintenance.

Appendix C – SoundSafe - Construction

Work environment

The focus of intervention in the work environment involve changes to equipment, machinery, tasks and structures where noise is generated and transmitted. The sources of noise on construction sites are site and situation specific, but can usually be readily identified. Construction work environment interventions involve 5 areas;

1. Identification of the specific noise source on the construction site is the first step.
2. Working with construction equipment and machinery distributers and manufactures to determine whether the sound power emissions for the equipment can be reduced, and if so, how, and whether new equipment to the market has lower emissions. This can be influenced by the development and outcome of the Prevention through Design (PtD) proposal if implemented (national strategy).
3. Design modification solutions for equipment and machinery can be implemented where appropriate, through the proposed SoundSafe “toolbox” resources involving practical engineering solution exemplars specific to construction and access to (web based) cost-benefit models for proposed noise management options.
4. Implementation of a “buy quiet” programme for equipment and machinery purchase and renewal. Case studies and recommendations for these would be available through the proposed SoundSafe “toolbox” resources.
5. The promotion and implementation of equipment and machinery maintenance schedules can be effective for significant sound level reductions.

Organisation

The focus of intervention in construction organisations involve;

1. Assessing the nature and extent of general OHS management within the business, and noise management in particular. This can be achieved by completion of a modified health and safety management systems assessment (Department of Labour or ACC templates).

2. The adoption and implementation of “best” or “good” practice models for noise management. These include implementation of noise control measures that actually improve productivity and reduce costs - in contrast to reliance on conventional enclosures and acoustic guarding.
3. The development of a noise management plan linked to equipment and machinery purchase and renewal; equipment and machinery maintenance schedules and personal HPD programme. The potential for the implementation of effective administration controls and other control options (work organisation) for noise exposure should be included.

People at work

The focus of the intervention for people at work would involve;

1. An education based, targeted, social marketing strategy aimed at control of noise at source on construction sites. This would target not only the principal and contractors involved in the construction but other external stakeholders and intermediaries in the supply chain. The primary focus would move from promotion of wearing hearing protection to practical and cost effective control at source solutions.

2. The education strategy would include an assessment of the opportunities for changes in the organisation of work and tasks on the construction site to reduce noise exposure, in addition to the promotion of efficient personal hearing protection selection, use and maintenance.

Appendix D – SoundSafe - Manufacturing

Work environment

The focus of intervention in the work environment involve changes to equipment, machinery, tasks and structures where noise is generated and transmitted. The source of noise in manufacturing workplaces are site and situation specific, but can usually be readily identified. Manufacturing work environment interventions involve 6 areas;

1. Identification of the specific noise source on the site is the first step.
2. Working with manufacturing equipment and machinery distributers and manufactures to determine whether the sound power emissions for the equipment can be reduced, if so how and whether new equipment to the market has lower emissions. This can be influenced by the development and outcome of the Prevention through Design (PtD) proposal if implemented (national strategy).
3. Design modification solutions for equipment and machinery can be implemented where appropriate, through the proposed SoundSafe “toolbox” resources involving practical engineering solution exemplars specific to manufacturing and access to (web based) cost-benefit models for proposed noise management options.
4. Implementation of a “buy quiet” programme for equipment and machinery purchase and renewal. Case studies and recommendations for these would be available through the proposed SoundSafe “toolbox” resources.
5. The promotion and implementation of equipment and machinery maintenance schedules can be effective for significant sound level reductions.
6. Design modification solutions for buildings and structures (production areas and workshops) can be implemented where appropriate, through the proposed SoundSafe “toolbox” resources involving practical engineering solution exemplars specific to manufacturing and access to (web based) cost-benefit models for proposed noise management options.

Organisation

The focus of intervention in the manufacturing organisation involves;

1. Assessing the nature and extent of general OHS management within the business, and noise management in particular. This can be achieved by completion of a modified health and safety management systems assessment (Department of Labour or ACC templates).

2. The adoption and implementation of “best” or “good” practice models for noise management. These include implementation of noise control measures that actually improve productivity and reduce costs - in contrast to reliance on conventional enclosures and acoustic guarding.
3. The development of a noise management plan linked to equipment and machinery purchase and renewal; equipment and machinery maintenance schedules and personal HPD programme. The potential for the implementation of effective administration controls and other control options (work organisation) for noise exposure should be included.

People at work

The focus of the intervention for people at work would involve;

1. An education based, targeted, social marketing strategy aimed at control of noise at source in the manufacturing site. This would target not only the site owner/ manager but other external stakeholders and intermediaries in the supply chain. The primary focus would move from promotion of wearing hearing protection to practical and cost effective control at source solutions.
2. The education strategy would include an assessment of the opportunities for changes in the organisation of work and tasks on the site to reduce noise exposure, in addition to the promotion of efficient personal hearing protection selection, use and maintenance.