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Session 2pPPa: Celebrating a "Long" Career: Explorations of Auditory Physiology and Psychoacoustics


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Celebrating Glenis Long's outstanding contribution to auditory physiology and psychoacoustics this presentation covers the New Zealand connection and particularly her involvement in our research into monitoring and prevention of noise-induced hearing loss (NIHL) in NZ. A large multidisciplinary project is being undertaken to investigate the nature of NIHL in NZ and establish a national approach for its prevention. This includes estimates of NIHL prevalence and the design and evaluation of education and prevention programmes to reduce the impact of noise. Using a modelling approach we estimated that NIHL contributes to 17-25% of cases of hearing impairment and is therefore a significant modifiable risk factor. A key component of our project is monitoring of noise injury and we have studied Distortion Product Otoacoustic Emissions (DPOAE) as a measure of early injury. To assess the impact of interventions we recorded DPOAEs using swept pure tones and extracted DPOAE components in noise and non-noise exposed individuals. OAE findings were compared with measures of auditory function. We found that the generator component correlated more strongly with auditory threshold and thus may be a better physiological index of injury. This research has informed a national strategy involving government and community agencies to mitigate noise effects.

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INTRODUCTION
Professor Glenis Long has had a very distinguished scientific career in psychoacoustics and auditory physiology. She is also a wonderful teacher and has been an extraordinary mentor to many students and scientists over her long career. And she is a Kiwi, whom we are very proud of and with whom we have had a lengthy and fruitful close research collaboration and association. We are very honoured to participate in this symposium to acknowledge her significant contribution and will take the opportunity to highlight some of the work we have undertaken with Glenis in New Zealand.

This presentation focuses on a major research effort we have embarked on with her involvement to support the establishment of national policy and an intervention programme in New Zealand to reduce the impact of noise exposure on hearing, both in industry and leisure environments. This work has many dimensions but a core part of the programme has been an epidemiology study of the incidence and prevalence of NIHL and, with Glenis’s collaboration, the evolution of techniques to monitor the impact of noise on hearing. This presentation provides a summary overview of this work, some of which has been published elsewhere (Thorne et al., 2011b, John et al., 2013, Welch et al., 2013, Grynevych et al., 2013).

Noise-induced hearing loss (NIHL) is clearly recognised worldwide as a significant health and disability problem and has become a major issue in New Zealand. Noise exposure causes damage to the inner ear in a dose-dependent manner. This is manifest as a progressive loss of hearing, particularly in the high frequencies; poor speech discrimination; a reduced ability to hear in background noise; and tinnitus. The impact of the hearing loss varies but for some individuals it can reduce employment options and cause social withdrawal, isolation and depression.

Recent estimates based on World Health Organisation (WHO) data indicate that about 538 million people globally have a hearing loss greater than 35dBHL (regarded by WHO as a significant disability) (Stevens et al., 2011). It further suggests that approximately 16% of these cases result from excessive noise (Smith, 2004) although this likely varies considerably across countries with an estimated range from 7% in developed nations to 21% in developing regions (Nelson et al., 2005). There is also a high economic cost. For example in Australia the cost burden of hearing impairment is estimated at $11.6b (1.6% of GDP) annually and NIHL is considered to account for about 30% of this (Access Economics, 2006).

Like many jurisdictions around the world, there is an increasing concern in New Zealand about the consequences of noise exposure on hearing and the economic and social cost of the hearing loss. The Accident Compensation Corporation (ACC) in NZ reports a steady increase in the number of NIHL claims over recent years at an increasing cost for rehabilitation (Thorne et al., 2008), and this along with public concern has driven a greater national focus on the development of intervention programmes to reduce or prevent NIHL. This has led to a programme of NIHL research and interventions (Thorne et al., 2011a; Laird et al., 2011a) as well as a move towards a national strategy framework to target NIHL in industry and the community (Laird et al., 2011b).

EPIDEMIOLOGY STUDIES
In New Zealand it has been difficult to identify exactly how many people are affected by NIHL and how many are at risk as there are very limited published data in this country. Some time ago the New Zealand Department of Health estimated that 50% of adult hearing loss in NZ was due to occupational noise (Hearing Report, 1984). As a rough indication of the number of people with NIHL, over 2,400 validated cases of NIHL were reported to the Notifiable Occupational Diseases System (NODS), a voluntary national register, between 1992 and 1998, (Driscoll et al., 2004) and a further 709 notifications occurred between 1998 and 2000 (Statistics New Zealand, 2000). While these voluntary reports cannot be taken as a reliable indication of the prevalence of NIHL, they place it as the second most voluntarily reported occupational disease in the country (after occupational overuse syndrome). McBride, (2005) estimated that 25% of the NZ workforce are affected by noise at work, and in a review of the rehabilitation claims for NIHL to the Accident Compensation Corporation we showed that the new claims rate for NIHL have been steadily increasing in recent years with noticeable increases between 1995-99 and 2000-2004 (Thorne et al., 2008). However, none of these data provide any real indication of the extent of the incidence and prevalence of NIHL in New Zealand and the lack of data is impeding the development of policy and targeted interventions for NIHL.
Rather than embark on an expensive and difficult audiometric population survey to assess the epidemiology of NIHL, we have made model estimates of the incidence and prevalence (Thorne et al., 2011b; Welch et al., 2013) based on an adaption of the World Health Organisation (WHO) model (Concha Barrientos et al., 2004). Recognising the need to quantify the disease burden related to occupational noise, and to understand its distribution within populations, the WHO has published a method for “occupational health professionals to carry out more detailed estimates of the disease burden associated with hearing loss from occupational noise both at national and subnational levels” (Concha Barrientos et al., 2004). Together with an introduction to the assessment of the environmental burden of disease (Pruss-Ustun, 2003) these provide a set of guidelines for the assessment of the NIHL burden. Essentially the approach that we took, with a modification of the model, involves the following steps: estimating the number of workers in each occupation and sector; estimating the proportion of these workers who are exposed to potentially harmful noise and by occupation and sector; estimating the relative risk of developing NIHL with noise exposure, based on international data; and then calculating the expected prevalence of hearing loss by multiplying the exposure rate by the number of workers and calculating the proportion with NIHL based on the relative risk compared with non-exposed workers in each occupation and sector. Once we had made estimates based on the international data we then attempted to verify these estimates by sample field measurements of noise levels and personal noise exposure in selected New Zealand industries (500 individuals and 99 companies).

Based on the noise measurements that we undertook in different industries (John et al., 2013), the proportion of workers exposed to levels of noise greater than 85dBA in each sector was similar to that estimated by Concha-Barrientos et al. (2004) for all sectors except Agriculture, Manufacturing and Construction, Transportation and Services. In these areas our NZ proportions were substantially higher. Among all the different sectors we assessed mining, construction, agriculture and manufacturing had the greatest proportion of workers exposed to noise levels above 85dB LAeq (75.0%, 66.7%, 57.9% and 42.6% respectively). Fewer than 25% of employees were exposed to noise levels exceeding 85dB LAeq in all other sectors with none in finance and public administration.

Using both the WHO data and our field measurements we then estimated the prevalence and incidence of NIHL within the workforce and population, using 2006 as the base census year. Our estimates of the prevalence (rate per 100000) of NIHL ($\geq$25dBHL-Ave1,2,3,4kHz) in the workforce range from 1473 (based on the WHO calculations) to 2140 (modified with inclusion of New Zealand data collected in this study) which is equivalent to 19-29% of the workforce. From this we calculate an incidence of NIHL in the workforce ranging from 54 to 77 new cases of NIHL per 100000 workers. Similar to other studies, the model estimates that the prevalence of NIHL (cases/100,000) is greatest in industries with exposures greater than 90dBA Leq (Mining, Construction, Manufacturing and Agriculture). If we take into account the different participation rates in these sectors the total number of NIHL cases is greatest in Manufacturing and Construction, followed by Agriculture and Trade. Our estimates of the prevalence of occupational NIHL ($\geq$25dBHL-Ave1,2,3,4kHz) in terms of total numbers of the New Zealand adult population, range from 51,962 (based on the WHO calculations) to 72,716 (based on New Zealand data collected in this study). Based on these population data it is estimated that between 1.54 and 1.73% of the New Zealand population have 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. Using an estimated prevalence of hearing loss in the New Zealand population as 10% (Greerville, 2005) we then suggest that between 13.5% and 17.5% of the hearing impaired population have purely an occupational NIHL and a total of 22.5-25.8% of hearing impaired people have some hearing loss from occupational noise exposure. These estimates are important to identifying industries and populations for targeted interventions and for policy planning around the prevention of NIHL. Refinement of these model-based estimates of workforce exposure rates can also be undertaken as further data are collected on specific industries.

**INTERVENTIONAL STUDIES**

The epidemiological data clearly demonstrates that NIHL is an issue in New Zealand. Apart from the specific consequences of noise exposure, NIHL is a large and modifiable component of the hearing loss burden in NZ and therefore interventions targeted at this condition have the potential to reduce the overall burden of hearing loss. Effective interventions for NIHL require multiple and coordinated approaches directed at a governmental, industry and community level. As part of a broader strategy we have been working the Accident Compensation Corporation and Department of Labour as well as community groups, such as the National Foundation for the Deaf on a number.
of novel intervention initiatives to promote an understanding of the preservation of hearing with noise exposure. These include the introduction of “Safe Sound Indicators” (Figure 1) in Early Childhood Education (ECE) Centres (http://www.nfd.org.nz) and a school hearing education programme, called the “ListenUp” programme (http://www.listenup.co.nz) based on the very successful Dangerous Decibels Programme in Portland, Oregon. New Zealand data (Laird et al., 2011a) indicate that a significant problem for NIHL and compliance with legislation in New Zealand lies with the small-to-medium sized enterprises, which constitute about 80% of the NZ businesses. We are therefore developing (Reddy et al., 2012) an interactive, holistic education programme for company employees with a predominant focus on small-to-medium sized enterprises. Over 1200 Safe Sound Indicators have now been placed in ECE centres and primary schools around New Zealand and their use is being evaluated. These noise “Traffic Lights” facilitate an understanding of the noise levels in the classroom among pre-school children and help teachers educate children about loud sound and the consequences as well as regulate noisy behaviour. Preliminary evaluation findings show these are well received as an important aid to fostering good behaviour to loud sound among young children. With the ListenUp programme over 80 educators, including 40 secondary school children have now been trained and are delivering noise awareness classes in schools and community settings. We are trialling the adaptation of this programme in industry and have so far trained 60 educators to work with adults using an adaptation of the Listen Up programme.

![Figure 1](https://example.com/safe_sound_indicator.png)

**FIGURE 1.** The Safe Sound Indicator from the National Foundation for the Deaf (www.nfd.org.nz) which has been placed in Early Childhood Education Centres and Primary Schools in New Zealand to educate young children about the hazards of loud sound.

**MONITORING NOISE-INDUCED HEARING LOSS**

Monitoring of hearing loss or cochlear injury is a key element of a NIHL intervention or prevention programme. The main method is pure tone audiometry, preferably under good acoustic testing conditions. Annual audiograms with a pre-employment baseline are important to assess the impact of the particular noise environment. However, the audiogram is not particularly sensitive to injury, which may occur before auditory thresholds reach the accepted clinical level. Interestingly, we have shown (Grynevych et al., 2013) that a 4kHz notch in the audiogram is far more correlative with noise history when thresholds are in the “normal” range than when there is a clinical hearing loss (greater than 20dBHL), but still the correlation is low. We have therefore investigated the use of physiological methods to evaluate cochlear injury and in particular the use of Distortion Product Otoacoustic Emissions (DPOAEs). Prediction of auditory thresholds using DPOAE amplitude or threshold have met with varying success, often because there is a lot of variability in the DPOAE measure. In an attempt to overcome this we have used the swept primaries approach developed by Long et al (2008), to separate the DPOAE generator and reflected components from DPOAE recordings and see if either or both show a better correlation to noise exposure. Briefly, analysis of the DPOAEs in a group of subjects with and without a noise history shows better correlation between the generator component or the combined DPOAE amplitude and the auditory threshold at 4kHz. The use of a swept primaries stimulus provided a higher resolution view of the DPOAE amplitude. Analysis across DPOAE frequency revealed that the maximum correlation did not occur at the equivalent auditory threshold frequency but was consistently between OAEs from f2 slightly higher or basal to the threshold frequency. These data are more fully
discussed by Coad et al, (2013) in a poster at this conference but suggest more detailed analysis of the DPOAE may provide a sensitive indicator of cochlear injury from noise exposure.

**CONCLUSION**

This presentation provides an overview of the broadly-based approach to the reduction of NIHL in New Zealand. This has been informed by the epidemiological research described here and an assessment of the current NZ industry compliance to noise regulations (Laird et al., 2011a). The intervention programmes are a small contribution but they are part of an evolving national strategy that is being developed by community, government and industry groups to develop a process to actively reduce the incidence of NIHL through industrial and leisure noise exposure and in the process reduce the overall burden of hearing loss in New Zealand. Glenis Long has played an integral role in this work and has provided the expertise in the psychoacoustics and otoacoustic emissions as well as the benefit of her overall experience to the development of our strategy.

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**REFERENCES**


