



Startle Reflex and Sensitisation

*How are these Biological Phenomena
relevant to Wind Turbine Noise Exposure?*

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Questions arising from 7 years of Clinical Field Observations

- Why do some people report becoming **more** affected by wind turbine noise (WTN) with ongoing exposure (“noise sensitised”)?
- Why do they report deterioration in both health & sleep quality, which improves if exposure to WTN ceases (crossover effect)?
- Why do WTN affected people then report the same sensations/symptoms are triggered by other pulsing noise?
- Why do people with autism and Post Traumatic Stress Disorder (PTSD) report rapid onset of intense anxiety and physiological stress symptoms if exposed to operating wind turbines?
- Why are WTN exposed people being diagnosed with PTSD?
- Why are uncommon ‘adrenaline’ surge pathologies occurring, (Takotsubo “heart attacks” and acute hypertensive crises), without the usual precipitants?

Q Are these issues related, and if so, how?

A Yes, via acute physiological stress events.

HOW they are related is the subject of this presentation.

Sensitisation

What is sensitisation?

“increased responsiveness as a result of repeated stimulation” Gotz & Janik 2011 This is in contrast to “habituation” which is *decreased* responsiveness as a result of repeated stimulation

Why is sensitisation to noise and vibration important?

From a public health perspective, sensitisation of individuals to noise will predictably lead to worsening individual health outcomes, especially via the well known disease pathways associated with chronic stress, and chronic sleep deprivation.

What is the Australian field evidence of worsening health & sleep in WTN exposed?

Individual cases

- Known privately to each of the three authors in some cases for 7 years across the four eastern and southern Australian states, some resulting in home and farm abandonment, relocation, or forced sale, because of worsening health and poor sleep quality in family members. Health and sleep improve after cessation of exposure to WTN, but new “noise sensitised” state continues.
- Resident public & private testimony by residents to three Australian Federal Senate inquiries, and testimony to legal proceedings including from WTN sensitised wind turbine “hosts”/leaseholders

Population Surveys

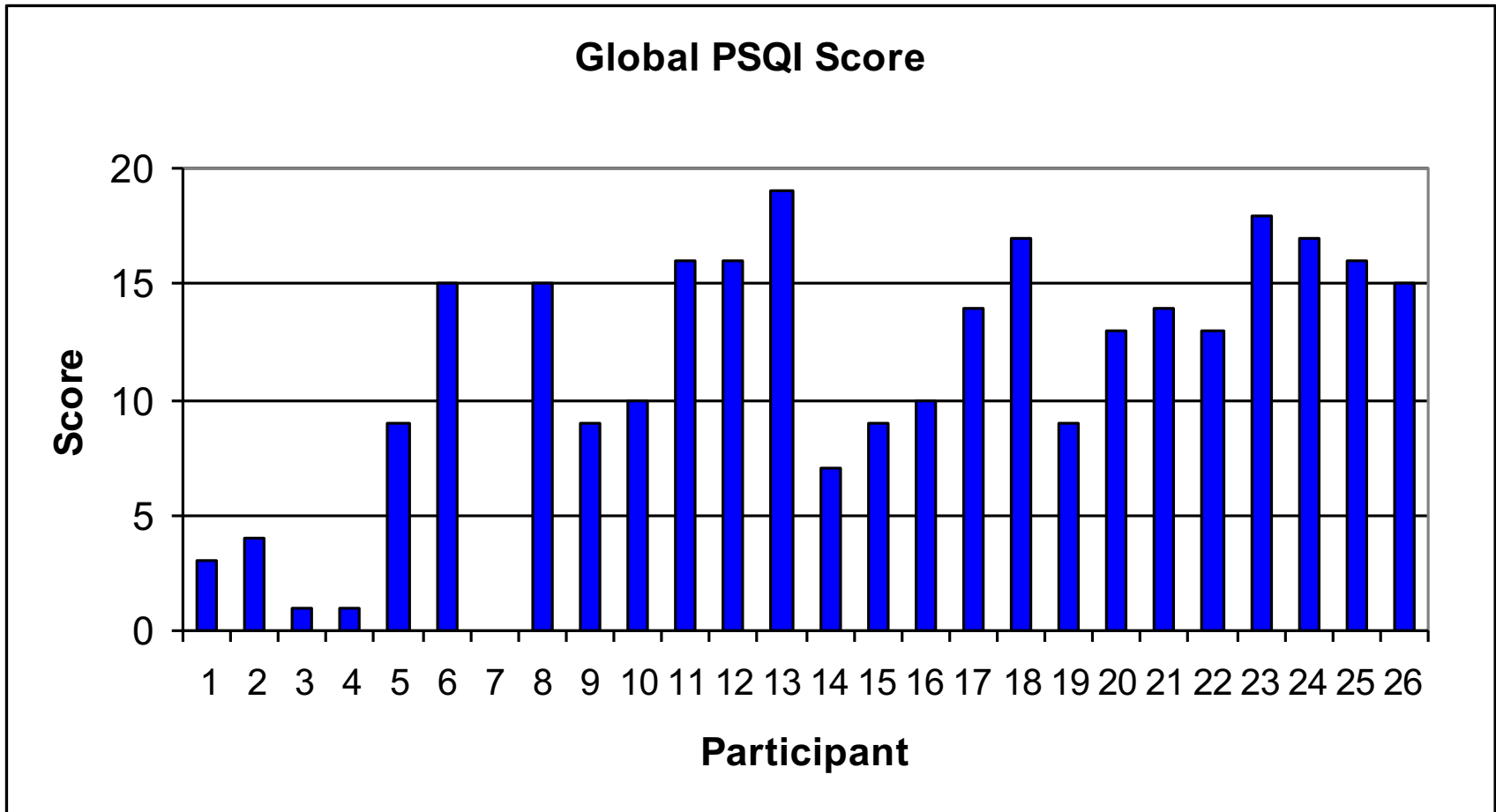
- Dr David Iser 2004 Toora, Victoria out to 2km – stress and sleep disturbance were noted
- Master’s student Frank Wang’s 2011 Population Survey out to 5km at Waterloo, South Australia
- Mary Morris’s 2012 Population Survey out to 10km at Waterloo, South Australia
- Patina Schneider’s 2012 & 2013 Cullerin Range Surveys out to 10km, New South Wales
- Anne Schafer’s 2013 Macarthur Preliminary Survey out to 10km, Victoria (only short term exposure)

Systematic data collection specific to Noise Sensitised people

- Mary Morris’s 2013 crossover study at Waterloo comparing sleep of noise sensitised residents when turbines were operating, to their sleep during shut down
- Steven Cooper’s intensive acoustic investigation for Pacific Hydro at their Cape Bridgewater Wind Farm (2014/5) looked at three homes with six noise sensitised people
- Dr Bob Thorne’s 2012 study of WTN sensitised people from Cape Bridgewater and Waubra – **key results follow**

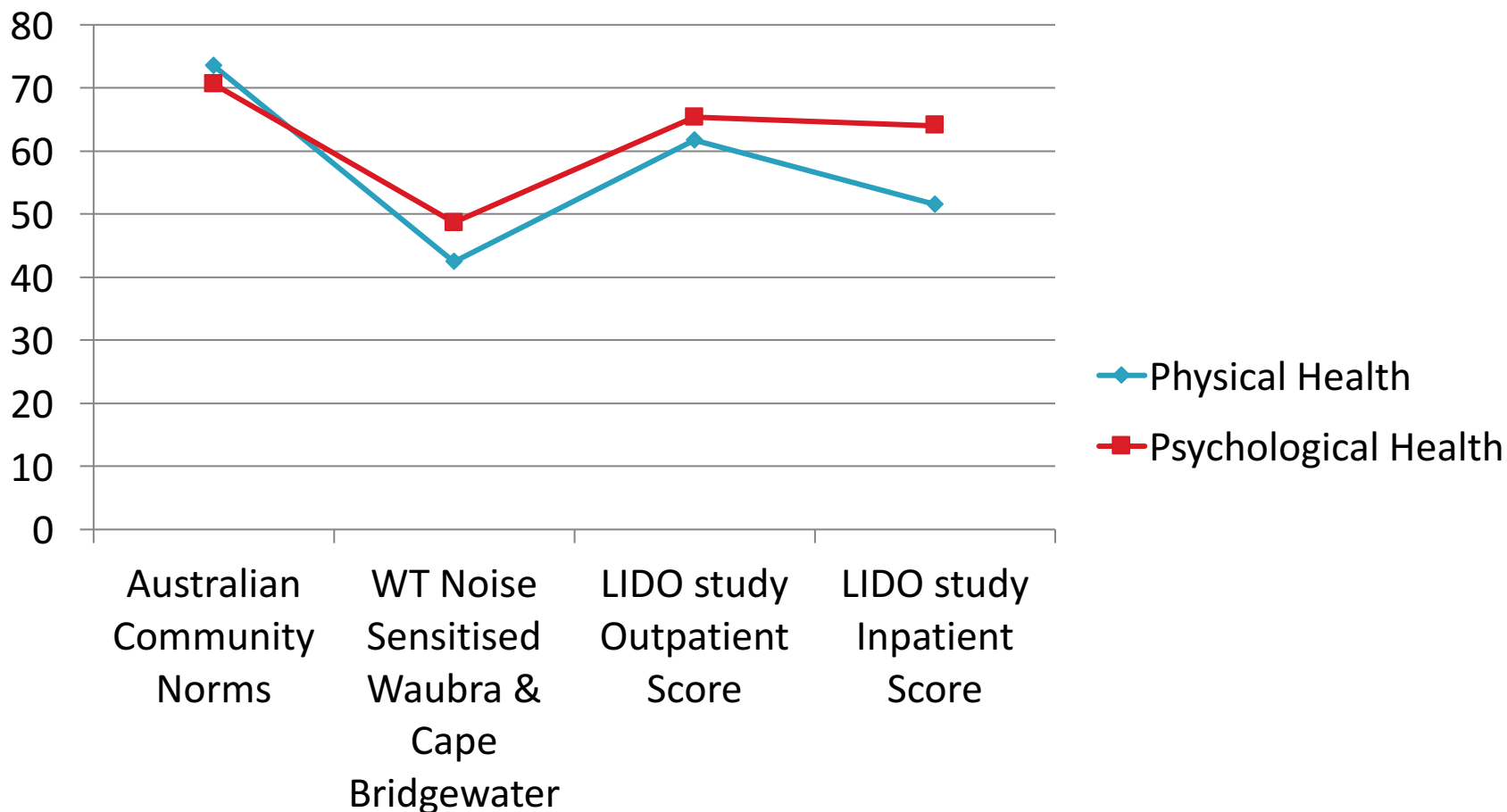
Sleep Quality (PQSI) in Wind Turbine Noise Sensitised Population subset

Dr Bob Thorne Waubra & Cape Bridgewater Study, 2012
Pittsburgh Sleep Quality Index = PQSI (above 5 indicates
problems, above 15 indicates severe problems)



Comparison WTN Sensitised group to General Community & LIDO Hospital Inpatient and Outpatient Study Norms

Dr Bob Thorne's Waubra & Cape Bridgewater Study, 2012



Q *What are the known biological mechanisms that could explain why the health and sleep quality of chronically exposed wind turbine noise (WTN) sensitised residents deteriorates with ongoing wind turbine noise exposure?*

Scientific Evidence linking Acoustic Startle Reflex and Sensitisation

Research into grey seals (*Halichoerus grypus*) by Gotz & Janik, 2011

Study investigated whether **repeated startling** of the seals via acoustic startle reflex caused habituation *or* sensitisation.

“repeated elicitation of acoustic startle reflex leads to rapid and pronounced sensitisation” and subsequent avoidance behaviour and fear conditioning.

Two groups of seals - exposures same dB (underwater), but different noise character – impulsive (pulses) vs slow rising. **It was the pulsing noise which resulted in sensitisation** – the slow rising sound showed no change in observed behaviour with repeated acoustic stimulus.

What is the Startle Reflex (SR)?

“The startle reflex is a physiological phenomenon, originating in the caudal brainstem, which can be elicited by an unexpected stimulus. It includes two responses: the initial motor response and a second orienting response”

Exaggerated Startle Reactions, Driessen et al Clin Neurophysiology, 2011

The response originating in the caudal brainstem means the SR cannot be due to a placebo effect, which will instead originate in the cortex or “thinking” centre of the brain. The initial motor response includes the reaction of the heart as part of the neurological reflex “fight flight” component – demonstrated by a sudden rapid increase in heart rate.

Clinical clues that SR is being activated in WTN exposed people

- Characteristic history of repeatedly “**waking up at night in an anxious frightened panicked state**” sometimes many times in a single night, accompanied with sensations of a “racing heart”
- **Repeated sudden episodes of acute severe anxiety**, in people with **no previous clinical history of anxiety**, and with no obvious trigger for their symptoms, which only occur when exposed to WTN, and again, accompanied with strong sensations of a “racing heart”
- Adrenal surge related pathology (Tako Tsubo & Acute Hypertensive Crises) in absence of usual clinical causes of adrenaline surge suggestive of acute, powerful, external stimuli eg acoustic trigger(s) (see *Presentation prepared for May 2015 ASA meeting in Pittsburgh by SL, given in her absence by Professor Robert McMurtry*)
- SR characteristic symptoms correlate with exposure to operating wind turbines & often wind direction and weather conditions – downwind or upwind, cloud cover, temperature inversion

Startle Reflex is triggered by multiple sensors – acoustic, vestibular, tactile

- *“The startle reflex is elicited by intense **tactile, acoustic, or vestibular stimuli**...Cross-modal summation is stronger than intra-modal temporal summation, suggesting that the **convergence of acoustic, vestibular and tactile information is important for eliciting startle**”* Yeomans et al Neuroscience & Biobehavioural Reviews 2002

This could be particularly important for WTN exposed people if their acoustic, vestibular, and tactile/pressure sensors are being activated suddenly, and concurrently.

Additional Clinical clues that SR is activated in WTN exposed people

Population Groups with known, scientifically established, *enhanced* startle reflex response whom we know also respond rapidly to WTN exposure

- **Autism** – *“children with autism spectrum disorders (ASD) exhibited larger startle magnitude to weak stimuli and prolonged startle latency”* Takahashi et al 2014
- **PTSD** – *“PTSD Veterans produced larger averaged ... heart rate responses ... compared to non PTSD veterans. Results of this study provide laboratory support for an exaggerated startle response in PTSD”* Orr SP et al 1995 Jnl Abnormal Psych

Examples of pre existing PTSD, with rapid triggering of PTSD symptoms from WTN

- Former US Marine from Falmouth Mass, USA – PTSD symptoms worsened when turbines commenced operating near his home (US courts have found in favour of him and his wife for a noise nuisance case, and the town's wind turbines were ordered to be shut down)
- Former soldier from the UK – turbine installed near his home with immediate PTSD symptoms worsening with ongoing exposure
- Young woman with history of childhood sexual assault, exposure to operating wind turbines newly installed near her home triggered dormant PTSD symptoms
- Two former Australian soldiers with PTSD, with casual (10 minute) exposure to 600kW wind turbines, with immediate triggering of PTSD symptoms, within minutes of exposure

Startle Reflex, WTN and PTSD de novo

- Examples of people with diagnosed PTSD de novo after chronic WTN exposure in the USA, UK and Australia. (known to SL - some have relocated following property purchase by wind developers, with non disclosure clauses, so their stories are not in the public domain)
- Why are they developing PTSD?
- **Is it related to repeated stimulation of SR?**

“trauma exposure initiates a process of disruption of an individual’s internal psychophysiology that is then progressively sensitized and kindled with the repeated exposures to triggers”

Professor Alexander MacFarlane, *“The long-term costs of traumatic stress: intertwined physical and psychological consequences”* World Psychiatry 2010 Feb; 9(1): 3–10.

Evidence linking disturbed REM sleep with increased risk of PTSD

“Overall, the literature suggests that disturbed REM or non-REM sleep can contribute to maladaptive stress and trauma responses and may constitute a modifiable risk factor for poor psychiatric outcomes. Clinicians need to consider that the chronic sleep disruption associated with nightmares may affect the efficacy of first-line PTSD treatments, but targeted sleep treatments may accelerate recovery from PTSD. The field is ripe for prospective and longitudinal studies in high-risk groups to clarify how changes in sleep physiology and neurobiology contribute to increased risk of poor psychiatric outcomes.”

Dr Anne Germain, PhD, University of Pittsburgh **“Sleep disturbances as the hallmark of PTSD: where are we now?”**

Am J Psychiatry 2013 Apr; 170(4): 372-82

Evidence linking WTN AM with sleep disturbance, reduced REM sleep

Smith et al – WiTNES small pilot study reported in 2016

“initial investigation into the particular acoustical characteristics of wind turbine noise that might have the potential to disturb sleep”.

Subjects: 6 young healthy volunteers, 5 nights of study, 3 nights of WTN exposure

Findings: “... ***nights with low frequency band modulation ... impacted sleep the most. The presence of beats and strong amplitude modulation contributed to sleep disturbance, reflected by more electrophysiological awakenings, increased light sleep and wakefulness, and reduced REM and deep sleep***”

Q *What are the **known biological mechanisms** that could **explain** why the **health and sleep quality** of chronically exposed wind turbine noise (WTN) sensitised residents **deteriorates with ongoing wind turbine noise exposures**?*

A *Repeated stimulation of the **startle reflex (SR)** by a trigger (or triggers) leads to increasing WTN sensitisation, with ongoing exposure. If SR occurs during sleep, repeatedly, in the context of sensitisation, there is a downward spiral in physical and mental health, with poor quality and disrupted REM sleep at its core. PTSD appears to be one consequence of prolonged exposure for some people.*

What are the Acoustic Triggers for SR?

Pulsing Amplitude Modulation?

Evidence from the 2016 WiTNES study by Smith et al – is it strong (dynamically pulsed) amplitude modulation?

Geoff Leventhall's evidence to the 2015 Australian Senate Inquiry Canberra hearing on 23 June, 2015 ***“I think that the most important aspect of wind turbine noise-which I said in the paper I published nearly 10 years ago-is the amplitude modulation ... because this is what upsets people”***.

Steven Cooper's Cape Bridgewater research – subsequent analysis of acoustic data showed the presence of strong amplitude modulation and the change in power output of the wind farm (Schomer principle).

Separately, Steven Cooper and Les Huson's acoustic field research at Cape Bridgewater identified intermittent strong wind gusts cause acute reactions in residents and concurrent pulsation pulses, as a result of resonant frequencies of the turbines.

Dr Nina Pierpont – 2009

Wind Turbine Syndrome

“Wind Turbine Syndrome, I propose, is mediated by the vestibular system—by disturbed sensory input to eyes, ears, and stretch and pressure receptors in a variety of body locations. These feed back neurologically onto a person’s sense of position and motion in space, which is in turn connected in multiple ways to brain functions as disparate as spatial memory and anxiety. Several lines of evidence suggest that the amplitude (power or intensity) of low frequency noise and vibration needed to create these effects may be even lower than the auditory threshold at the same low frequencies. Re-stating this, it appears that even low frequency noise and vibration too weak to hear can still stimulate the human vestibular system, opening the door for the symptoms I call Wind Turbine Syndrome.”

Dr Bob Thorne, 2017

“The crux of the matter is that despite all the evidence that there are a whole lot of factors which affect noise sensitivity and noise annoyance; if there is an acoustic trigger which stimulates the startle reflex, and this happens repeatedly, a train of events is set in motion leading to sensitization which is a one way street to worsening health and quality of life. It is the classic biological positive feedback loop, which reinforces the harm.”

What happens when someone is noise sensitised?

Cooper's latest work presented earlier to the ASA contained details of a series of 9 noise sensitised people exposed to inaudible pulsing ("dynamically pulsed amplitude modulated") sound which had previously been recorded from a bedroom near the Cape Bridgewater Wind Farm. **The sound did not include infrasound frequencies, but was instead low-mid frequency sound between 30 & 1200Hz, at or below the threshold of hearing and had a contribution of 12dB(A) in a background level of 23dB(A) (ie would normally be described as inaudible).**

Cooper found that whilst blinded to the timing of the stimulus the noise sensitised people could tell with 100% accuracy when the sound was on or off, and they also developed some characteristic sensations they experience back in their own homes. A control group of 9 people not pre exposed to WTN, including 4 acoustic colleagues, was subject to the same test. None of the control group could detect the sound but 2 of that control group could detect pulsations.

This small pilot double blind provocation study provides scientific evidence that when noise sensitised people describe symptoms and sensations including the sensation of "pulsing" they are not imagining their symptoms, nor are they making them up. **Rather, their brain and body are reacting in a reproducible way to the WTN stimulus present in the environment.**

This pilot study therefore indicates evidence of direct causation.

The Consequences of Noise Sensitisation

At the individual level

- Will increasingly react to pulsing sounds when present which others may not perceive.
- These sounds are not regulated, and the regulatory authorities currently do not act to protect residents from further harm (let alone primary prevention of sensitisation).
- The consequences for the individual's health are profoundly negative if they stay exposed, and the sensitisation can affect where they work, live, study, and sleep for the rest of their lives – because of the persisting cross sensitisation effect. For children, exposed in utero or in their childhood, this potentially means the rest of their lives.

At the family level

- Once one family member is adversely affected by noise sensitisation, this inevitably affects others especially if sleep is disturbed. In addition, farming families are often multigenerational, and the elderly and the young are acknowledged to be vulnerable.

At the community level

- Worsening mental and physical health in circumstances (especially in rural areas) where access to health care is often already reduced compared to the city and suburbs.
- Decreased rural populations as families move away, and are not replaced by other residents in what have become newly uninhabitable homes, because of noise pollution.

Relevant Psychoacoustic Concepts

- Startle noise is intrusive noise
- Defined as sound character, and preception
- Standard acoustical objective measures can be applied eg LAeq
- Standard Psychoacoustical measures can be applied eg loudness, fluctuation
- The concept of *unbiased annoyance* helps to bring together different measures of perception, eg rumble, tonality
- Useful for risk identification
- Has different values calculated for night and day

Where to from here?

1. Accurate independent full spectrum noise recordings inside the homes of people reporting adverse effects, where possible with concurrent physiological monitoring (heart rate and sleep), and detailed analysis in the time domain, to accurately determine the acoustic triggers for their symptoms, ***with careful attention to sound character at the time the physiological events occur***
2. Such data collection to be conducted in a way which is acceptable to, and which involves, the community.
3. Determining and setting criteria ***inside*** dwellings rather than outside limits, to address health and sleep impacts, and to ***prevent*** sleep disturbance and adverse health effects, including sensitisation.
4. **Effective regulatory enforcement, in order to prevent lifetime sensitisation and its sequelae including sleep disturbance, health damage and noise nuisance**

Any Questions?

For questions relating to physiology – contact Sarah sarah@waubrafoundation.org.au

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