Assessing Occupational and Recreational Noise Levels during National Hockey League Games and its Impact on Employees and Attendants

By

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Workers and attendees of sporting events can be exposed to harmful levels of noise during the event, potentially affecting hearing This study assessed the noise exposure of workers and attendees at 12 National Hockey league games at PNC arena in Raleigh, North Carolina. Nine employees were placed on various arena levels while wearing noise dosimeters, with one dosimeter placed in an office in the arena for area noise monitoring. A sound level meter was also placed in a fixed location on the lowest arena level. The employees were recruited by email, and during meetings before the game. The noise levels were compared between rival and non-rival games, and between arena levels. The results from the sound level meter showed that the highest average noise level was at Game 1 (89.2 ± 5.3 dBA), while the lowest average was at Game 4 (83.2 ± 7.4 dBA), both of which were non-rival games. The results from personal monitoring showed that Game 1 (88.1 ± 2.0 dBA), Game 4 (85.1 ± 2.7 dBA), and Game 12 (85.1 ± 5.9 dBA) had 8-hr TWAs exceeding the ACGIH TLV of 85 dBA. It also showed that the 8-hr TWAs in all the games did not exceed the OSHA PEL of 90 dBA. The 8-hr TWAs for non-rival games for both ACGIH and OSHA PEL (83.6 ± 2.6 dBA and 76.4 ± 3.6 dBA, respectively) were not significantly different (t= –0.72, p=0.48 and t= –1.26, p=0.21, respectively) from those of rival games (83.0 ± 1.8 dBA and 75.1 ± 2.0 dBA, respectively). The greatest difference between

the rival and non-rival games was observed on the noise dose% for both OSHA PEL and ACGIH, with the OSHA noise dose% of 19.2% for non-rival games and 15.4% for rival games. Moreover, the ACGIH noise dose% for the non-rival games was 98.5% and that of the rival games was 89.7%. However, such differences for both ACGIH and OSHA PEL noise doses were not significant (t= –0.47, p=0.64 and t= –1.34, p=0.18, respectively). The ACGIH Lavg for the non-rival games (90.1 ± 2.0 dBA) was not significantly different (t= –0.81, p=0.42) from that of the rival games (89.6 ± 1.4 dBA). Similarly, the OSHA PEL Lavg for the rival games (81.7 ± 1.6 dBA) was not significantly different (t= –1.39, p=0.17) from that of the non-rival games (82.9 ± 3.0 dBA). Level 2 of the arena had the highest ACGIH Lavg of 91.1 ± 5.8 dBA. The office has the lowest ACGIH Lavg (86.5 ± 1.7 dBA). The ACGIH TWA for the office was 79.4 ± 3.7 dBA. For the OSHA PEL, level 1 has the highest Lavg level of 83.9 ± 3.9 dBA and a TWA of 77.4 ± 4.4 dBA. The office level was the lowest OSHA PEL Lavg of 76.4 ± 4.1 dBA and the lowest TWA of 69.3 ± 6.1 dBA. Level 2 had the highest maximum noise level of 106.7 ± 6.8 dB while the office had the lowest maximum level of 100.5 ± 3.2 dB. Findings of this study will be beneficial to identify recommended controls for noise exposure for workers and attendees, such as worker rotation and wearing hearing protection.

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CHAPTER I: INTRODUCTION

In 2008, more than 150 million individuals attended professional sporting events across five major sports leagues, Major League Baseball (MLB), National Football League (NFL), National Hockey League (NHL), National Basketball Association (NBA), and Major League Soccer (MLS) (US Travel, 2019). Attendees of sporting events usually are fans, players, concession workers, and event staff, who are potentially exposed to excessive noise. Noise during sporting events may create pivotal moments for the home team. The scoreboard and public announcers often have crowds increase their noise levels to excite home team players and distract the opponent team. In addition to crowd cheering, the music volume often increases to elevated levels during these periods. This can affect the participants' hearing since they spend several hours at these sporting events (Scoppa, 2021).

Excessive noise can be physically dangerous for most people. If the noise levels are over 90 decibels (dB), gradual hearing loss may be possible and if the noise exposure exceeds 140 dB, noise exposure can cause permanent hearing loss (CDC, 2022). Heavy exposure to noise during sporting events can lead to headaches, fatigue, heart problems, and hearing loss (Eichwald et al., 2018). The economic cost to society from age-related hearing loss has been estimated to be $297,00 over the lifetime per person (Carroll et al., 2017). Hearing loss can be associated with lower employment rates, lower worker productivity, and high health care loss (Carroll et al., 2017). A person with hearing loss is more likely to be unemployed or underemployed (Carroll et al., 2017). Nationally, the total cost of first-year hearing loss treatment is projected to increase fivefold between 2002 and 2030, from $8.2 billion to $51.4 billion (about $160 per person in the US) (Carroll et al., 2017).

Noise is the most common environmental cause of hearing loss among young and middle-aged adults (Carroll et. al., 2017). In 2014, an estimated 21.0 % of adults older than 18

years had difficulty following conversation amid background noise, 11.2% had tinnitus, and 5.9% had sensitivity to everyday sounds (Carroll et. al., 2017).

Not only do attendees have to be careful about excessive noise, but the workers at these sporting events must also be concerned. According to the Occupational Safety and Health Administration (OSHA), 22 million workers are exposed to potentially damaging noise yearly (OSHA, n.d.(b); NIOSH, 2018). Noise levels can be a problem in the workplace if there is ringing or humming in the ears after leaving work, a need to shout to be heard by a co-worker at an arm's length away, and temporary hearing loss when leaving work (OSHA, n.d.(b)). OSHA standards require employers to implement a hearing conservation program where the noise exposure is at or above 85 dB, averaging over 8 working hours or an 8-hour time-weighted average (TWA) (OSHA, n.d.(b)). The hearing conservation program that OSHA has implemented aims to prevent initial occupational hearing loss, preserve, and protect remaining hearing, and equip workers with the knowledge and hearing protection devices necessary to safeguard themselves (OSHA, n.d.(b)).

Noise-induced hearing loss (NIHL) is caused by exposure to noise; for example, the ear's sensitivity is temporarily reduced during the working shift. NIHL can be demonstrated audiometrically as a temporary shift in the hearing threshold (Ryan et al., 2017). A worker with NIHL can feel like their ears are blocked. When employees take a sufficient break from loud noises, they can recover and regain the hearing they have lost temporarily (NIDCD, 2022). If the workers do not have enough time to recover from the day of loud noises, over an extended period, their inner ear hair cells can die due to metabolic deficit (NCEH, 2020).

Prolonged loud noise exposure can kill the nerve endings in the inner ear. Loud noise exposure could result in permanent hearing loss that cannot be corrected through surgery or medicine (NCEH, 2020). Noise induced hearing loss can limit the ability of a person to hear

high-frequency sounds and understand speech which then impairs the ability to communicate (NIDCD, 2022). Hearing aids can help with hearing loss but cannot bring the hearing capabilities back to 100% (NIDCD, 2022). Other health effects of high noise levels can be physical and psychological stress, reduced productivity, interference with communication and concentration, and contribute to workplace accidents and injuries that would make it difficult to see the warning signals from other workers (OSHA, n.d.(a); NIOSH, 2018).

Not only does noise exposure cause hearing loss, but it can also affect other body parts. New research from National Institute for Occupational Safety and Health (NIOSH) has examined the relationship between loud noises at work and conditions like high blood pressure, high cholesterol, and hearing difficulty (CDC, 2018(a)). The study found that most hearing difficulty cases among workers (58%) were linked to loud noise at work and could be prevented if the noise were reduced to safe levels. Nine percent of high cholesterol and 14% of high blood pressure cases among workers could be linked to loud noise on the job, and workers with a history of loud noise at work were less likely to have had their blood pressure, or their cholesterol checked (CDC, 2018(a)). Noise-induced hearing loss can be prevented through training, education, and personal protective equipment (OSHA, n.d.(b)).

CHAPTER II: LITERATURE REVIEW

Sound is harmonic pressure variations that we can hear in the air (Gray, 2000). Sound is also the physical phenomenon consisting of alternating compression and expansion of air that propagates in all directions from a source (Passchier-Vermeer & Passchier, 2000). A small change in pressure is depicted as the result of alternating compressions and expansions (Passchier-Vermeer & Passchier, 2000). Whereas noise is an unwanted sound, it can be continuous, variable, intermittent, or impulsive, depending on how it changes over time (CCOHS, 2014).

The difference between sound and noise depends on the listener and the circumstances. Noise or sound can become hazardous to an individual if the noise is too loud or exposed for a prolonged period and if the exposure is frequent (OSH, 2014). Sound is produced by vibrating objects and reaches the listener's ears as waves in the air or other media (OSH, 2014). An object vibrates, which then causes a change in air pressure. The pressure then changes as it travels in waves through the air and produces sound.

Decibel (dB) is used to measure sound levels that human ears respond to logarithmic changes in intensity (Gary, 2010). Ears are responsive to percentage change. Thus, log scales are helpful because equal changes in dBs are equal percentages. An increase of 10 dB is perceived as doubling loudness; a decrease of 10 dB is perceived as halving loudness (Gary, 2010).

Sound is measured using three weighting scales: A, B, and C (Cranston et al., 2013). These weighting scales were developed based on human perception of loudness at variable frequencies (Cranston et. al., 2013). Ears can detect various forms of frequency weighting but, our ears are not proficient at detecting all the frequencies at the same standards (Cranston et al., 2013). A-weighting scale is the closest to what a human ear can perceive and has measurements that highlight higher frequencies and underemphasize low frequencies (Cranston et al., 2013). B-

weighting is close to A-weighing, but it is seldom used. C-weighting is used when impulse and blast-type noises are represented by a rapid rise and fall in sound pressure (Cranston et al., 2013). OSHA recommends unweighted measurements for impulse sounds (Adams et al., 2016).

Human Ear

The human ear has three main parts: the outer ear, the middle ear, and the inner ear. The outer ear consists of an auricle, the external auditory canal, and the inner end of the tympanic membrane. The function of the outer ear is to collect sound waves and bring them to the tympanic membrane. With the way that the outer ear is shaped, some sounds and frequencies are amplified and attenuated (Cranston et al., 2013). When pressure waves enter the ear, sounds at 2000 Hz and 4000 Hz are amplified by 10-15 dB (Cranston et al., 2013).

The function of the middle ear is to transmit sound (Adams et al., 2016). As the pressure wave travels from the outer ear to the middle ear, the wave amplifies the force as it moves to the inner ear and cochlea (Cranston et al., 2013). The ossicles allow pressure waves to be transformed into mechanical forces and be amplified (Adams et al., 2016). The oval and round windows act as portals where these forces are transferred into the inner ear (Adams et al., 2016). The middle ear also provides partial protection against loud noise by the tightening of the tensor tympani and stapedius muscles, leading to the tightening of the tympanic membrane that then cannot transfer acoustic energy to the inner ear (Cranston et al., 2013). However, these muscles can experience fatigue and are not reliable for consistent protection (Cranston et al., 2013).
The inner ear consists of two functional units: the vestibular apparatus, the vestibule, and semicircular canals (contain the sensory organs of postural equilibrium) and the cochlea (consists of the sensory organ of hearing). The inner ear is the final step in hearing, which translates the mechanical wave created by the ossicles and eardrum into a nerve impulse that is then interpreted by the brain (Cranston et al., 2013). The cochlea, a snail-shaped spiral organ, is the

most important functional unit of the inner ear (Cranston et al., 2013). The organ of Corti, the primary organ in the inner ear to perceive sound, lies on the basilar membrane within the cochlea (Adams et al., 2016). The cochlea has approximately 4,000 inner hair cells and 12,000 outer hair cells used to begin neural impulses in the auditory nerve (Adams et al., 2016). The impulses occur in the basilar membrane and cause the stereocilia of the hair cells to bend (Adams et al., 2016). The basilar membrane then moves up and down, resulting in the shearing force that leads to the bending of the stereocilia (Cranston et al., 2013). The electrical response then travels through the vestibulocochlear nerve and the brain interprets the signal as sound (Adams et al., 2016).

Health and Safety Effects of Noise Exposure

The World Health Organization (WHO) estimates that 1.1 billion young people worldwide could be at risk of hearing loss due to unsafe listening practices (WHO, 2015). In 2014, an estimated 21.0% of adults older than 18 years had difficulty following conservation amid background noise, 11.2% had tinnitus, and 5.9% had sensitivity to everyday sounds (Yulia et al., 2017). During 2011-2012, 21 million U.S. adults who reported no exposure to loud or very loud noise at work exhibited hearing damage suggestive of noise-induced hearing loss (Yulia et al., 2017).

There are three physical characteristics to sound that can affect human hearing: amplitude, frequency, and duration. Amplitude is how loud an individual perceives the sound; frequency is the pitch; and duration is how long the sound lasts (Cranston, 2012). Exposure to loud noise levels, even for a short duration, can lead to mechanical trauma and metabolic stress to the organ of Corti (Gopal et al., 2019). The loud levels can cause a shift in threshold sensitivity that depends on an initial shift from exposure, and the degree of recovery is based on characteristics of the noise exposure, including intensity, duration, frequency, and the individual

characteristics of the person exposed (Gopal et al., 2019). Temporary threshold shifts (TTS) are when the person can recover to baseline within weeks after exposure (Gopal et al., 2019). When TTS is repeated, normal thresholds will have more difficulty, and a permanent threshold shift (PTS) can occur (England et al., 2014). During TTS, the stereocilia (inner hair cells) of the outer hair cells become less stiff and disarrayed, responding poorly to simulation but will recover and function normally again with time (Rose et al., 2008). PTS is diagnosed when there is a loss of stereocilia, which are replaced by a scar (Rose et al., 2008).

Regarding noise characteristics, spectrum, intensity, duration, and temporal pattern are used for estimating TTS and PTS (England et al., 2014). The TTSs and PTSs for broad spectrum noise results are in the 3000 Hz to 6000 Hz frequency range (England et al., 2014). TTS becomes greater when exposed to noise levels increase by 8-12 hours of exposure (England et al., 2014). When noise is at a constant excess above 80 dB, sound pressure will result in the greatest TTS (England et al., 2014). PTS can occur in repeated prolonged exposure to harmful noise (England et al., 2014).

In a recreational setting, loud noise exposure may result in auditory-related symptoms such as tinnitus, hyperacusis, and difficulty understanding speech in noise (Gopal et al., 2019). Exposure to extensive noise can lead to noise-induced temporary threshold shift (NITTS) and noise-induced permanent threshold shift (NIPTS) (Adams et al., 2016). NITTS is a temporary, reserved loss in hearing sensitivity, which can be the result of short-term exposure to harmful noise or neural fatigue in the inner ear (Adams et al., 2016). With NITTS, a person's hearing can return to its condition prior to exposure to noise or acoustic trauma (Adams et al., 2016). Tinnitus is the perception of ringing or buzzing in the ears without any sound in the environment (Roberts et al., 2018). Tinnitus can be caused by exposure to impulse noise, such as a gunshot or explosion, but has also been found to be related to chronic noise exposure, NIHL, and

aging (Roberts et al., 2018). Temporary tinnitus can warn an individual that they have been exposed to hazardous noise. Tinnitus can be acute or chronic. Acute or temporary tinnitus symptoms last for short periods (e.g., a few seconds or days) and occur after exposure to loud sounds. Chronic tinnitus is long-lasting (e.g., months to years) and can result from a cochlear injury (WHO 2015).

Acoustic trauma refers to a temporary or permanent hearing loss due to a sudden intense acoustic event, such as an explosion (Adams et al., 2016). The result of acoustic trauma can be conductive or sensorineural hearing loss. Conductive hearing loss is when a perforated eardrum or damage to the middle ear ossicles occurs. Sensorineural hearing loss is when an event with high levels of noise causes permanent damage to the hair cells in the cochlea (Adams et al., 2016).

Noise exposure causes sensorineural hearing loss, which is preventable but irreversible (Roberts et al., 2018). Early noise-induced hearing loss (NIHL) is characterized by reduced hearing sensitivity at the 3,4 and 6 kHz audiometric test frequencies with recovery at lower and higher frequencies (Roberts et al., 2018). An individual with NIHL can have a broad range of difficulties, including overall audibility, inability to hear speech sounds, reduced dynamic range, impairment of sound localization, and difficulty separating sounds (Beach et al., 2013). NIHL can make hearing sound difficult, affecting social life, learning, and employment outcomes. High-level noise can also affect an individual's sleep, raise blood pressure, and increase stress levels (Beach et al., 2013). Noise can also affect learning impairment in children and adults (Beach et al., 2013).

Noise exposure affects hearing and can also be a risk factor for cardiovascular disease (Roberts et al., 2018). A study of 1,455 blue-collar workers found that workers exposed to noise more significantly than 80 A-weighted decibels (dBA) had significantly higher total cholesterol

and triglycerides than workers exposed to noise below 80 dBA (Roberts et al., 2018). Noise exposure can lead to elevated blood pressure levels even after noise exposure has ceased (Roberts et al., 2018). Mental health can also be affected by exposure to noise due to loud noises being an annoyance and a cause of stress (Roberts et al., 2018).

Studies have found a connection between exposure to occupational noise, NIHL, and occupational injuries. Sustained noise exposure can lead to excessive fatigue, which then leads to an increase in errors due to the loss of concentration and predictable cognitive failures (Picard et al., 2008). Stress and fatigue can happen due to higher demand of effort to understand the communication of others. High occupational noise levels can lead to communication barriers that would reduce the detection of noise, identification of noise sources and understanding the speech of another co-workers (Cordeiro et al., 2005). It can also lead to error from a lack of identification of warning signals (Yoon et al., 2015). If a worker has NIHL, they require louder warning signals so they can recognize such warning signal (Yoon et al., 2015). Girard et al. (2009) conducted a study about the connection between high occupational noise exposure and risk of single and multiple accidents at work settings and found that 22,556 of the 53,982 noise-exposed participants experienced at least one accident (Girard et al., 2009). A study by Picard et al. (2008) concluded that a daily dose of noise exposure of >89 dBA can be hazardous even for those suffering from mild hearing loss (Picard et al., 2008). A study done by Hossein et al. (2012) on 1,062 workers showed an increased risk of occupational injuries when exposed to a sound pressure level (SPL) of greater than 85 dB. Corderio et al. (2005) showed that workers who were always and sometimes exposed to a higher level of noise were at 5.0 and 3.7-times higher risk of work-related injuries, respectivelyWhere the workers were instructed to deem a work environment very noisy when they can hear their co-workers as a point of reference (Corderio et al.,2005) Yoon et al. (2015) reported a dose-response relationship between noise

exposure and the risk of occupational injury, with an odds ratio of 1.92 for noise exposure levels of 80-90 and >90 dB and an odds ratio of 3.63 for noise exposure levels less than 80 dB.

Noise Exposure in a Recreational Setting

The frequency of NIHL in the young adult population has increased in recent years (Wattman & Antony, 2019). This can likely be explained by increased exposure to recreational noise. A person can be exposed to recreational noise at concerts, nightclubs, sporting events, and shooting firearms during hunting or target practice, wherein exposure may occur for several hours at a high noise level (Wattman, & Antony, 2019). Using earphones at a higher volume level can cause hearing loss. Mohammadpoorasl et al. (2019) suggested that 60.2% of students reported a history of hearing loss and hearing impairment, where 86.4% of participants reported using earphones in the past. An exposed individual may not notice a difference in hearing from recreational activities because these activities can be infrequent (Wattman & Antony, 2019). The average individual underestimates the hearing problems associated with loud noises of recreational events. They will not acknowledge the damage that recreational events cause, though they can cause muffled hearing and/or tinnitus and cause fatigue in the ear's sensory cells (Lee & Wooaje, 2019). The WHO stated that regular participation in recreational settings with high noise levels could carry a severe threat of irreversible hearing loss due to night clubs and pop concerts having an average noise level of 100 dB (Lee & Wooaje, 2019).

Feder et al. (2019) showed that an estimated 6.6 million Canadians were exposed to an estimated cumulative leisure noise level at or above the occupational noise exposure limit of 87 dBA for Canada federal level (CCOHS, 2014). These leisure activities included motorcycles or snowmobiles that were driven at highway speed, sporting or entertainment events, amplified music, car and home stereos, firearms or personal listening devices. Feder et al. (2019) stated

that Canadians are likely to develop some degree of NIHL if they were to continue their way of leisure activities that have high noise levels.

Gopal et al. (2019) studied the levels of hearing loss for individuals listening to the iPod touch at various volume levels such as 100%, 75%, 50% and 0% for 30 minutes. A volume level of 100% gave an average noise exposure of 97.0 dBC; 75% level was 83.3 dBC and 50% level 65.6 dBC (Gopal et al., 2019). The study results showed that listening to music for 30 minutes at 100% showed a significant decrease of 2000 Hz and 2833 Hz, while no significant changes were found for 75%, 50% and 0% Hz (Gopal et al., 2019). Temporary threshold shift was seen at frequencies ranging from 2000 to 8000 Hz (Gopal et al., 2019). Frequencies at 500 and 1000 Hz did not show significant shifts (Gopal et al., 2019). When the study followed up with evaluations a week later, it was indicated that the pure-tone thresholds had returned to the pre-music exposure levels (Gopal et al., 2019).

However, results from research on the prevalence of NIHL due to recreational noise are not consistent. A study by Keppler et al. (2015) showed no association between NIHL and recreational noise exposure. This can be attributed to the difficulty in accurately estimating the number of subjects exposed and obtaining a sample of young individuals with representative sound levels, patterns, and duration of exposure (Keppler et al., 2015). Recreational noise exposure can be based on occupational risk criteria and has temporal and dynamic variation compared to occupational noise (Keppler et al., 2015).

Like adults, children can be exposed to noise exposure while doing leisure activities. Children are also more likely than adults to engage in recreational behavior that involves high noise exposure from attending concerts and sporting events and listening to personal music players (Roberts & Neitzel, 2019).

Noise Exposure in Sporting Events

When there are many spectators in a crowded sporting event, there is a strong affinity to cheer together for their favorite players/team, which can cause high noise levels due to the intensity of the cheering in the competition. Individuals at these sporting events may not pay attention to the high levels of noise created in the stadium (Lee & Woojae, 2019). For example, a football world cup in 2010 had noise levels ranging from 80 dBA to 110 dBA (Lee & Woojae, 2019). Noise exposure at this high level can cause temporary or permanent hearing loss and tinnitus.

NIOSH conducted a Health Hazard Evaluation of workers and fans in arenas during motocross and monster truck events and found that seven of the eight employees were exposed to levels that exceeded the OSHA action limit of 85 dBA (Morley, 1998). Every noise measurement taken during the investigation exceeded the NIOSH Recommended Exposure Limit (REL) and the ACGIH Threshold Limit Value (TLV) (Cranston et al., 2015).

A study during three National Hockey League (NHL) Stanley Cup playoff games conducted by Hodgetts and Liu (2006) showed that continuous sound of 104, 101, and 103 dBA were exceeded over 3 hours. After the games, the subjects experienced muffled sounds and mild tinnitus (Hodgetts & Liu, 2006). The audiometric data showed that the hearing thresholds of the subjects deteriorated by 5 to 10 dB at most frequencies (Hodgetts & Liu, 2006). The subjects had the biggest change in the hearing threshold at 4,000 Hz and experienced a temporary threshold shift in one year of 20 dB (Hodgetts & Liu, 2006), showing a significant change in hearing status. The study also collected otoacoustic emissions data, which showed one subject experienced a decrease in the strength of the outer hair cell responses (Hodgetts & Liu, 2006).

Engard et al. (2010) conducted a study on noise exposure, characterization, and comparison of three football stadiums, wherein 11 of the 28 workers' noise doses exceeded the OSHA action level of 85 dBA; 27 of 28 workers were overexposed to noise based on the ACGIH

TLV for noise exposure; and 24 of 25 fans were also overexposed according to WHO recommendations. The mean noise levels were 120, 116, and 120 dB at a medium college, large college fields, and the NFL stadium field, respectively. The mean peak exposure of 142 dB at the medium-sized college stadium exceeded the WHO peak limit of 140 dB. Personal dosimeters used in the study had peak measurements ranging from 89-146 dB (Engard et al., 2010).

In Cranston et al. (2013) study about noise characterization and exposure of indoor sporting events, 6 out of 15 workers were found to be overexposed to noise using personal dosimeters based on the ACGIH TLV, while none were overexposed based on the OSHA action limit or permissible exposure limit (PEL). Three out of 9 fans sampled during the home games were overexposed based on the ACGIH TLV, while no fans had exceeded the OSHA PEL or action limit. At a 2nd avenue, 11 of the 19 workers with personal dosimeters were overexposed based on the ACGIH TLV, but none were overexposed based on the OSHA PEL or action limit. Ten out of 11 fans that wore personal dosimeters were overexposed based on the ACGIH TLV and no fans were overexposed based on the OSHA PEL or action limit. All three games in one studied venue ranged from 105 dBA to 124 dBA. Using area monitoring, the noise levels for all games ranged from 110 dBA to 117 dBA (Cranston et al., 2013).

Occupational Noise Exposure

Exposure to hazardous noise is the most common occupational risk in the U.S. and worldwide (Themann et al., 2019). About 22 million U.S. workers are currently exposed to hazardous occupational noise, with 33% of working-age adults with a history of occupational noise exposure having audiometric evidence of NIHL and 16% of noise-exposed workers having a material hearing impairment (Themann et al., 2019; NIOSH, 2018). In the U.S., the annual compensation for occupational noise-induced hearing loss (ONIHL) is approximately 242.4 million (Chen et al., 2020). The mining, construction, and manufacturing sectors have the highest

prevalence of noise exposure and hearing loss (Thiemann et al., 2019). However, hearing loss and noise exposure are in every sector. A fourth of self-reported hearing difficulty among workers in the U.S. is due to occupational exposures (Themann et al., 2019). The workplace noise and NIHL grew when the mechanization of work increased in the early 20th century (Themann et al., 2019).

ONIHL is a partial or complete hearing loss in one or both ears as the result of employment and is a function of continuous or intermittent noise exposure and usually develops slowly over several years (Chen et al., 2020). ONIHL is a sensory neural phenomenon involving inner ear injury. It is bilateral and symmetrical, and it usually affects the higher frequencies at 4 kHz that spread to other frequencies of 3 and 6 kHz and recovery at 8 kHz (Chen et al., 2020). Age groups from 30-44 and 45-59 years are at higher risk when exposed to occupational noise, corresponding to the ages of peak labor force participation (Chen et al., 2020). Other work-related injuries can occur among workers with ONIHL, which may be attributed to difficulty hearing warning signals, monitoring equipment, reacting to environmental sounds, and coordinating with other workers (Chen et al., 2020). ONIHL can also place workers in a bad mood, resulting in poor cognition, sleep disorders, and cardiovascular diseases (Chen et al., 2020).

Occupational Noise Standard and Exposure limits

Workers in any industry in the U.S. are covered by OSHA's Occupational Noise Exposure standard found in Title 29 Code of Federal Regulations (CFR), 1910.95 (OSHA, 2019). Employers must implement a hearing conservation program when noise exposure is at or above 85 dB (action level), averaging over eight working hours or an 8-hour time-weighted average (TWA). Hearing conservation programs aim to prevent initial occupational hearing loss, preserve and protect remaining hearing, and equip workers with the knowledge and hearing protection

devices, if necessary, to safeguard themselves. Employers are required to measure noise levels, provide free annual audiometric exams, hearing protection and training, and conduct evaluations of the adequacy of the hearing protectors in use. The exposure measurement must include all continuous intermittent and impulsive noise within an 80 dB to 130 dB range and be taken during a typical work situation (OSHA, 2019). Employers must repeat noise monitoring when they change the production process or controls that may increase noise exposure (OSHA, 2019).

The NIOSH Recommended Exposure Limit (REL) for occupational noise exposure is 85 dBA, which is A-weighted as an 8-hour time-weighted average and uses a 3-dB exchange rate (NIOSH, 2018). Exposures above this level are hazardous (Eichwald et al., 2018). The ACGIH has established the threshold limit values (TLVs) for occupational exposure to noise at 85 dBA with a 3-dBA exchange rate (ACGIH, 2022.)

Noise Exposure Limits for Non-Occupational Settings

The U.S. EPA and WHO have recommended exposure limits for environmental noise. EPA's exposure limit is a 24-hour TWA of 70 dBA that uses a 3-dB exchange rate to prevent NIHL. The limit was to protect 96% of the general population from hearing loss greater than 5 dB at the 4 kHz audiometric frequency. The WHO also recognized that hearing impairment was unlikely for exposures below 75 dBA or below 70 dBA and thus established a recommended limit of 70 dBA consistent with the US EPA recommendations (Roberts et al., 2019). Some local municipalities have laws to help with noise limits and protection from NIHL. In 2014, Minneapolis City Council passed an ordinance making it compulsory for bars and clubs to give free earplugs to patrons (WHO, 2015).

Noise Exposure Monitoring

There are different types of noise measuring instruments, including sound level meter, noise dosimeter, sound intensity meters and narrow-band analyzers (Anna, 2008). When

evaluating noise exposures, A-weighted sound level is required at the ear of the person being monitored (Anna, 2008). Sound pressure, sound intensity and/or the vibration of the equipment at different frequencies need to be measured to find the source of the noise (Anna, 2008). When conducting noise level testing, a sound level meter (SLM) is the basic instrument for an occupational hygienist and is referred to as an area noise monitoring instrument. It can be used to map information of the different areas of sound within the workplace (OSHA, 1996). The SLM has the following parts: microphone, preamplifier, amplifier with calibrated gain, frequency weighting filters, meter response circuits, and an analog meter or digital readout. Most of the SLMs on the market give an option for frequency weightings A and C but some will give a flat response (Anna, 2008). Fast and slow are the two response characteristics that SLM have. A fast response is wherein the SLM follows the sound level as it changes, while slow response gives an average of the changing sound level. It is mandated by OSHA that sound measurements be made with the slow meter response. When measuring peak response for OSHA compliance, meters have an impulse response or a peak response for transient or impulse sounds (Anna, 2008). The SLM will respond instantaneously to sounds of short durations, but the SLM readings will decay slowly to facilitate reading the value (Anna, 2008). In situations wherein the noise level fluctuates, a single number from a meter is difficult. The SLM will then measure the sound levels over time to calculate the integrated sound level Leq which has a 3-dB exchange rate or the Losha, which has a 5-dB exchange rate.

A personal noise dosimeter is an instrument that measures noise dose within an individual's hearing zone. Noise dose has a percentage of an allowable maximum dose of 100% that is 90 dBA for 8 hours (Anna, 2008). A hearing zone is a hypothetical sphere within a 30-cm radius that encircles the head (Adams et al., 2016). The dosimeter is worn on the body and functions as a microphone that senses the acoustic pressure and converts it into an electrical

signal for processing. The noise dosimeter integrates and computes the desired noise measurements. Noise dosimeters are battery powered and derived directly from SLM to simplify measurement and computer procedures (Adams et al., 2016.). When collecting data, a dosimeter can calculate a projected dose that is based on a short, exemplary sample (Anna, 2008). When using a dosimeter, different noise dose criteria, exchange rates and thresholds can be selected (Anna, 2008). For example, a dosimeter can be set at 85 dBA dose criteria, 5 dB exchange rate and the 80 dBA threshold. Threshold levels are the noise level below which cannot be detected by an instrument and may be based on specific criteria. Dosimeters can collect noise data based on criterion levels and exchange rates for OSHA PEL, OSHA AL, and ACGIH TLV (Adams et al., 2016).

Noise Exposure Reduction and Control

In the workplace, controls for noise exposure have three categories: engineering controls, administrative controls, and personal protective equipment (OSHA, n.d.(b)). Engineering controls may involve modifying or replacing the noisy equipment, making physical changes to the transmission path of the noise source or to reduce the noise exposure (OSHA, n.d.(b)). Some changes an employer can make would be choosing low noise tools and machinery, ensuring maintenance and lubrication of machinery and equipment (such as oil bearings) and placing barriers such as sound walls or curtains between the noise source and the employee. The employers can create an enclosure for the equipment to isolate the equipment, or the employer can enclose the source of the noise from the employee (OSHA, n.d.(b)).

Administrative controls change the workplace such as changing the schedule. An employer can implement administrative controls by operating the noisiest machines during shifts when there are only a select number of employees working, imposing a time limit on how long an employee works with excessive noise sources, providing a quiet room where workers can take

a break from high levels of noise, and simply distancing an employee (OSHA, n.d.(b)). Having regular hearing screenings and routine exams with primary care providers can help reduce diagnosis delays and improve access to hearing aids for those with hearing loss (Yula et al., 2017). In 2014, a report found that only 46.0% of adults who had trouble hearing had seen a healthcare professional about hearing in the past five years (Yula et al., 2017). An individual's hearing loss can progress for years before the individual perceived or is diagnosed. An individual should talk to a personal health care provider about hearing loss symptoms, tests, and ways to protect hearing, which can help with early diagnosis and access to hearing rehabilitation if needed (Yulia et al., 2017).

If engineering and administrative controls cannot reduce or eliminate noise sources, personal protection equipment (PPE) t should be available to employees. PPE can be less successful than engineering controls and administrative controls because they depend on employees to take the proper actions to reduce the noise (CDC, 2018(b)). PPE should be used in combination with engineering controls and administrative controls (CDC, 2018(b)). This would be devices such as ear plugs or earmuffs so the exposure to the noise levels while working will be less than 85 dBA for an 8-hour TWA. NIOSH recommends hearing protectors when work exposes employees to greater than 85 dBA as an 8-hour TWA. When workers are exposed to a single impulse noise level that exceeds 140 dBA and an 8-hr TWA that exceed 100 dBA, double hearing protection (e.g., earplugs and earmuff together) should be worn (CDC, 2018(b)). Hearing protection does not block out all the sound, but measurements of efficacy show that devices can reduce exposure to loud sound by 5-45 dB (WHO, 2015). However, the individual must wear ear protection correctly and consistently to work. When wearing ear protection, it is best to choose what is the correct hearing device for either leisure or workplace.

It is difficult to implement engineering and administrative controls to reduce noise exposure in sporting events. However, an attendee at a sporting event can take breaks when the noise is excessive and move away from loud sounds at venues to protect individual hearing. A great way to determine if the sound is too loud for a person is if one must raise their voice to be heard above the crowd when the other person is at an arm's length away (WHO, 2015). PPE is easy to implement into wearing at sporting events and is the more feasible way to protect oneself at a sporting event or leisure activities. A person's motivation for noise exposure prevention depends on the individual's perception of the health threat of excessive noise (WHO, 2015). Individuals are less tolerant of noise and more motivated to take protective action when they have experienced symptoms of tinnitus and have a positive attitude towards hearing health. (WHO, 2015). When individuals believe that other health problems are more important than noise-induced hearing problems, the individuals will believe excessive noise is pleasurable and the noise exposure prevention practice will be ignored (WHO, 2015).

CHAPTER III: SPECIFIC AIMS OF THE STUDY

The purpose of this study is to assess the noise exposure during National Hockey League games of Carolina Hurricanes in eastern North Carolina. The specific aims of this study were to::

1) Characterize the noise exposure of employees during the home games of a national hockey team and compare the noise exposure of employees during hockey games to the OSHA Permissible Exposure Limit (PEL), OSHA action level, and ACGIH Threshold Limit Value.
2) Characterize the noise levels in various areas of the arena during the home games of a national hockey team.
3) Estimate the noise exposure of attendees during the home games of a national hockey team; and
4) Determine the effects of potential risk factors (e.g., arena seating level, employee title or task, game type) on noise exposure among workers and attendees of national hockey games.

CHAPTER IV: HYPOTHESES AND RESEARCH QUESTIONS

Hypothesis 1: The 8-hr time-weighted-average (TWA) noise exposure of employees during home games for professional hockey team (i.e., Carolina Hurricanes) will exceed the OSHA Permissible Exposure Limit of 90 dBA and the ACGIH Threshold Limit Value (TLV) of 85 dBA.

Justification 1: A study by Cranston et al. (2012) that conducted noise monitoring in a semi-professional level hockey league found that workers and fans had noise exposures exceeding the ACGIH TLV. With the Carolina Hurricanes being a professional team and playing in a larger area with a higher seating capacity and, thus, a bigger crowd, the noise exposure levels of employees and attendees are expected to be higher.

Hypothesis 2: The 8-hr TWA noise exposure of employees during home rival games for the Carolina Hurricanes is higher than that during home non-rival games.

Justification 2: During the rival games, there is likely more noise and a larger amount of attendee participation during the game to create a loud and lively environment. When a team is winning during these rival games, the crowd participates more in cheering and creating an annoyance to the opposing team. In an article by Jones (2014) about the December 2013 rival games, the Carolina Hurricanes brought in 17,737 people to attend the rival game against the Washington Capitals and also brought in 18,124 for another rival against the Pittsburgh Penguins. The average attendance in previous games ranged from 14,974 to 15,403 per game in 2013-2014 season (Jones, 2014). An article by Smith (2019) stated that players commented on how much the crowd noise was awesome, insane and an “extra player” for the home team during the 2019 Stanley Cup playoffs versus the Capitals, a rival of the Carolina Hurricanes.

Hypothesis 3: The 8-hr TWA noise exposure levels on the higher seating level of the arena are lower than that on the lower seating levels.

Justification 3: The greater number of people is typically on the lower level of the bowl at the arena. The speakers at the arena are facing down to the lower bowl. When the team played in the Stanley Cup playoffs in 2021, the team only had 12,000 fans that could be in the arena. So, the Hurricanes then placed most of the fans into the lower bowl. The crowd for the game was so loud that the players thought that there were at least 18,000 fans in the arena which was close to a sold-out game (Kaplan, 2021).

Research Questions:

Research questions that will be answered by this study are:

1) What is the noise exposure of employees in the PNC arena during a National Hockey League non-rival game and how does it compare with rival game?
2) Will the noise exposures be different for each seating level in the PNC arena during a National Hockey League game?

CHAPTER V: SIGNIFICANCE OF THE STUDY

Noise is not just a hazard at workplaces but also in recreational settings. There are few research studies on noise exposure for recreational activities, but similar noise studies for National Hockey League games in an arena are limited. In a previous study on NHL hockey playoffs, it only took 6 minutes to reach the maximum allowable daily noise dose (Hodgetts & Liu, 2006). Hearing loss can happen to frequent attendees at sporting events (Hodgetts & Liu, 2006). This study has the potential to fill in the knowledge gaps in the published literature.

Since there are very few studies on occupational and recreational noise exposures during NHL games in indoor settings, it is important to investigate if noise exposure levels during the NHL games are different from other sports scenarios (e.g., outdoor NFL games). In comparison, NHL games may not have as large as a crowd compared to the NFL games. Moreover, the indoor arena where NHL games are held can potentially create a noisier atmosphere, which can be due to having more surface areas that amplifies sound (Boyd et al., 2015). At an indoor arena, there are more hard surfaces, such as walls and ceilings, which will create a sound reverberation. When sound hits a wall, this gives the attendees the same sound but two different versions a split second apart (Steinbach, 2018). Arenas are designed to have sound delivered from a point source system and speakers that are concentrated in a certain location, with speakers that dispersed around the arena. When the system is dispersed, it can use several speakers that are placed throughout the arena in various sections.

Education on NIHL is essential to reduce such health risk among attendees and workers at the arena. Workers that are exposed to an 8-hr TWA of 85 dB need to have a hearing conservation (HC) program implemented by their employer (OSHA, 2002). There is currently no HC program for attendees for recreational activities, especially professional sporting events that have high noise exposures. This study will assist in assessing the risk of noise exposure and

NIHL among workers of a National Hockey League game and in providing a basis for recommendations for occupational health and safety training. Study findings may also assist in educating attendees about their noise exposures, the associated health effects and NIHL risk, and how they can protect their hearing during these recreational events.

If this study shows that noise exposure levels exceed the OSHA PEL, OSHA action level and the ACGIH TLV, these findings can help in establishing the need for a HC program, which will consequently provide education about noise, NIHL and noise control and exposure reduction measures. It can also further research on determining if there is a need for regulations on noise levels at recreational activities. The study findings may also help educate professional sports teams that, even though loud noise can distract players on the opposite team, it can also damage the hearing of the attendees and workers at the game that are not wearing proper hearing protection. If the noise exposure levels are less than the OSHA PEL, OSHA action limit and AGCIH TLV, study findings would inform stakeholders that workers and/or regular attendees to a professional hockey game at an indoor arena may have lower risk of NIHL. Further studies, such as this proposed, are needed to determine noise exposures during games that have higher attendance or during playoff games.

CHAPTER VI: METHODS

Participant Recruitment

An Institutional Review Board (IRB) approval UMCIRB 23-000763 was obtained prior to data collection and was needed for the workers who wore the noise dosimeters during their shift during a Carolina Hurricanes game. See Appendix A for the ECU IRB Initial Letter of Approval.

When recruitment took place for the employees of the PNC in Raleigh, North Carolina (NC), the investigator sent a recruitment email to the Vice President (VP) of Entertainment and Production, who then forwarded the email to the managers of PNC to help disseminate information to employees about the study. The investigator attended staff meetings to directly provide information about the study (e.g., noise dosimeters to wear), to give the opportunity to ask questions and to recruit study participants. The email sent highlighted that the study involves conducting a noise assessment by measuring noise levels in the arena during Carolina Hurricane Hockey games and stated that participants will wear a noise dosimeter on their dominant side shoulder and be worn for the entire shift, that the device will not record audio or video and that there will be no harmful effects of wearing the dosimeter. It was also noted that only job titles will be obtained from the participants and no personal identification information (e.g., name, age, etc.) will be collected. Appendix B shows the Informed Consent Form used in the study.

Noise Dosimetry

A group of workers at PNC arena in Raleigh, NC were monitored for personal noise exposure using a personal noise dosimeter (Cirrus doseBadge5, North Yorkshire, United Kingdom). Workers were monitored over the entire work shift (4-5 hours) during 12 Carolina Hurricane games from October 2023 to January 2024, with 6 games being regular home games and the other 6 games being rival games (i.e., games against Washington Capitals, New York

Rangers, Pittsburgh Penguins). The dosimeters were fastened to the employees' shirts worn during their complete shift. The dosimeter was placed at shoulder level of the dominant side of the worker's body and 4 inches from the worker's ear. This was done to ensure that the dosimeter collects noise measurements represented the sounds the ear would hear. With 9 dosimeters available for use, a maximum of 8 workers were personally monitored per monitoring shift while 1 dosimeter was placed on fixed location in the arena. The employees monitored were selected from a pool of workers who agreed to participate, depending on the number of workers available. A number (i.e., #1 to #8) was assigned to the participant that will match the assigned number to the noise dosimeter during the monitoring day. The job titles of the employees were collected as the noise dosimeter was placed on the shoulder, but no other personal identifying information was collected. Participants were asked where they would be stationed during the game on that monitoring day and where they were staying in one section or moving to different sections during the game. The workers monitored were as follows: 1) an usher at Section 112; 2) a user located between section 119; 3) a usher at section 125; 4) club level lounge area near section 229; 5) a usher at section 301; 6) usher at the bottom area of section311; 7) usher at the bottom area between the section 321; and 8) usher at the bottom of section 327(see Figure 1). The personal noise dosimeter provided time weighted averages (TWAs) and 1-minute averages of noise exposure levels in A-weighted decibels (dBA) and a daily noise exposure dose (%). One channel was dedicated to the OSHA noise permissible exposure limit (PEL) (90 dBA criterion level, 90 dBA threshold level, 5 dB exchange rate, slow response, A-weighting). A second channel was set to the OSHA hearing conservation (HC) (90 dBA criterion level, 80 dBA threshold level, 5 dB exchange rate, slow response, A-weighting). A third channel was set to the ACGIH threshold limit value (TLV) (85 dBA criterion level, 80 dBA threshold level, 3 dB exchange rate, slow response, A-weighting). Each dosimeter was programmed to data log 1-min

averages and was calibrated using a class 2 acoustic calibrator (CR:518, Cirrus Research, North Yorkshire, United Kingdom) at the start and end of each monitoring day.

Area Noise Monitoring

Sound pressure levels (SPLs) produced by the crowd noise, sounds of the game, the public announcer and other various game day noise was measured by using two types of noise-measuring instruments placed around the PNC arena for area noise monitoring: a sound level meter (Casella CEL-620, Kempston, Bedford, United Kingdom) and noise dosimeters (Cirrus doseBadge5, North Yorkshire, United Kingdom). The sound level meter, with settings at A-weighting and slow response, was secured to a tripod at a height of 1.1 meters from the ground and will be placed in Section 102 at the top of the stairs in the lounge area by the ADA section. This section was chosen because the sound level meter will be in a safe location that is near the audience and near employees (see Figure 1) for the entire game time, including warmups and post-game festivities, for about 4 hours. The sound level meter was calibrated using an acoustical calibrator (CEL-120/2 Kempston, Bedford, United Kingdom) before and after each set of noise measurements during the monitoring day. Similar to the sound level meter, one noise dosimeter was placed in a fixed location within the arena for the entire game time, which was inside the production office near section 334 on the third level (Figure 1). The sound level meter and noise dosimeter for area noise monitoring were deployed during the same 12 Carolina Hurricane games from October 2023 to January 2024 when noise dosimetry was conducted.

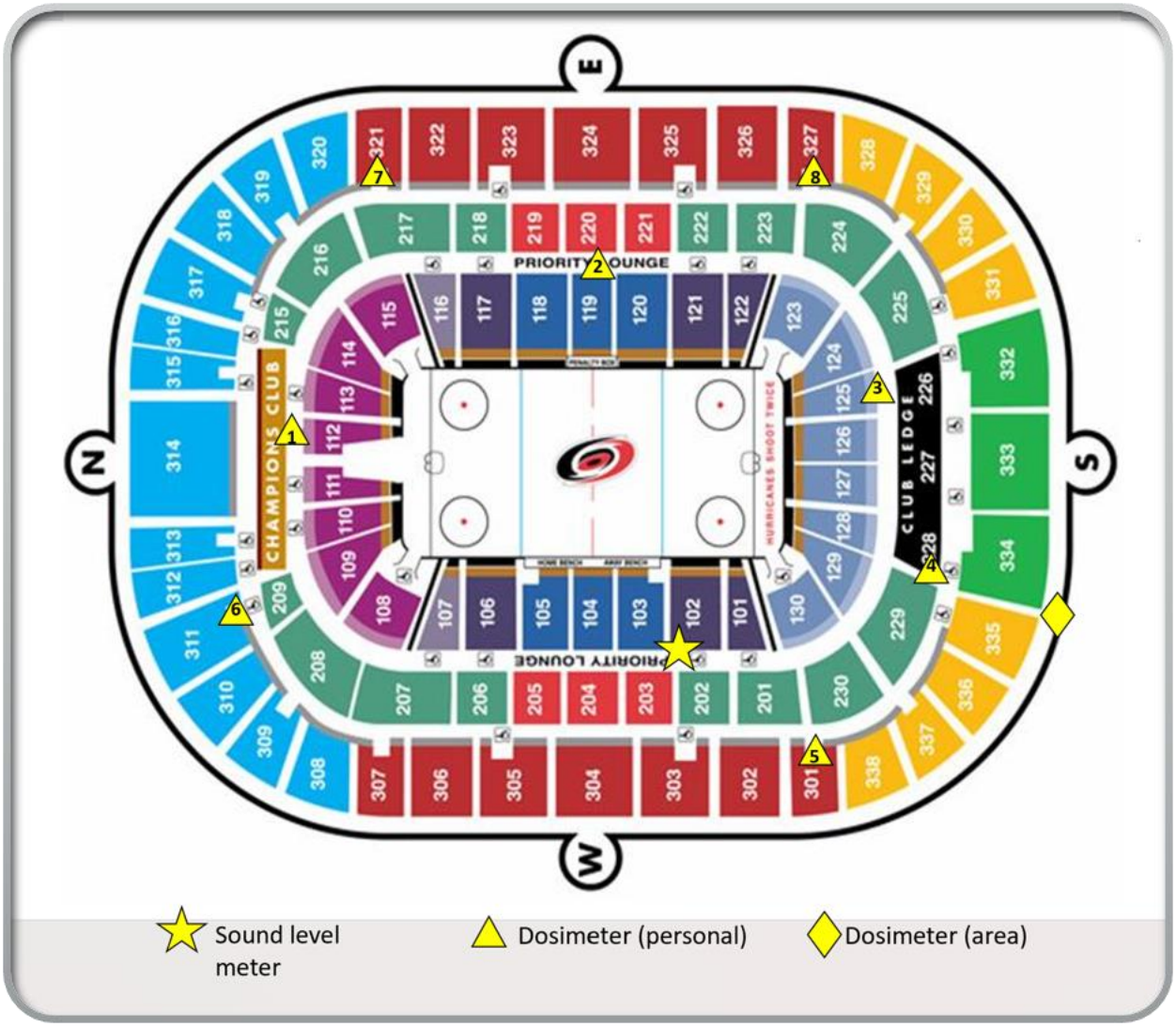

Figure 1. Locations of Noise Monitoring Points on the PNC Arena Seating Chart.

Data Analysis

The mean, median, maximum, and standard deviation for TWA noise exposure levels by game, job title, area section and seating level, using OSHA and NIOSH noise metrics, were determined. The TWA noise exposure data obtained using OSHA and NIOSH channels were compared to their corresponding occupational exposure limits for noise (OSHA PEL and NIOSH REL, respectively) to determine the exceedance percentages (i.e., percentage of TWA noise exposure measurements that exceeded 90 and 85 dBA). Analysis of variance (ANOVA) tests

were conducted to compare mean TWA and maximum noise exposure levels and noise dose by game, area section and seating level. T-tests were also conducted to compare mean TWA and maximum noise exposure levels and noise dose between rival and non-rival games. The Statistical Package for Social Sciences (SPSS, version 28.0.1.1, IBM, Armonk, NY) was used to analyze the data. A p-value of <0.05 was considered as statistically significant.

CHAPTER VII: RESULTS

Characteristics of Monitored Hockey Games

Twelve (12) hockey games were monitored in this study, 4 of which were rival games and 8 were non-rival games. Table 1 shows the game information on the date of occurrence, name of opponents during the game and whether it is a rival or non-rival game. The following sections describe the noise characteristics for each monitored game.

Table 1. Information of hockey games monitored in the study.

Game #	Date	Name of Opponents	Rival/ Non-rival	Number of attendees	Hurricanes Win or Loss	Number of Goals by Hurricanes	Weekend Game
1	Oct. 11, 2023	Ottawa Senators	Non-rival	17,917	Win	5	No
2	Oct. 26, 2023	Seattle Kraken	Non-rival	15,644	Win	3	No
3	Oct. 27, 2023	San Jose Sharks	Non-rival	16,558	Win	3	Yes
4	December 2, 2023	Buffalo Sabers	Non-rival	16,316	Win	6	Yes
5	December 17, 2023	Washington Capitals	Rival	15,856	Loss	1	Yes
6	December 23, 2023	New York Islanders	Rival	17,322	Loss	4	Yes
7	January 6, 2024	St. Louis Blues	Non-Rival	17,530	Loss	1	Yes
8	January 13, 2024	Pittsburgh Penguins	Rival	17,715	Win	3	Yes
9	January 19, 2024	Detroit Red Wings	Non-Rival	17,448	Win	4	No
10	January 21, 2024	Minnesota Wild	Non-Rival	16,573	Loss	2	Yes
11	January 25, 2024	New Jersey Devils	Rival	16,445	Win	3	No
12	January 27, 2024	Arizona Coyotes	Non-Rival	17,426	Win	3	Yes

Game #1: Versus Ottawa Senators

Though the Ottawa Senators are not technically a rival team for the Carolina Hurricanes, this game was a louder game for a non-rival due to being the first game for the regular season. Table 2 shows the averages (Lavg and 8-hr TWA), dose and maximum (LASmax) noise levels by dosimeter channel measured during the Ottawa Senators game at various locations in the arena.

Table 2. Averages (Lavg), 8-hr dose and time-weighted-average (TWA) and maximum noise levels by dosimeter channel and location during the Ottawa Senators Game, October 11, 2023

Section #	Duration (h:mm)	ACGIH				OSHA PEL				Maximum (LASmax) (dBA)
		Lavg (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>85 dBA	Lavg (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>90 dBA	
112	3:45	95.2	192.8	89.7	Yes	90.8	52.4	85.3	No	111.1
119	3:45	94.4	172.5	88.9	Yes	90.3	48.9	84.8	No	107.2
125	3:45	95.6	203.8	90.1	Yes	89.5	43.7	84.0	No	111.9
1st level average		95.1 ± 0.6	189.7 ± 15.9	89.6 ± 0.6	Yes	90.2 ± 0.7	48.3 ± 4.4	84.7 ± 0.7	No	110.1 ± 2.5
229	3:45	94.0	163.2	88.5	Yes	89.1	41.4	83.6	No	106.5
2nd level average		94.0	163.2	88.5	Yes	89.1	41.4	83.6	No	106.5
301	3:45	93.8	158.8	88.3	Yes	89.0	40.8	83.5	No	111.7
311	3:45	94.2	167.8	88.7	Yes	90.2	48.2	84.7	No	111.1
321	3:45	94.1	165.5	88.6	Yes	88.3	37.0	82.8	No	109.7
327	3:45	91.9	122.0	86.4	Yes	86.0	26.9	80.5	No	105.2
3rd level average		93.5 ±1.1	153.5 ±21.4	88.0 ± 1.1	Yes	88.4 ±1.8	38.2 ± 8.9	82.9 ± 1.8	No	109.4 ±2.9
Office	3:45	89.1	82.8	83.6	No	81.7	14.8	76.2	No	104.2
Overall average		93.6 ±2.0	158.8 ± 36.5	88.1 ± 2.0	Yes	88.3 ±2.9	39.3 ± 11.9	82.8 ± 2.9	No	108.7 ±3.0

The monitoring period was conducted for 3 hours and 45 minutes from 6:30 – 10:15 PM. For this game, the average noise levels (Lavg) were the loudest on the first level of the arena. The Lavg for this game was 93.6 ± 2.0 dBA for ACGIH and 88.3 ± 2.9 dBA for OSHA PEL. The sections in level 3 had averages of 93.5 ± 1.1 dBA for ACGIH and 88.4 ± 1.8 dBA for OSHA PEL, which were the quietest levels for the game compared to levels 1 (Lavg of 95.1 ± 0.6 for ACGIH and 90.2 ± 0.7 for OSHA PEL) and level 2 (Lavg of 94.0 for ACGIH and 89.1 for OSHA PEL). This kept the loudest sections on the lower sections of the arena. The middle

sections of the arena were the quietest where the north and south ends had trends of being the loudest. The maximum noise levels in each section ranged from 104.2 dB (office) to 111.9 dB (section 125). The maximum noise levels typically follow a pattern, increasing during player introductions and moments of scoring or goal announcements.

The 8-hr TWA noise levels for each monitored section in the arena, ranging from 76.2 – 85.3 dBA, did not exceed the OSHA PEL of 90 dBA, with noise doses ranging from 14.8 – 52.4%. However, 8-hr TWA noise levels, ranging from 86.4 – 90.1 dBA (noise dose ranging from 122.0 – 203.8%), exceeded the ACGIH TLV of 85 dBA, except in the production office where the 8-hr TWA was 83.6 dBA and the noise dose was 82.8% (Table 2).

Figure 2 shows a sample noise profile that demonstrates the time history of personal noise exposure for a study participant assigned to Section 321. Some examples of the spikes for this data, as indicated by blue arrows on Figure 2, would be at 8:20 pm when the Carolina Hurricanes scored a goal, and another at 9:40 pm when the scoreboard is promoted people to be loud.

The sound level meter is also placed on the first level in section 102 and monitored for a duration of 2 hours and 21 minutes. Figure 3 shows the noise profile that demonstrates the time history of area noise level at Section 102. The average for the sound level meter is 89.2 ± 5.3 dBA and the maximum level is at 113.2 dB at 9:50 pm (indicated by a blue arrow on Figure 3), which was during the end of game festivities and the minimum was at 9:58 pm which is after the three stars of the game announcement where everyone is filing out to the arena sections.

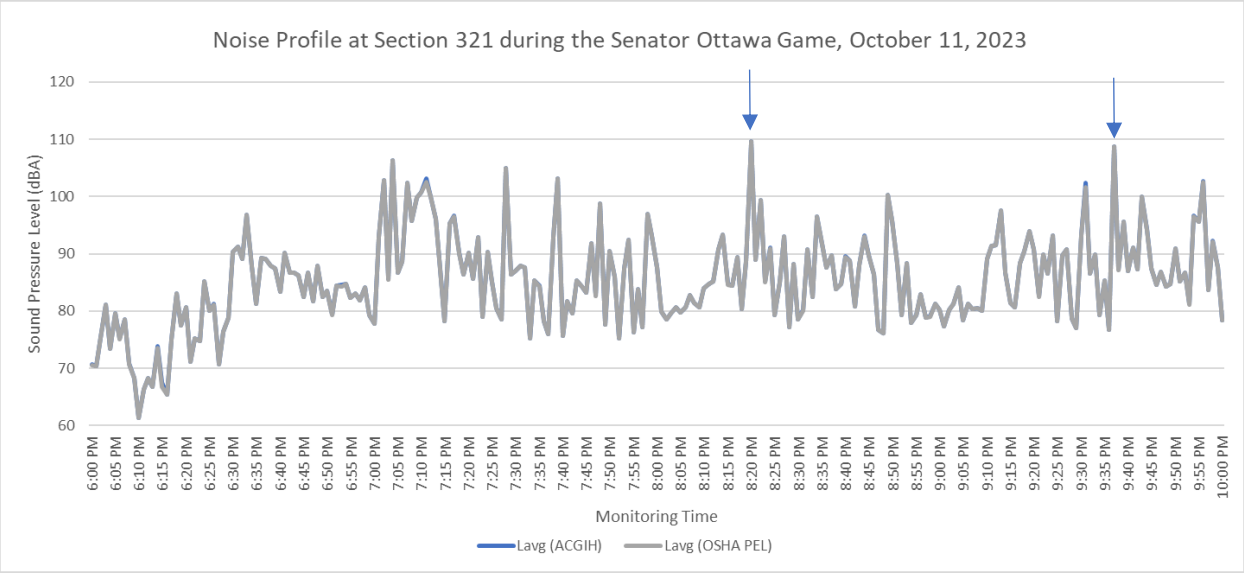

Figure 2. Time history of personal noise exposure of employee assigned at section 321, October 11, 2023. (Note: OSHA and ACGIH graphs lines overlap.)

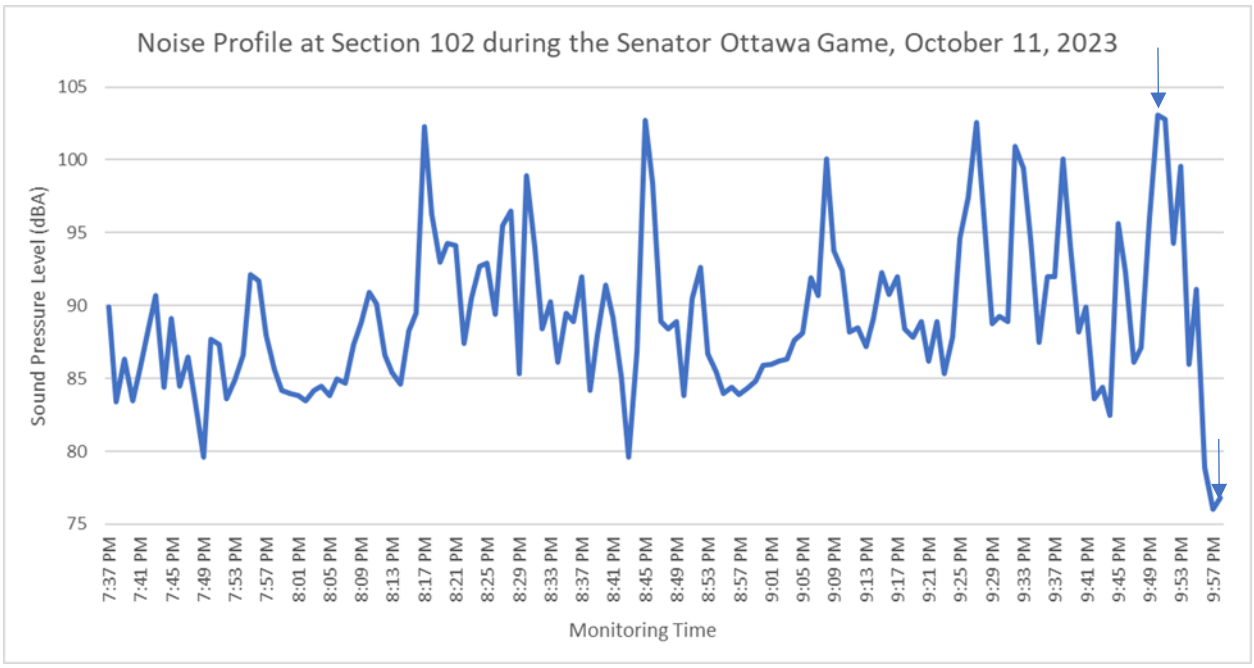

Figure 3. Time history of area noise level at section 102, October 11, 2023

Game #2: Versus Seattle Kraken

The Seattle Kraken are a non-rival team for the Carolina Hurricanes. The game reflected this with lower average noise levels than the first game of the season. This game was held during the week which can affect the attendance of the game. Table 3 shows the averages (L_{avg} and 8-hr TWA), dose and maximum (LASmax) noise levels by dosimeter channel measured during the Seattle Kraken game at various locations in the arena.

Table 3. Averages (L_{avg}), 8-hr dose and time-weighted-Average (TWA) and maximum noise levels by dosimeter channel and location during the Seattle Kraken Game, October 26, 2023.

Section #	Duration (h:mm)	ACGIH				OSHA PEL				Maximum (LASmax) (dBA)
		Lavg (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>85 dBA	Lavg (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>90 dBA	
112*	-	-	-	-	-	-	-	-	-	-
119	3:30	89.2	78.3	83.2	No	81.2	12.9	75.2	No	103.6
125	3:30	90.7	96.4	84.7	No	84	19	78	No	106.6
1st level average		90.0 ± 1.1	87.4 ±12.8	84.0± 1.1	No	82.6 ± 2.0	16 ± 4.3	76.6 ± 2.0	No	105.1 ± 2.1
229	3:30	90.7	96.4	84.7	No	83.6	18	77.6	No	108.2
2nd level average		90.7	96.4	84.7	No	83.6	18	77.6	No	108.2
301	3:30	86.9	56.9	80.9	No	78.1	8.4	72.1	No	105.6
311	3:30	91.3	104.8	85.3	Yes	85.1	22.2	79.1	No	106.4
321	3:30	89	76.2	83.0	No	81.9	14.2	75.9	No	103.9
327	3:30	90.2	90	84.2	No	82.4	15.3	76.4	No	107.3
3rd level average		89.4 ± 1.9	82 ± 20.4	83.4 ± 1.9	No	81.9 ± 2.9	15 ± 5.7	75.9 ± 2.9	No	105.8±1.4
Office	3:30	87.3	60.2	81.3	No	77.6	7.8	71.6	No	103.5
Overall average		89.4 ± 1.6	82.4 ± 17.5	83.4 ± 1.6	No	81.7 ± 2.7	14.7 ± 5.0	75.7 ± 2.7	No	105.6 ± 1.8

* Did not monitor

The monitoring period was conducted for 3 hours and 30 minutes from 6:30 – 10:00 PM for the dosimeters and 1 hour and 15 minutes for the sound level meter. For this game, the average noise first level (Lavg of 90.0 ± 1.1 dBA for ACGIH and the 82.6 ± 2.0 dBA for OSHA PEL) was slightly louder than the third level (Lavg of 89.4 ± 1.9 dBA for ACGIH and 81.9 ± 2.9 dBA. However, the second level had the loudest average (Lavg of 90.7 dBA for ACGIH and 83.6 dBA for OSHA PEL). The ends of the arena such as north and south ends, have a trend of being

the loudest, whereas the middle tends to be quieter. The maximum noise levels in each section ranged from 103.5 dB (office) to 108.2 dB (section 229). These maximum levels had a trend of be during the players introductions or during goals or the announcement of goals. The minimum for these sections were during either play or during warmups.

The 8-hr TWA noise levels for each monitored section in the arena, ranging from 71.6 – 79.1 dBA, did not exceed the OSHA PEL of 90 dBA, with noise doses ranging from 7.8 – 22.2%. Similarly, 8-hr TWA noise levels, ranging from 84.7 – 81.3 dBA (noise dose ranging from 56.9 – 60.2%), did not exceed the ACGIH TLV of 85 dBA, except in the section 311 where the 8-hr TWA was 85.3 dBA and the noise dose was 104.8% (Table 3).

The sound level meter had a shorter monitoring period than the dosimeter due to having problems placing dosimeters on the staff, causing the average to be less than the other sections. Figure 4 shows a sample noise profile for Section 321 for this game. Some examples of the spikes for this data are at 7:03pm when the players were being announced, 7:44pm when there was a goal scored and 9:12pm when there was a Hall of Fame announcement for the team.

The sound level meter placed in section 102 monitors noise for a duration of 1 hour and 45 minutes. The average for the sound level meter is 85.2 dB and the maximum level is at 110.1 dB at 7:44pm which was during the first goal of the game and the minimum was at 6:30 pm which is where warmups start and not many people are in the arena bowl at the time. Some of the spikes that are shown in Figure 5 are 7:02 pm where the Players are being announced and they are entering the arena ice, and 7:44pm where the first goal of the game was scored. Figure 5 shows the noise profile that demonstrates the time history of area noise level at Section 102.

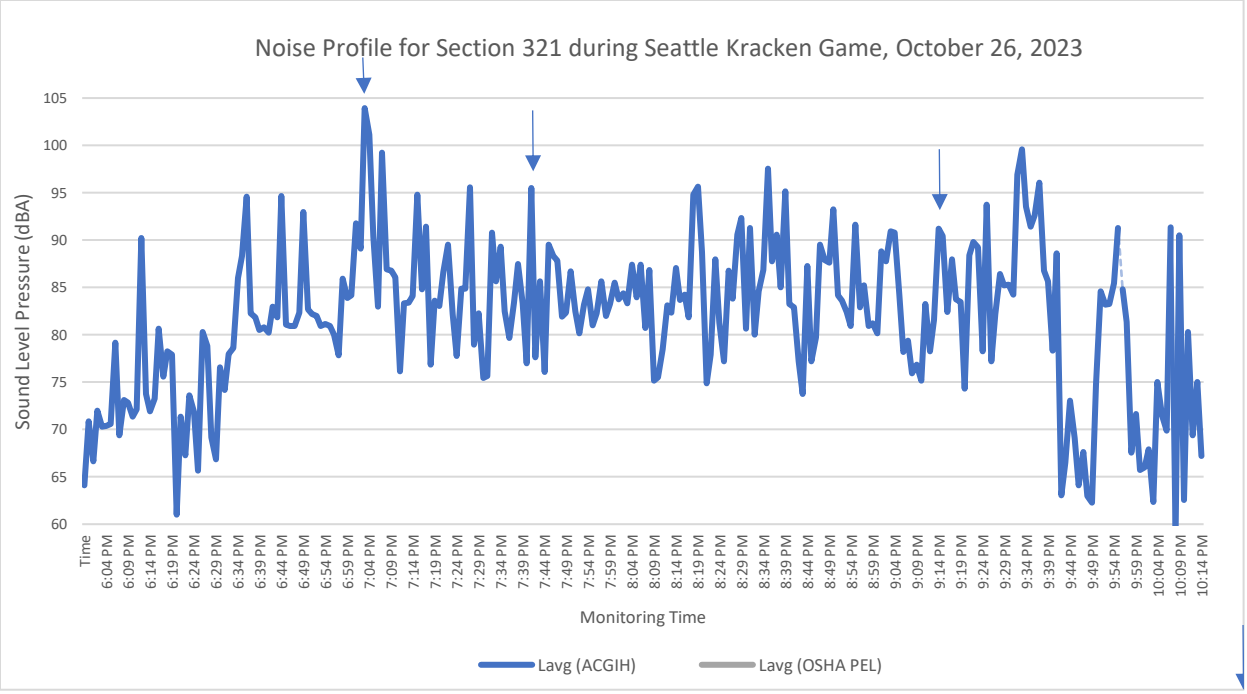

Figure 4. Time history of personal noise exposure of employee assigned at section 321, October 26, 2023. (Note: OSHA and ACGIH graphs lines overlap.)

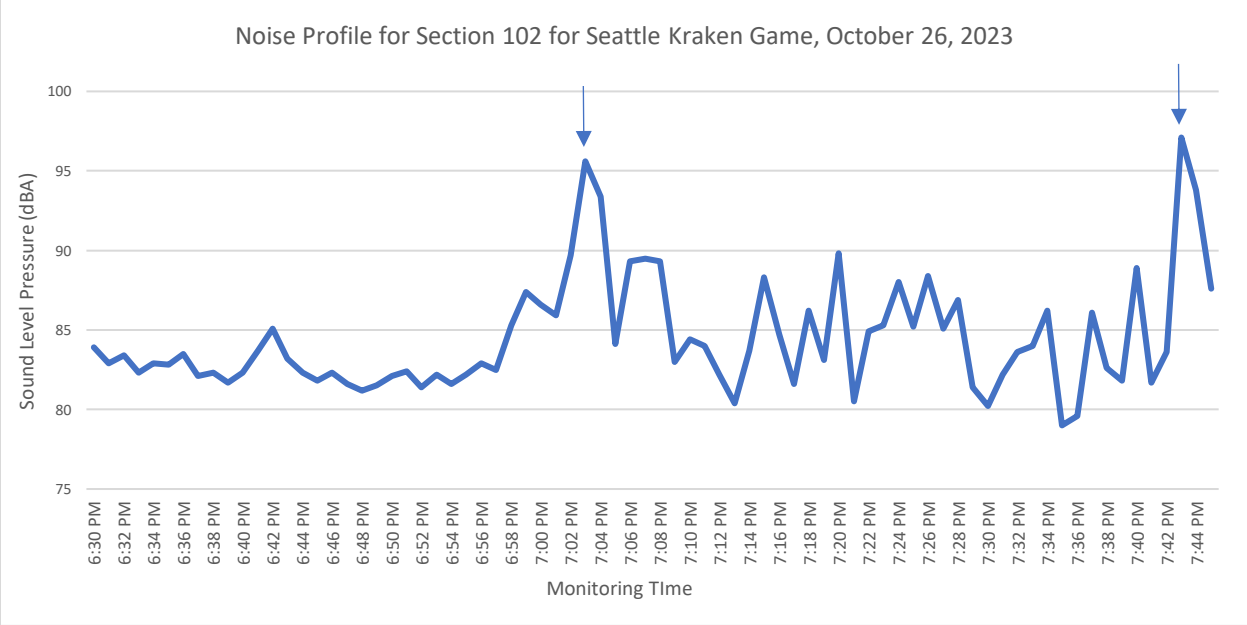

Figure 5. Time history of area noise level at section 102, October 26, 2023

Game #3: Versus San Jose Sharks

The San Jose Sharks are a non-rival team for the Carolina Hurricanes. This game was about the same sound pressure level as the game day before. Table 4 shows the averages (Lavg and 8-hr TWA), dose and maximum (LASmax) noise levels by dosimeter channel measured during the San Jose Sharks game at various locations in the arena.

Table 4. Averages (L_{avg}), 8-hr dose and time-weighted-average (TWA) and maximum noise levels by dosimeter channel and location during the San Jose Sharks Game, October 27, 2023.

Section #	Duration (h:mm)	ACGIH				OSHA PEL				Maximum (LASmax) (dBA)
		Lavg (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>85 dBA	Lavg (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>90 dBA	
112*	-	-	-	-	-	-	-	-	-	-
119	3:20	92.3	114.6	86.0	Yes	85.7	23.0	79.4	No	108
125	3:19	89.1	70.2	82.5	No	81.3	11.9	74.7	No	106.4
1st level average		90.7 ± 2.3	92.4 ± 2.3	84.3± 2.5	No	83.5± 3.1	17.5± 7.8	77.1± 3.3	No	107.2 ± 1.1
229	3:20	90.1	84.5	83.8	No	83.7	17.4	77.4	No	103.7
2nd level average		90.1	84.5	83.8	No	83.7	17.4	77.4	No	103.7
301	3;05	88.5	62.6	81.6	No	81.2	11.4	74.3	No	109
311	3:19	86.4	48.3	79.8	No	72.6	6.3	70.1	No	99.9
321	3:19	87.5	56.3	80.9	No	79.8	9.7	73.2	No	98,8
327	3:19	88.9	68.3	82.3	No	81.1	11.6	74.5	No	106.3
3rd level average		87.8 ± 1.1	58.9 ± 8.6	81.2 ± 1.1	No	79.7 ± 2.1	9.8 ± 2.5	73.0 ± 2.0	No	103.5 ± 4.9
Office*	-	-	-	-	-	-	-	-	-	-
Overall average		89.0 ± 1.9	72.1 ± 21.9	82.4 ± 2.0	No	81.4 ± 2.8	13.0 ± 5.5	74.8 ± 3.0	No	104.6 ± 3.9

* Did not monitor

The monitoring period was conducted for 3 hours and 20 minutes from 6:30 – 9:50 PM. The first level had the loudest average (Lavg of 90.7 ± 2.3 dBA for ACGIH and 83.5 ± 3.1 dBA for OSHA PEL) compared to the second (90.1 dBA for ACGIH and 83.7 dBA for OSHA PEL) and third levels (87.8 ± 1.1 dBA for ACGIH and 79.7 ± 2.1 dBA for OSHA PEL. Similar to other games, the maximum noise levels were measured during the players introductions or during

goals or the announcement of goals, while the minimum levels were during either play or during warmups.

The 8-hr TWA noise levels for each monitored section in the arena, ranging from 70.1 – 79.4 dBA, did not exceed the OSHA PEL of 90 dBA, with noise doses ranging from 6.3 – 23.0%. Similarly, 8-hr TWA noise levels, ranging from 79.8 – 83.8 dBA (noise dose ranging from 48.3 – 84.5%), did not exceed the ACGIH TLV of 85 dBA, except in the section 119 where the 8-hr TWA was 86.0 dBA and the noise dose was 114.6% (Table 4).

The sound level meter had a shorter monitoring period than the dosimeter due to having problems placing dosimeters on the staff, causing the average to be less than the other sections. Figure 6 shows a sample noise profile for Section 119. Some examples of the spikes for this data, as shown in Figure 6, are at 7:05 pm when it is puck drop time, when the horn is prompting the fans in the arena and the players to respond with "Let's Go Canes" chant, 7:12 pm when the scoreboard is prompted the crowd to chant "Let's Go Canes", 7:44pm when there was a goal scored and 9:33pm when there was a penalty, when the Hurricanes were going on the power play and the team shows the offender in the penalty box with uplifting music. Some of the quieter times include instances, such as at 6:44pm when it was after warmups and there is no more cheering, just watching the pre-game interviews, and at 9:18pm when there is a break in between the periods.

The sound level meter in section 102 monitored noise for a duration of 2 hours from 7:50pm to 9:50 pm. The sound level meter for this game ran from the start of the second period to the end of the game after all the festivities of the win was over. Some of the spikes that were in this game was at 8:42pm when there was a big save from the goalie, 9:14 pm when a goal was scored a minute before and the goal announcement was made, and 9:46pm when there the team does the storm surge at the middle of the ice after winning the game. Some of the quieter parts of

the game were 8:22pm, 9:10pm and 9:42pm during game play when the Carolina Hurricanes were not playing the greatest and nothing exciting were going on at the time. Figure 7 shows the noise profile that demonstrates the time history of area noise level at Section 102.

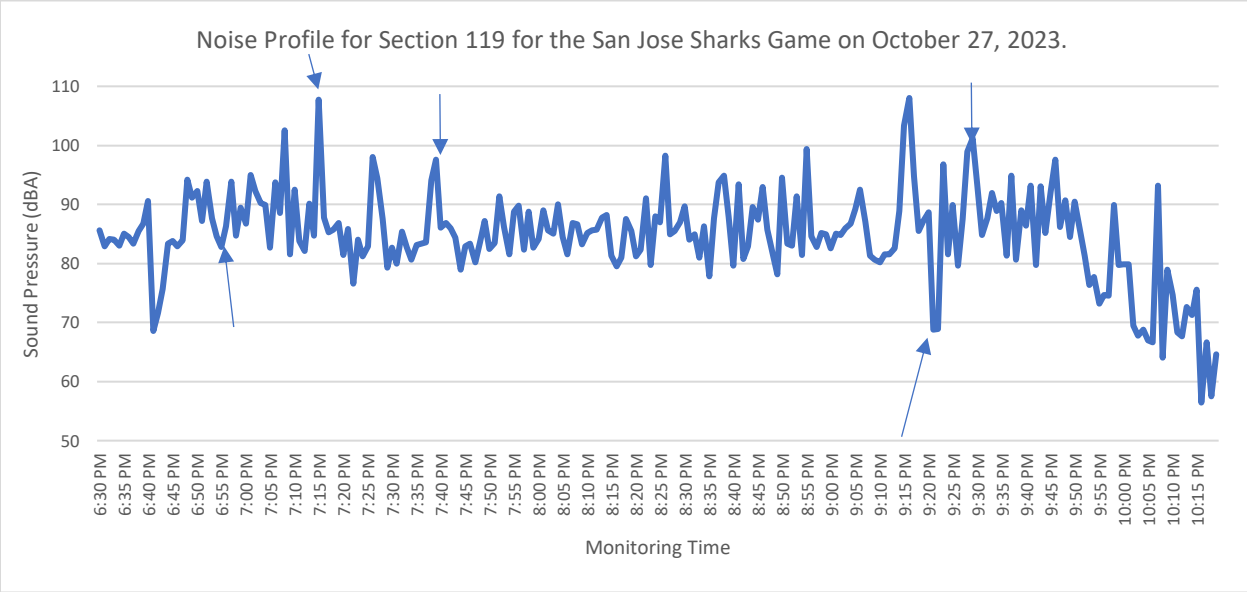

Figure 6. Time history of personal noise exposure of employee assigned at section 119, October 27, 2023.

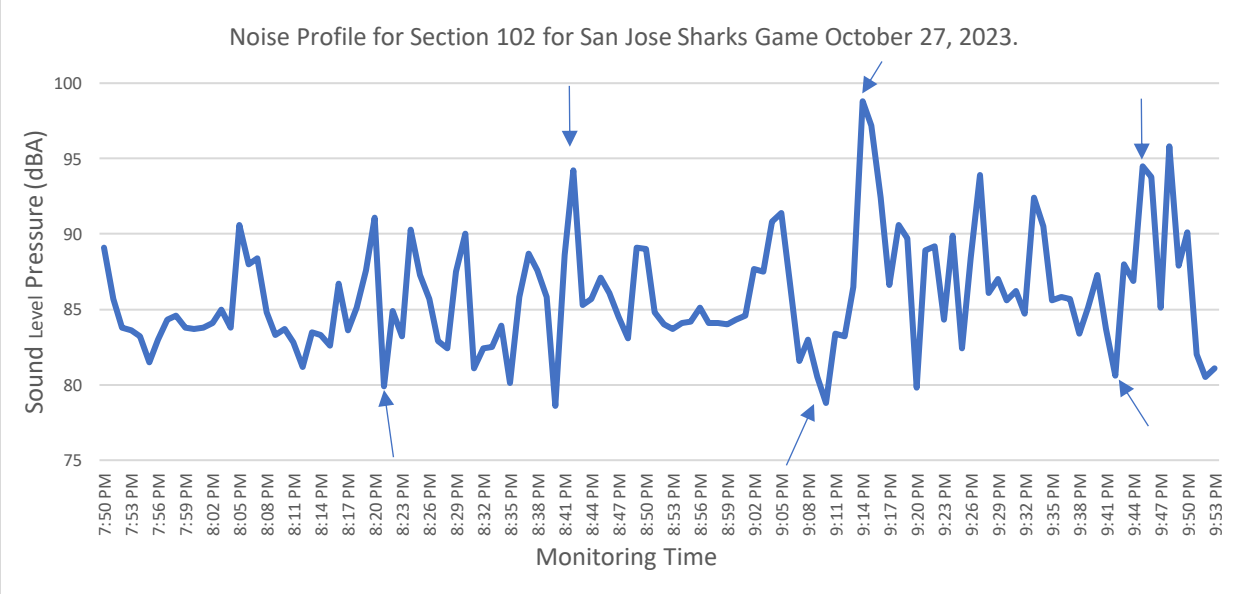

Figure 7. Time history of area noise level at section 102, October 27, 2023.

Game #4: Versus Buffalo Sabers

The Buffalo Sabers are a non-rival team for the Carolina Hurricanes, so this game was about the same noise level as the game day before. Table 5 shows the averages (L_{avg} and 8-hr TWA), dose and maximum (LASmax) noise levels by dosimeter channel measured during the Buffalo Sabers game at various locations in the arena.

The monitoring period was conducted for 3 hours and 20 minutes from 6:30 – 9:50 PM. The third level had the loudest average noise level (Lavg of 89.9 ± 1.6 dBA for ACGIH and 83.2 ± 1.6 dBA for OSHA PEL) compared to other levels. For the first level, the middle of the arena tended to be the loudest sections (e.g., section 119 with the Lavg of 91.0 dBA for ACGIH and 84.3 dBA for OSHA PEL). For the third level, the loudest tended to be the end of the middle sections towards the south end of the arena (e.g., section 301 with the Lavg of 92.7 dBA for ACGIH and 87.5 dBA for OSHA PEL. The maximum noise level tends to be during the players' introduction, during goals or the announcement of goals and when fights break out. The minimum noise levels for these sections were during either play or during warmups.

Table 5. Averages (L_{avg}), 8-hr dose and time-weighted-average (TWA) and maximum noise levels by dosimeter channel and location during the Buffalo Sabers Game, December 2, 2023.

Section #	Duration (h:mm)	ACGIH				OSHA PEL				Maximum (LASmax) (dBA)
		Lavg (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>85 dBA	Lavg (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>90 dBA	
112*	-	-	-	-	-	-.	-	-	-	-
119	3:20	91.0	95.7	84.7	No	84.3	18.9	78	No	106.9
125	3:20	88.7	69.6	824	No	82	13.7	75.7	No	100
1st level average		89.9± 1.6	82.7± 18.5	83.6±1 .6	No	83.2± 1.6	16.3± 3.7	76.9 ± 1.6	No	103.4± 4.9
229	-	-	-	-	-	-	-	-	-	-

2nd level average		-	-	-	-	-	-	-	-	-
301	3:20	92.7	121.2	86.4	Yes	87.5	29.5	81.2	No	108.2
311	3:15	88.9	69.8	82.4	No	80.2	10.4	73.7	No	105.4
321	3:15	91.3	97.3	84.8	No	84.9	20	78,4	No	106.7
327	3:20	95.9	188.8	89.6	Yes	90.3	43.4	84	No	113.8
3rd level average		92.2 ± 2.9	119.3 ± 50.9	85.8 ± 3.0	Yes	85.7 ± 4.3	25.8 ± 14.1	79.3 ± 4.4	No	108.5 ± 3.7
Office*	-	-	-	-	-	-	-	-	-	-
Overall average		91.4 ± 2.7	107.1 ± 44.5	85.1 ± 2.7	Yes	84.9 ± 3.7	22.7 ± 12.1	78.5 ± 3.7	No	106.8 ± 4.5

*Did not monitor

The 8-hr TWA noise levels for each monitored section in the arena, ranging from 73.7 – 84 dBA, did not exceed the OSHA PEL of 90 dBA, with noise doses ranging from 10.4 – 43.4%. Similarly, 8-hr TWA noise levels, ranging from 82.4 – 84.8 dBA (noise dose ranging from 69.8 – 97.3%), did not exceed the ACGIH TLV of 85 dBA, except in the sections 301 (8-hr TWA = 86.4 dBA; noise dose = 121.2%) and 327 (8-hr TWA = 89.6 dBA; noise dose = 188.8%) (Table 5).

Figure 8 shows a sample noise profile for Section 301. Some examples of the spikes for this data are at 6:30pm when it was the start of warmups, 7:40 pm when there was a goal scored, 8:15pm when there are bad plays happening, 8:44pm when there was a fight on the ice, 9:40pm when the game ended, and the crowd was chanting the name of the 1st star of the game.

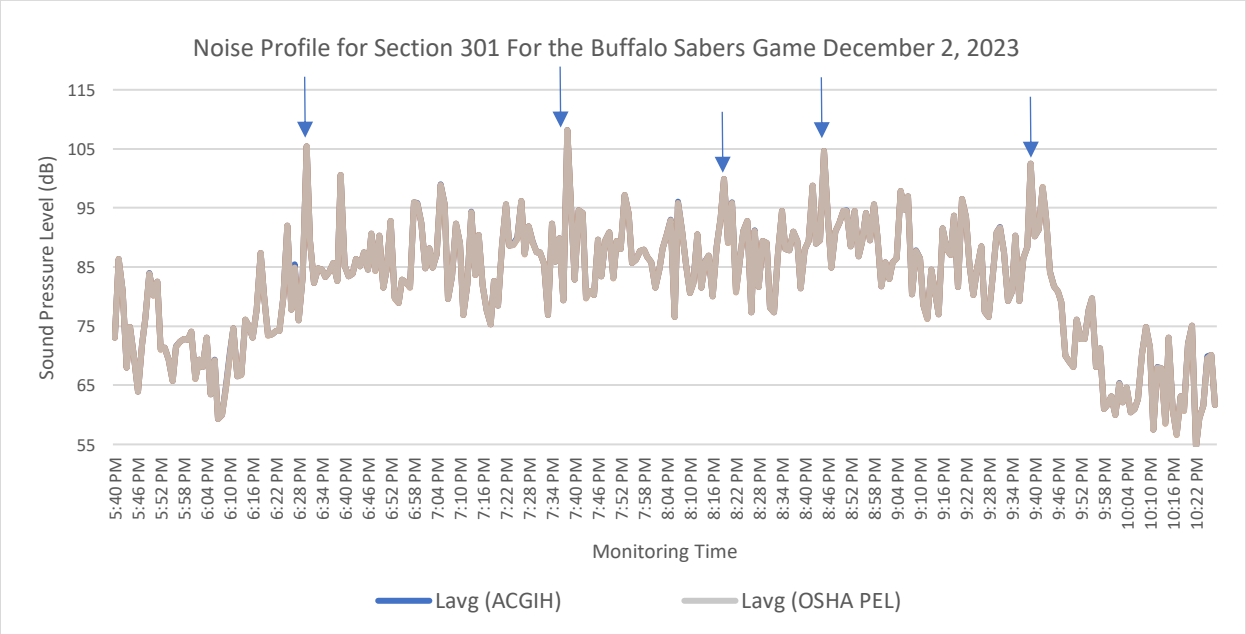

Figure 8. Time history of personal noise exposure of employee assigned at section 301, December 2, 2023. (Note: OSHA and ACGIH graphs lines overlap.)

The sound level meter in section 102 monitored noise for a duration of 3 hours and 20 minutes from 6:30 – 9:50 PM. The sound level meter for this game ran from the start of warmups to the end of the game after all the festivities of the win was over. This section had more spikes than the above example of section 301. Some of the spikes that were in this game was at 7:26pm when the score board was prompting the crowd to cheer, 8:04pm when there was a penalty play and a goal, 8:22 pm when the Hurricanes had a penalty kill, 8:42pm when there was goal, 9:35pm at the end of the game and the start of the storm surge. Figure 9 shows the noise profile that demonstrates the time history of area noise level at Section 102.

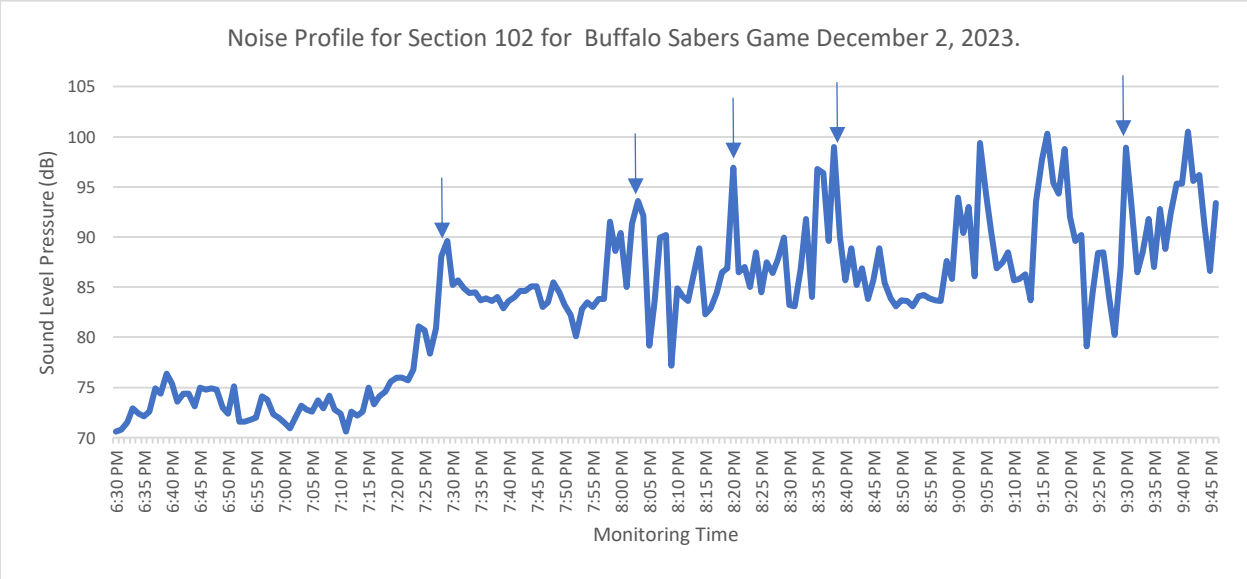

Figure 9. Time history of area noise level at section 102, October 27, 2023.

Game #5: Versus Washington Capitals

The Washington Capitals are a rival team for the Carolina Hurricanes. This game was quieter than the last game even though the Washington Capitals are a rival to the Hurricanes.

Table 6 shows the averages (L_{avg} and 8-hr TWA), dose and maximum (LASmax) noise levels by dosimeter channel measured during the Buffalo Sabers game at various locations in the arena.

The monitoring period was conducted for 3 hours and 30 minutes from 5:30 – 9:00 PM. The first level of the arena had the loudest average noise (Lavg of 90.6 ± 1.2 dBA for ACGIH and 84.6 ± 1.9 dBA for OSHA PEL) compared to the third level (Lavg of 88.0 ± 1.0 dBA for ACGIH and 79.7 ± 1.9 dBA for OSHA PEL) and second level (Lavg of 87.4 dBA for ACGIH and 78.3 dBA for OSHA PEL). The third and second levels, however, had monitors that did not record for the whole game which affected the average for the third level. The 3 first-level sections 112, 119, 125 were all close to the same averages, and section 125 which is on the north end of the arena was the quietest (Lavg of 87.9 dBA for ACGIH and 82.4 dBA for OSHA PEL). For the third level, the loudest tended to be the middle of the arena (i.e., section 327 with Lavg of 87.9 dBA for ACGIH and 79.5 dBA for OSHA PEL) and the south end of the arena (i.e., section 301 with Lavg of 89.3 dBA for ACGIH and 82.4 dBA for OSHA PEL), whereas the north end was the quietest (i.e., section 311 with Lavg of 86.9 dBA for ACGIH and 78.5 dBA for OSHA PEL. The maximum noise levels, ranging from 99.3 dBA – 105 dBA, tend to be during the players' introduction, during goals or the announcement of goals and when fights break out. The minimum for these sections were during either play or during warmups.

Table 6. Averages (L_{avg}), 8-hr dose and time-weighted-average (TWA) and maximum noise levels by dosimeter channel and location during the Washington Capitals Game, December 17, 2023.

Section #	Duration (h:mm)	ACGIH				OSHA PEL				Maximum (LASmax) (dBA)
		Lavg (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>85 dBA	Lavg (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>90 dBA	
112	3:30	91.2	103.3	85.2	Yes	86.1	25.5	80.1	No	105.3
119	3:30	91.4	106.2	85.4	Yes	85.3	22.8	79.3	No	103.9
125*	3:30	89.3	79.4	83.3	No	82.4	15.3	76.4	No	97.4

1st level average		90.6 ± 1.2	96.3 ± 14.7	84.6 ± 1.2	No	84.6 ± 1.9	21.2 ± 5.3	78.6 ± 1.9	No	103.7 ± 1.5
229	1:12	87.4	20.9	73.7	No	78.3	3	64.6	No	102.1
2nd level average	1:12	87.4	20.9	73.7	No	78.3	3	64.6	No	102.1
301	3:30	89.3	79.4	83.3	No	82.4	15.3	76.4	Yes	102.3
311	3:30	86.9	56.9	80.9	No	78.5	8.9	72.5	No	97.5
321	3;30	87.8	64.5	81.8	No	78.2	8.5	72.2	No	104.9
327	2:19	87.9	43.3	79.0	No	79.5	6.8	70.6	No	103.0
3rd level average		88.0 ± 1.0	61.0 ± 15.1	81.3 ± 1.8	No	79.7 ± 1.9	9.9 ± 3.7	72.9 ± 2.5	No	101.9 ± 3.1
Office	2:19	84.8	28.2	75.9	No	71.9	2.4	63	No	99.3
Overall average		88.4 ± 2.1	64.7 ± 30.4	80.9 ± 4.1	No	80.3 ± 4.3	12.1 ± 8.2	72.8 ± 6.0	No	102.2 ± 2.5

The 8-hr TWA noise levels for each monitored section in the arena, ranging from 80.1 – 63.0 dBA, did not exceed the OSHA PEL of 90 dBA, with noise doses ranging from 2.4 – 25.5%. Similarly, 8-hr TWA noise levels, ranging from 73.7 – 83.3 dBA (noise dose ranging from 20.9 – 79.4%), did not exceed the ACGIH TLV of 85 dBA, except in the sections 112 (8-hr TWA = 85.2 dBA; noise dose =103.3%) and 119 (8-hr TWA =85.4 dBA; noise dose =106.2 %) (Table 6).

Figure 10 shows a sample noise profile for Section 119. Some examples of the spikes for this data are at 6:36pm when there was a penalty, 7:18 pm when there was a goal scored, 7:20pm when there is penalty, 7:38 when there was penalty, 8:15pm when a big play happened and penalty, 8:40 when the start of overtime play began.

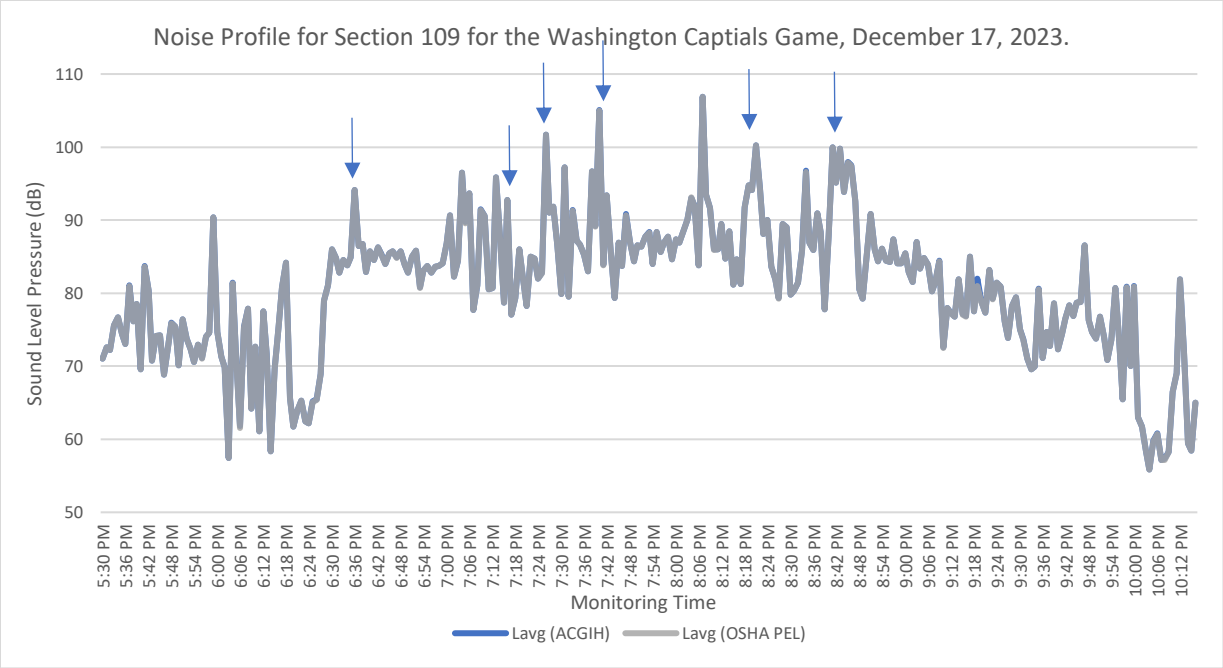

Figure 10. Time history of personal noise exposure of employee assigned at section 109, December 17, 2023. (Note: OSHA and ACGIH graphs lines overlap.)

The sound level meter in section 102 monitored noise for a duration of 3 hours and 25 minutes from 5:30 – 8:55 PM. The sound level meter for this game was from the start of warmups to the end of the game. Some of the spikes that were in this game were at 6:24pm when there was almost a goal, 7:18 when there was a goal, 8:15 when there was a penalty and a goal, and 8:46 when it was the start of the overtime shootout. Figure 11 shows the noise profile that demonstrates the time history of area noise level at Section 102 during this game.

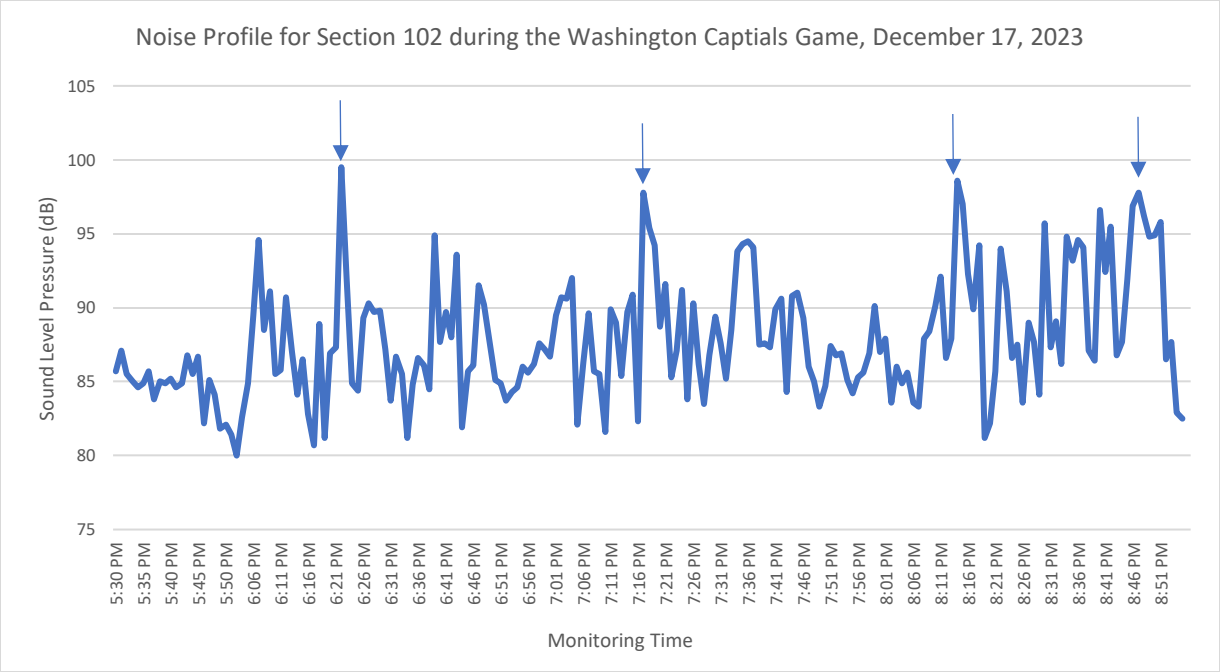

Figure 11. Time history of area noise level at Section 102, December 17, 2023.

Game #6: Versus New York Islanders

The New York Islanders are a rival team for the Carolina Hurricanes. This game was about the same as the Washington Capitals game. Table 7 shows the averages (L_{avg} and 8-hr TWA), dose and maximum (LASmax) noise levels by dosimeter channel measured during the Buffalo Sabers game at various locations in the arena.

Table 7. Averages (L_{avg}), 8-hr dose and time-weighted-Average (TWA) and maximum noise levels by dosimeter channel and location during the New York Islanders, December 23, 2023.

Section #	Duration (h:mm)	ACGIH				OSHA PEL				Maximum (LASmax) (dBA)
		L_{avg} (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>85 dBA	L_{avg} (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>90 dBA	
112	3:45	90.1	95.1	84.6	No	83.9	20.1	78.4	No	104.3
119	3:45	89.3	85.1	83.8	No	81.8	15	76.3	No	103.8
125	3:45	92.1	125.4	86.6	Yes	84	20.4	78.5	No	111.2
1st level average		90.5 ± 1.4	101.9 ± 21.0	85.0 ± 1.4	Yes	83.2 ± 1.2	18.5 ± 3.0	77.7 ± 1.2	No	106.4 ± 4.1
229	3:45	88.1	72.0	82.6	No	79.3	10.6	73.8	No	103.3

2nd level average		88.1	72.0	82.6	No	79.3	10.6	73.8	No	103.3
301	1:50	86.8	29.4	76.2	No	78.8	4.9	68.2	No	98.2
311	3:45	87.6	67.2	82.1	No	79.6	11.1	74.1	No	103.4
321	3:45	87.7	68.2	82.2	No	79.7	11.2	74.2	No	98.8
327	3:45	86	62.7	81.6	No	78.9	10.1	73.4	No	100.7
3rd level average		87.3 ± 0.3	56.9 ± 18.5	80.5 ± 2.9	No	79.3 ± 0.5	9.3 ± 3.0	72.5 ± 2.9	No	100.3
Office	3:45	86.1	54.6	80.6	No	77.4	8.2	71.9	No	98.9
Overall average		88.3 ± 1.9	73.3 ± 26.9	82.3 ± 2.9	No	80.4 ± 2.3	12.4 ± 5.2	74.3 ± 3.2	No	102.5 ± 4.0

The monitoring period was conducted for 3 hours and 45 minutes from 6:30 – 10:15 PM. The first level had the loudest average noise level (Lavg of 90.5 ±1.4 dBA for ACGIH and 83.2 ± 1.2 dBA for OSHA PEL) compared to the third level (Lavg of 87.3 ± 0.3 dBA for ACGIH and 79.3 ± 0.5 dBA for OSHA PEL) and second level (Lavg of 88.1 dBA for ACGIH and 79.3 dBA for OSHA PEL). The first level had the loudest sections at the north end (i.e., section 112 with Lavg of 90.1 dBA for ACGIH and 83.9 dBA for OSHA PEL), while the quiet section was 119 having the Lavg of 89.3 dBA for ACGIH and 81.8 dBA for OSHA PEL. Monitored sections at the third level were all about the same noise averages. Similar to other games, the maximum noise level tends to be during the players introduction, during goals or the announcement of goals and when fights break out, while the minimum noise levels for these sections were during either play or during warmups.

The 8-hr TWA noise levels for each monitored section in the arena, ranging from 68.2 – 78.4 dBA, did not exceed the OSHA PEL of 90 dBA, with noise doses ranging from 4.9 – 20.1%. Similarly, 8-hr TWA noise levels, ranging from 76.2 – 84.6 dBA (noise dose ranging from 29.4 – 95.1%), did not exceed the ACGIH TLV of 85 dBA, except in section 125 where the 8-hr TWA was 86.6 dBA and the noise dose was 125.4% (Table 7).

Figure 12 shows a sample noise profile for Section 321. Some spikes for section 321 at found at 7:45pm when there was penalty kill for the Hurricanes, 8:05 pm when the Hurricanes

scored a goal, 8:55pm when there was a penalty, and 9:53pm when the crowd was cheering "Let's go Canes!".

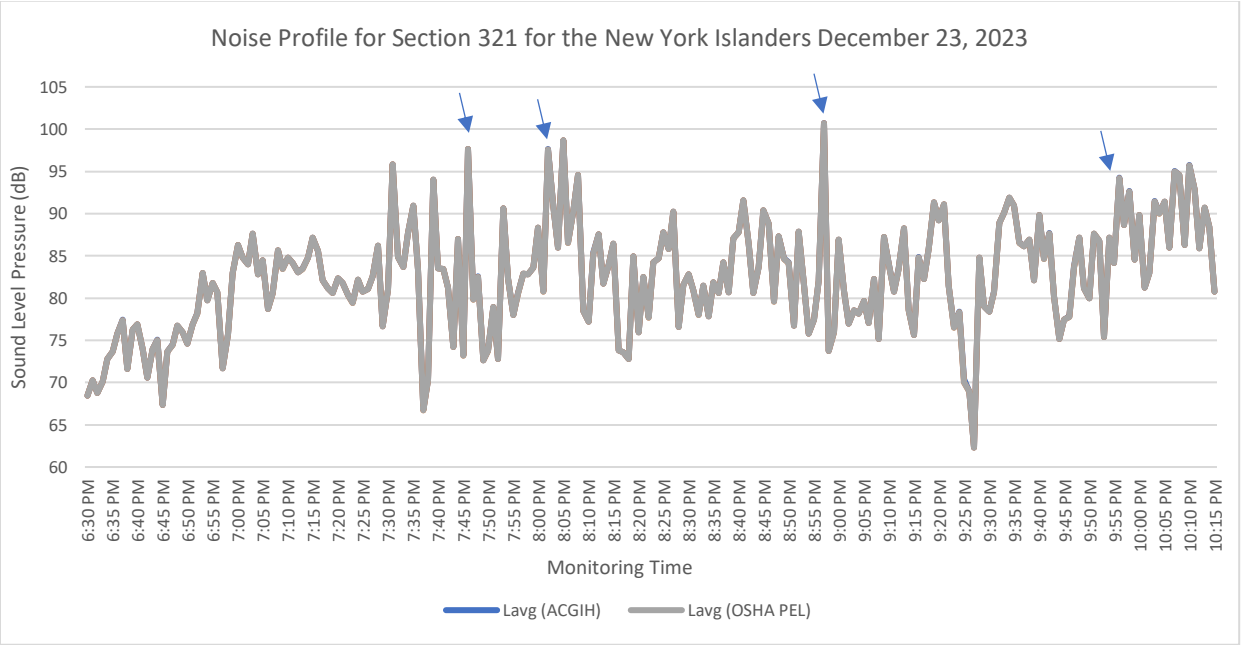

Figure 12. Time history of personal noise exposure of employee assigned at section 321, December 23, 2023. (Note: OSHA and ACGIH graphs lines overlap.)

The sound level meter in section 102 monitored noise for a duration of 3 hours and 15 minutes from 7:00 – 10:15 PM, which is from the start of warmups to the end of the game. Some of the spikes found in this game were at 8:05pm when the Hurricanes scored a goal, 8:42 when there a penalty, 8:43 when there was a goal, 8:36pm when there was a goal, and 10:01 when there was a "Let's go Canes" chant going. Figure 13 shows the noise profile that demonstrates the time history of area noise level at Section 102.

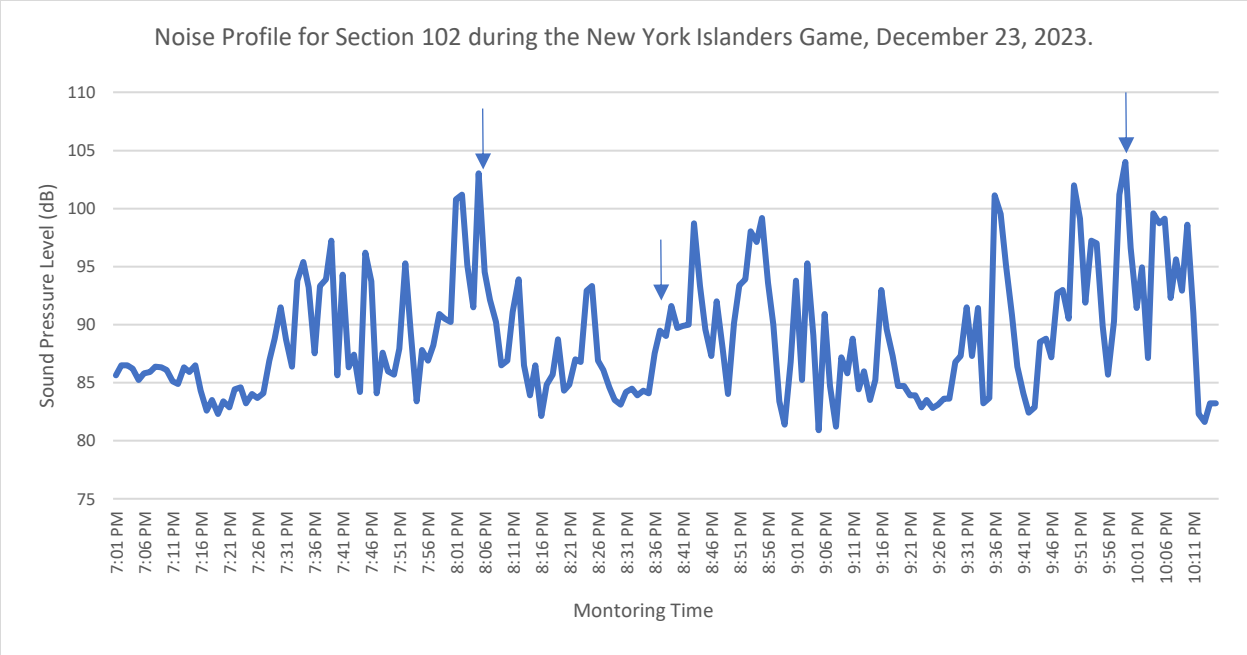

Figure 13. Time history of area noise level at section 102, December 23, 2023.

Game #7: Versus St. Louis Blues

The St. Louis Blues is not a rival for the Carolina Hurricanes. This game was about the same as the New York Islanders game. Table 8 shows the averages (L_{avg} and 8-hr TWA), dose and maximum (LASmax) noise levels by dosimeter channel measured during the St. Louis Blues game at various locations in the arena.

Table 8. Averages (L_{avg}), 8-hr dose and time-weighted-average (TWA) and maximum noise levels by dosimeter channel and location during the St. Louis Blues Game, January 6, 2024.

Section #	Duration (h:mm)	ACGIH				OSHA PEL				Maximum (LASmax) (dBA)
		L_{avg} (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>85 dBA	L_{avg} (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>90 dBA	
112	1:57	87.4	34.0	77.2	No	78.6	5.0	68.4	No	97.?
119	3:20	91.0	95.7	84.7	No	85.6	22.6	79.3	No	103.9
125	1:57	88.1	37.5	77.9	No	81.0	7.0	70.8	No	98.3
1st level average		88.8 ± 1.9	55.7 ± 34.7	79.9 ± 4.1	No	81.7 ± 3.6	11.5 ± 9.6	72.8 ± 5.7	No	99.8 ± 3.6

229	3:20	89.3	75.6	83.0	No	82.1	13.9	75.8	No	103.4
2nd level average		89.3	75.6	83.0	No	82.1	13.9	75.8	No	103.4
301	3:20	91.0	95.7	84.7	No	85.6	22.6	79.3	No	103.9
311	3:20	88.0	63.2	81.7	No	80.9	11.8	74.6	No	101.4
321	3:20	88.4	66.8	82.1	No	80.8	11.6	74.5	No	100.9
327	1:43	87.8	31.6	76.7	No	80.0	5.4	68.9	No	98.2
3rd level average		88.8 ± 1.5	64.3 ± 26.2	81.3 ± 3.3	No	81.8 ± 2.5	12.9 ± 7.1	74.3 ± 4.3	No	101.1 ± 2.0
Office	1:28	83.5	14.9	71.3	No	68.4	0.9	56.2	No	94.6
Overall average		88.3 ± 2.2	57.2 ± 29.2	79.9 ± 4.5	No	80.3 ± 5.1	11.2 ± 7.6	72.0 ± 7.1	No	100.2 ± 3.3

The monitoring period was conducted for 3 hours and 20 minutes from 7:30 – 10:50 PM. For this game, it seems to be about the same averages at each section, with the 2nd level being the highest (Lavg of 89.3 dBA for ACGIH and 82.1 dBA for OSHA PEL). The first level had the loudest sections (e.g., 119) with having the ACGIH Lavg of 91.0 dBA and the OSHA PEL Lavg of 85.6 dBA, with the middle section slightly more than the north or south ends. For the third level, all the middle sections were louder than the north or south ends. The maximum noises level tends to be during the players introduction, during goals or the announcement of goals and when fights break out, while the minimum levels for these sections were during either play or during warmups.

The 8-hr TWA noise levels for each monitored section in the arena, ranging from 56.2 – 79.3 dBA, did not exceed the OSHA PEL of 90 dBA, with noise doses ranging from 0.9 – 22.6%. Similarly, the 8-hr TWA noise levels, ranging from 71.3 – 84.7 dBA (noise dose ranging from 14.9– 95.7%), also did not exceed the ACGIH TLV of 85 dBA (Table 4).

Figure 14 shows a sample noise profile for Section 311. Some spikes for section 311 would be at 7:30pm when warmups start, 8:03pm when players hit the ice and puck drop, 8:24pm when the "Let's Go Canes" chant is prompted, 9:25pm during penalty kill for the Hurricanes, 10:32pm during the start of overtime, and 10:46pm during the end of game when Blues scored.

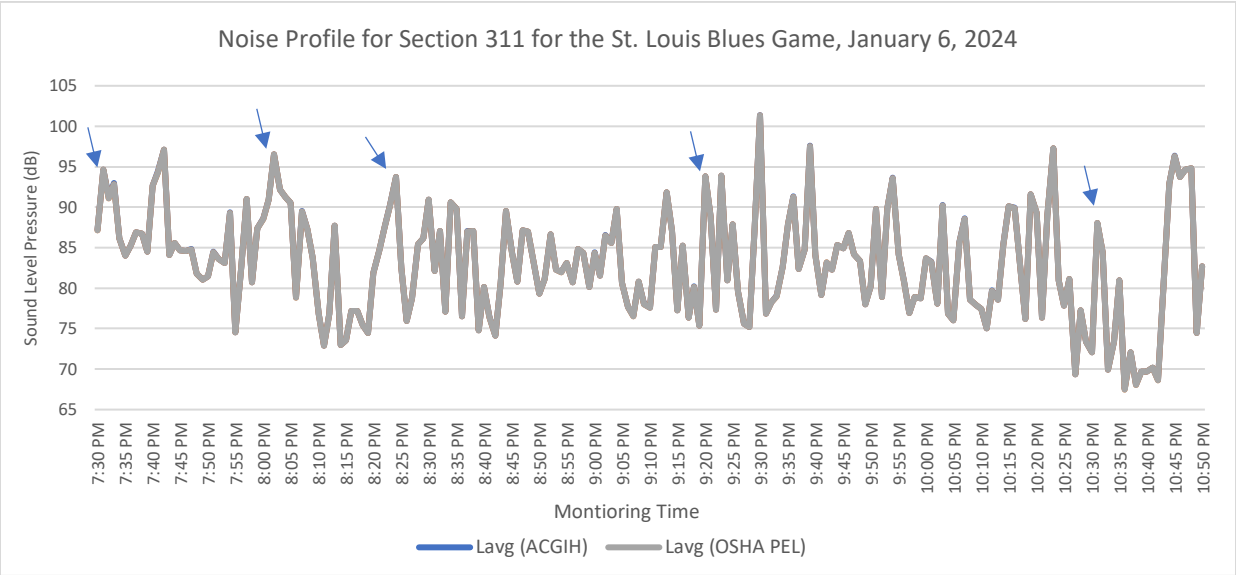

Figure 14. Time history of personal noise exposure of employee assigned at Section 321, January 6, 2024. (Note: OSHA and ACGIH graphs lines overlap.)

The sound level meter in Section 102 monitored noise for a duration of 2 hours and 50 minutes from 8:00pm – 10:50pm, which was from the start of the game to the end of the game. Some of the spikes found in this game were at 8:32pm when there was a goal, 8:37pm when there was announcement for who was going to the NHL all-star game, 9:25pm when there was a penalty kill for the Hurricanes, 10:19pm when Stormy the Mascot was pumping up the crowd, 10:32pm at the start of overtime, 10:46pm when the Blues scored to end the game. Figure 15 shows the noise profile that demonstrates the time history of area noise level at Section 102.

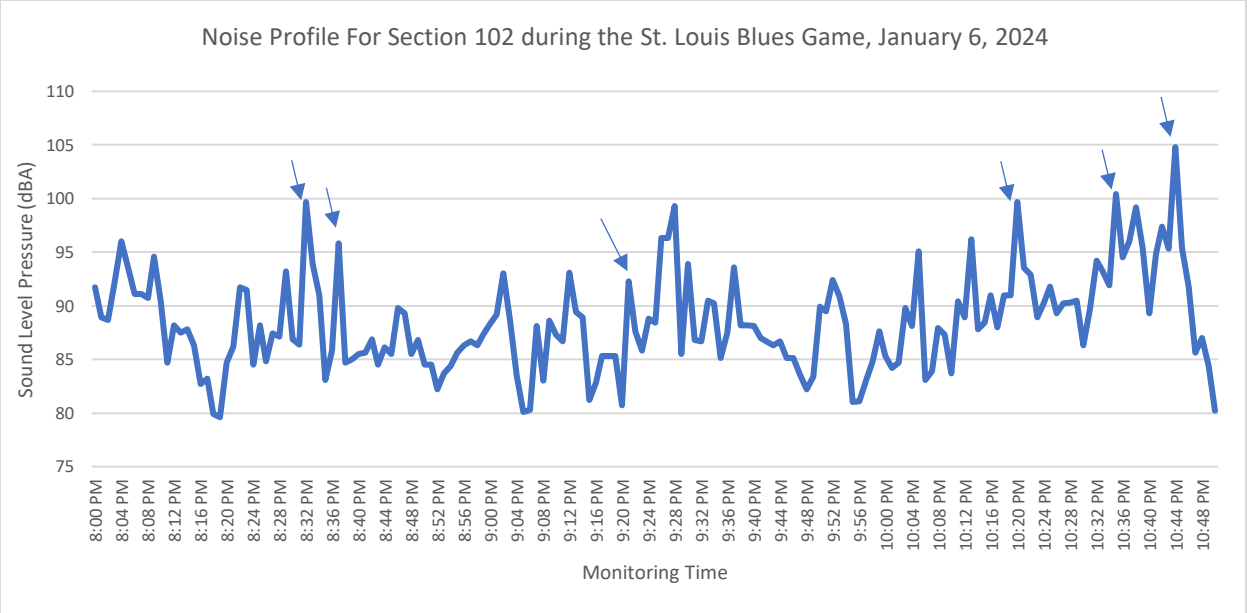

Figure 15. Time history of area noise level at section 102, January 6, 2024.

Game #8: Versus Pittsburgh Penguins

The Pittsburgh Penguins are a rival for the Carolina Hurricanes. This game was louder than the St. Louis Blues game. Table 9 shows the averages (L_{avg} and 8-hr TWA), dose and maximum (LASmax) noise levels by dosimeter channel measured during the Pittsburgh Penguins game at various locations in the arena.

Table 9. Averages (L_{avg}), 8-hr dose and time-weighted-average (TWA) and maximum noise levels by dosimeter channel and location during the Pittsburgh Penguins, January 13, 2024.

Section #	Duration (h:mm)	ACGIH				OSHA PEL				Maximum (LASmax) (dBA)
		L_{avg} (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>85 dBA	L_{avg} (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>90 dBA	
112*	-	-	-	-	-	-	-	-	-	-
119	3:20	91.8	107	85.5	Yes	85.9	23.6	79.6	No	105.8
125	3:20	87.7	60.6	81.4	No	79.9	10.3	73.6	No	100.1
1st level average		89.8 ± 2.9	83.8 ± 32.8	83.5 ± 2.9	No	82.9 ± 4.2	17.0 ± 9.4	76.6 ± 4.2	No	103.0 ± 2.9
229	3:20	92.6	119.5	86.3	Yes	84.9	20.5	78.6	No	111.9
2nd level average		92.6	119.5	86.3	Yes	84.9	20.5	78.6	No	111.9
301	3;20	93.2	129.9	86.9	Yes	88.2	32.5	81.9	No	108.7
311	3;20	88.7	69.6	82.4	No	81.4	12.6	75.1	No	100.9
321	3:20	90.7	91.8	84.4	No	84.2	18.6	77.9	No	100.9
327	3;20	88.5	67.7	82.2	No	80.5	11.2	74.2	No	103.3
3rd level average		90.3 ± 2.2	89.8 ± 28.9	84.0 ± 2.2	No	83.6 ± 3.5	18.7 ± 9.7	77.3 ± 3.5	No	105.2 ± 3.7
Office*	-	-	-	-	-	-	-	-	-	-
Overall average		90.5 ± 2.2	92.3 ± 27.4	84.2 ± 2.2	No	83.6 ± 3.1	18.5 ± 8.0	77.3 ± 3.1	No	105.5 ± 4.3

* Did not monitor

The monitoring period was conducted for 3 hours and 20 minutes from 6:30 – 9:50 PM. For this game, the 3rd level is the loudest, with the ACGIH Lavg of 90.3 ± 2.2 dBA and the OSHA PEL Lavg of 83.6 ± 3.5 dBA. The 2nd level had a louder average noise level (ACGIH Lavg of 92.6 dBA and OSHA Lavg of 84.9 dBA) than the 1st level (ACGIH Lavg of 89.8 ± 2.2 dBA and OSHA PEL Lavg of 82.9 ± 4.2 dBA). The first level had the loudest sections, with the middle section slightly noisier than the north end. For the third level, Section 301 with the north end was louder (ACGIH Lavg of 93.2 dBA and OSHA PEL Lavg of 88.2 dBA) than all the other sections. The maximum noise level tends to be during the players introduction, during goals or the announcement of goals and when fights break out, while the minimum level for these sections was during either play or during warmups.

The 8-hr TWA noise levels for each monitored section in the arena, ranging from 73.6 – 81.9 dBA, did not exceed the OSHA PEL of 90 dBA, with noise doses ranging from 10.3 – 32.5%. Similarly, the 8-hr TWA noise levels, ranging from 82.2 – 84.4 dBA (noise dose ranging from 67.7 – 91.8%), did not exceed the ACGIH TLV of 85 dBA, except in the sections 301, 229, 119, wherein the 8-hr TWA ranged from 85.9 - 86.6 dBA and the noise dose ranging from 107.0 - 129.9% (Table 9).

Figure 16 shows a sample noise profile for Section 119. Some spikes for section 119 would be at 7:17pm when there was a goal, 9:30pm when the scoreboard was prompting the crowd to cheer, 9:36pm when the Penguins scored the tying goal, and 9:42pm when the Hurricanes score the winning goal in overtime.

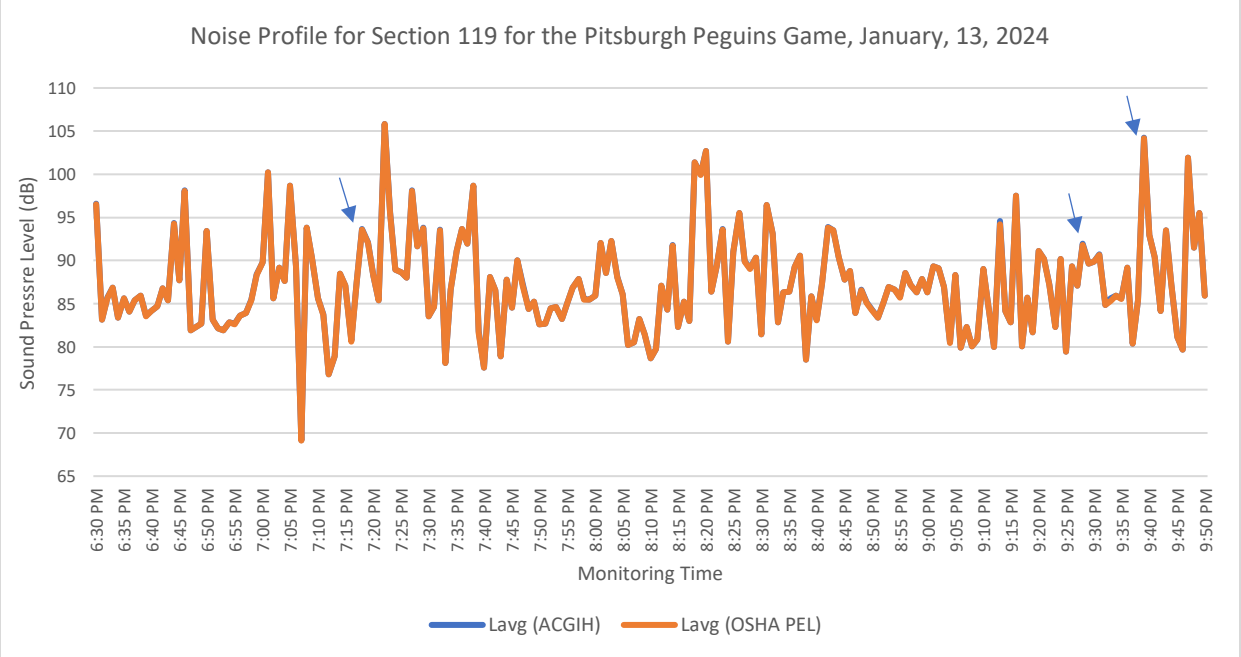

Figure 16. Time history of personal noise exposure of employee assigned at section 119, January 13, 2024. (Note: OSHA and ACGIH graphs lines overlap.)

The sound level meter in Section 102 monitored noise for a duration of 3 hours and 20 minutes from 6:30 – 9:50 PM, which was from the start of warmups to the end of the game. Some of the spikes found in this game were at 7:05pm when the line up for the game is being announcement, 7:20pm when there were big hits, 8:00pm when the Hurricanes came on the ice for the second period, 9:36pm when the Pittsburgh Penguins scored the tying goal, 9:42pm when the Hurricanes won the game in overtime. Figure 17 shows the noise profile that demonstrates the time history of area noise level at Section 102.

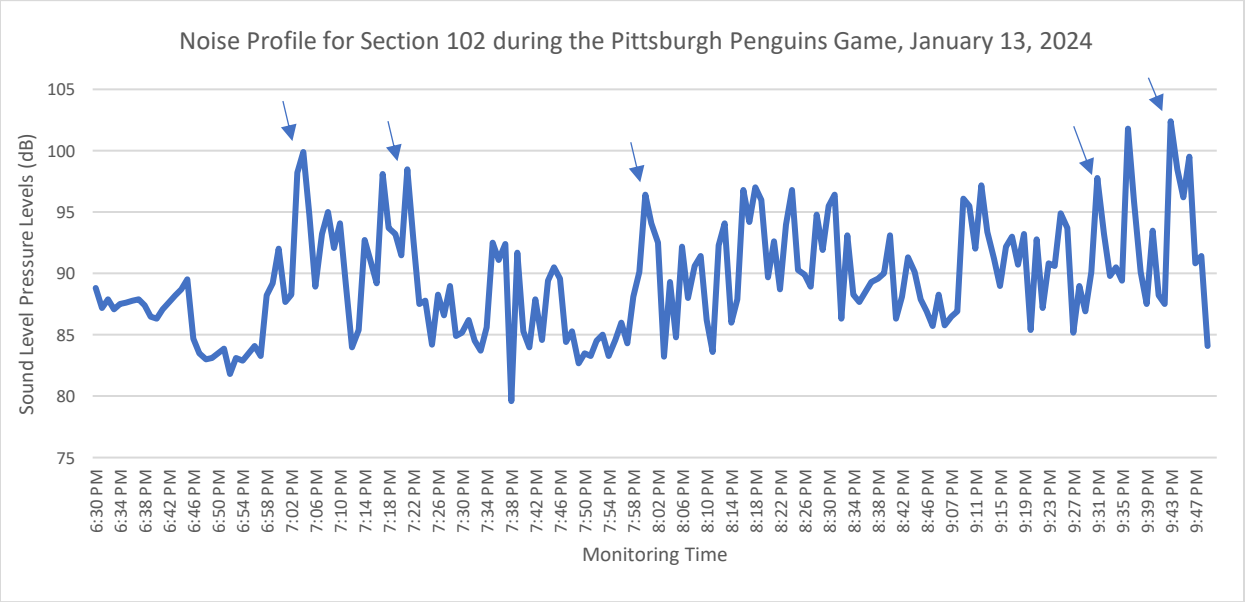

Figure 17. Time history of area noise level at Section 102, January 13, 2024.

Game #9: Detroit Red Wings

The Detroit Red Wings are a non-rival for the Carolina Hurricanes. This game was about the same as the Pittsburgh Penguins game. Table 10 shows the averages (L_{avg} and 8-hr TWA), dose and maximum (LASmax) noise levels by dosimeter channel measured during the Minnesota Wild game at various locations in the arena.

Table 10. Averages (L_{avg}), 8-hr Dose and Time-Weighted-Average (TWA) and Maximum Noise Levels by Dosimeter Channel and Location during the Detroit Red Wings Game, January 19, 2024.

Section #	Duration (h:mm)	ACGIH				OSHA PEL				Maximum (LASmax) (dBA)
		L_{avg} (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>85 dBA	L_{avg} (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>90 dBA	
112	3:15	91.1	94.6	84.6	No	85.5	21.8	79	No	103.2
119	3:15	90.4	85.9	83.9	No	84.5	19	78	No	104.9
125	3:15	90.2	83.5	83.7	No	83.5	16.5	77	No	105.8
1st level average		90.6 ± 0.5	88.0 ± 5.8	84.1 ± 0.5	No	84.5 ± 1.0	19.1 ± 2.7	78.0 ± 1.0	No	104.6 ± 1.3
229	3:15	88.3	64.2	81.8	No	81.2	12.0	74.7	No	99.2
2nd level average		88.3	64.2	81.8	No	81.2	12.0	74.7	No	99.2
301	3:15	90.3	84.7	83.8	No	83.8	17.2	77.3	No	103.8
311	3:15	90	81.3	83.5	No	84	17.7	77.5	No	101
321	3:15	90.3	84.7	83.8	No	84.6	19.2	78.1	No	101.3
327	3:15	94.4	149.5	87.9	Yes	86.7	25.7	80.2	No	114.6
3rd level average		91.3 ± 2.1	100.1 ± 33.0	84.8 ± 2.1	Yes	84.8 ± 1.3	20.0 ± 3.9	78.3 ± 1.3	No	105.3 ± 6.4
Office	3:15	86	46.7	79.5	No	76.5	6.3	70	No	98
Overall average		90.1 ± 2.2	86.1 ± 27.7	83.6 ± 2.2	No	83.4 ± 3.0	17.3 ± 5.6	76.9 ± 3.0	No	103.5 ± 4.9

The monitoring period was conducted for 3 hours and 15 minutes from 6:30 – 9:45 PM. For this game, the 3rd level had the loudest noise (i.e., section 327 with the ACGIH Lavg of94.4 dBAs and the OSHA PEL Lavg of 86.7 dBA) with the 1st level being louder (ACGIH Lavg of 90.6 ± 0.5 dBA and OSHA PEL Lavg of 84.5 ± 1.0 dBA) than the 2nd level (ACGIH Lavg of 88.3 dBA and OSHA PEL Lavg of 81.2 dBA). The first level had the loudest sections, with the north end slightly more than the south end and the middle end. For the third level, Section 327 with the middle north end was louder than all the other sections. The maximum noise levels (ranging from 98.0 - 105.8 dBA) were measured during the players introduction, during goals or the announcement of goals and when fights break out, while the minimum noise levels were measured during either play or during warmups.

The 8-hr TWA noise levels for each monitored section in the arena, ranging from 70.0 – 80.2 dBA, did not exceed the OSHA PEL of 90 dBA, with noise doses ranging from 6.3 – 25.7%. Similarly, the 8-hr TWA noise levels, ranging from 79.5 – 84.6 dBA (noise dose ranging from 46.7 – 94.6%), did not exceed the ACGIH TLV of 85 dBA, except in section 327 wherein the 8-hr TWA was 87.9 dBA and the noise dose was 149.5% (Table 10).

Figure 18 shows a sample noise profile for Section 327. Some spikes for section 327 were found at 7:07pm during puck drop, 7:13pm during a goal by Hurricanes, 8:35pm during a goal by Detroit, 8:54pm during a siren for the beginning of the 3rd period, and 9:16pm during a goal by the Hurricanes.

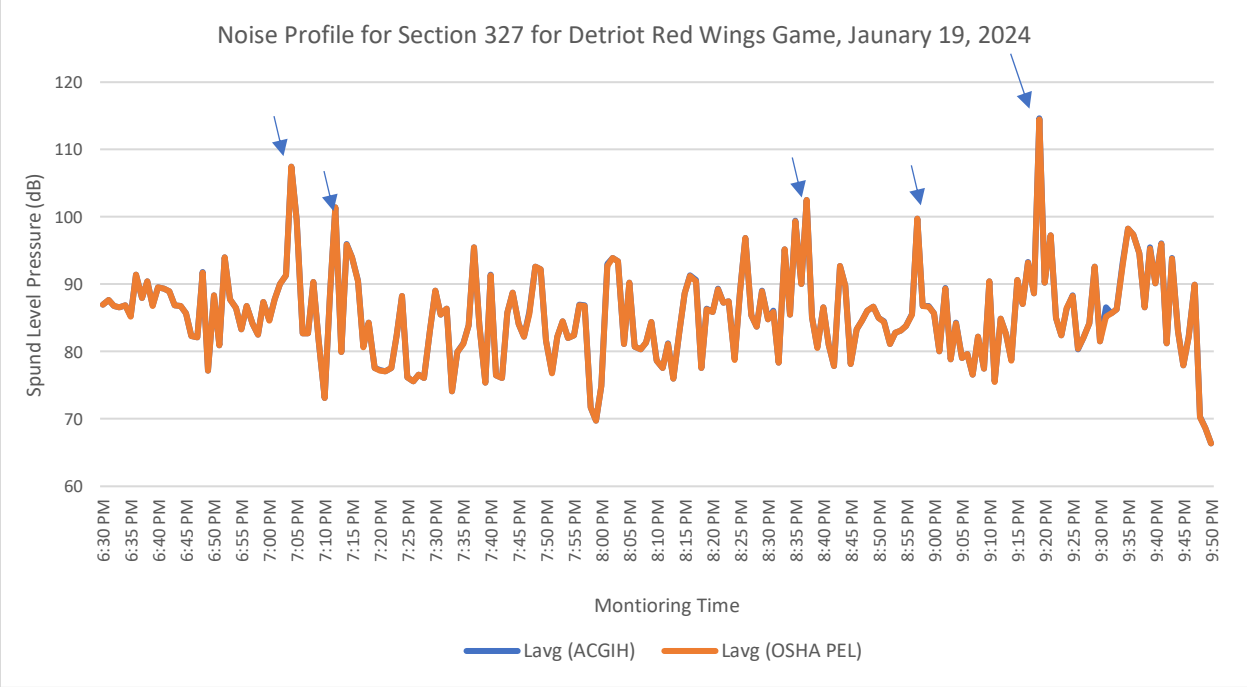

Figure 18. Time history of personal noise exposure of employee assigned at section 327, January 19, 2024. (Note: OSHA and ACGIH graphs lines overlap.)

The sound level meter in Section 102 monitored noise for a duration of 2 hours and 45 minutes from 7:00pm – 9:45pm, which was from the start to the end of the game. Some of the

spikes in this game for this section are: 7:12pm during a Detroit goal, 7:24pm during a horn for the “Let’s Go Canes” chant, 8:02pm during a series of good plays, 8:30pm during a Hurricanes goal, 9:16pm during a Hurricanes goal, 9:35 at end of game, storm surge. Figure 19 shows the noise profile that demonstrates the time history of area noise level at Section 102.

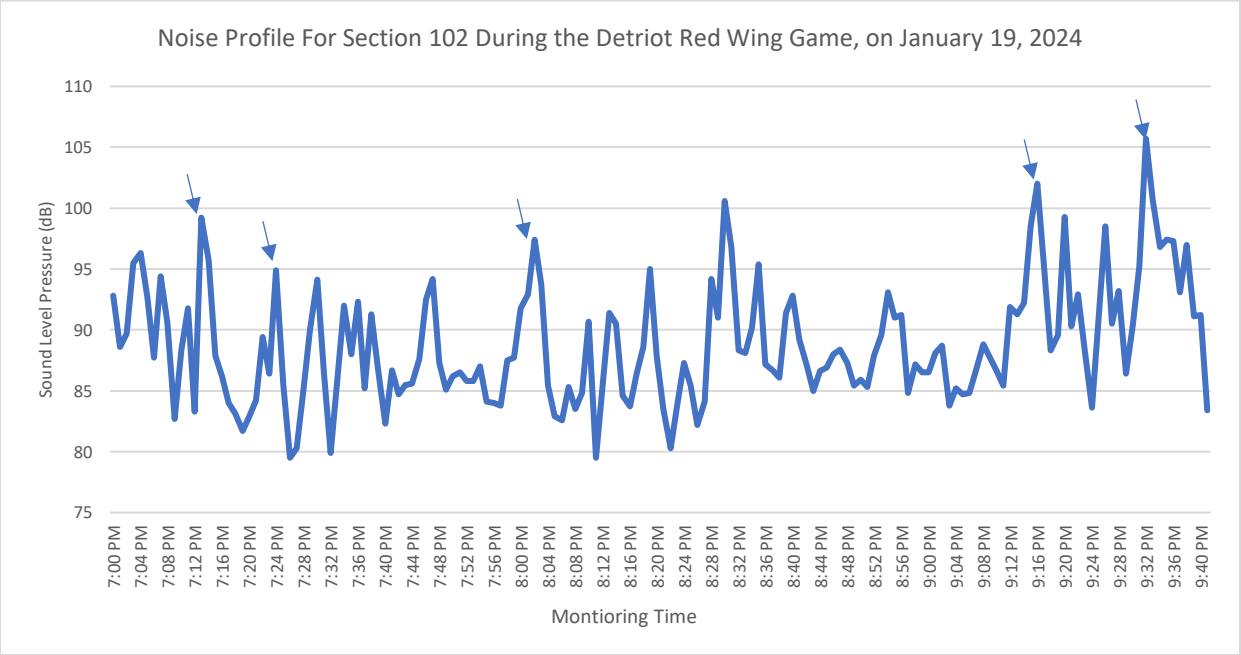

Figure 19. Time history of area noise level at section 102, January 19, 2024.

Game #10: Minnesota Wild

The Minnesota Wild is a non-rival for the Carolina Hurricanes. This game was one of the least noisy games monitored in this study. Table 11 shows the averages (L_{avg} and 8-hr TWA), dose and maximum (LASmax) noise levels by dosimeter channel measured during the Minnesota Wild game at various locations in the arena.

Table 11. Averages (L_{avg}), 8-hr dose and time-weighted-average (TWA) and maximum noise levels by dosimeter channel and location during the Minnesota Wild Game, January 21, 2024.

		ACGIH	OSHA PEL	

Section #	Duration (h:mm)	L_{avg} (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>85 dBA	L_{avg} (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>90 dBA	Maximum (LASmax) (dBA)
112	3:15	89.1	71.7	82.6	No	81.6	12.7	75.1	No	103.2
119	3:15	85.6	44.1	79.1	No	73.4	4.1	66.9	No	99.3
125	3:15	88	61.6	81.5	No	80	10.2	73.5	No	99.4
1st level average		87.6 ± 1.8	59.1 ± 14	81.1 ± 1.8	No	78.3 ± 4.3	9.0 ± 4.4	71.8 ± 4.3	No	100.13 ± 1.86
229	3:15	85	40.6	78.5	No	71.9	3.3	65.4	No	97.8
2nd level average		85	40.6	78.5	No	71.9	3.3	65.4	No	97.8
301	3:15	89.2	72.7	82.7	No	81.5	12.5	75	No	102.3
311	3:15	89.2	72.7	82.7	No	82.6	14.6	76.1	No	100.8
321	3:15	86.9	52.9	80.4	No	77.2	6.9	70.7	No	98.8
327	3:15	86.3	48.6	79.8	No	77.9	7.6	71.4	No	97.6
3rd level average		87.9 ± 1.5	61.7 ± 12.8	81.4 ± 1.5	No	79.8 ± 2.7	10.4 ± 3.7	73.3 ± 2.7	No	99.8 ± 2.0
Office	3:15	88	61.6	81.5	No	80.9	11.5	74.4	No	101.4
Overall average		87.5 ± 1.6	58.5 ± 12.5	81.0 ± 1.6	No	78.6 ± 3.8	9.3 ± 4.0	72.1 ± 3.8	Yes	100.0 ± 1.9

The monitoring period was conducted for 3 hours and 15 minutes from 4:30 – 7:45 PM. For this game, 3rd level is the loudest section 301 with the ACGIH Lavg of 89.2 decibels and the OSHA PEL Lavg was 81.5 decibels, with the 1st level being louder with section 112 with the ACGIH Lavg of 89.1 decibels and the OSHA PEL Lavg 81.6 decibels than the 2nd level with the ACGIH Lavg of 85 decibels and 71.9 decibels. The first level had the loudest sections, with the north end slightly more than the south end and the middle end. For the third level, Sections 301 and 311 were louder than other sections.

The 8-hr TWA noise levels for each monitored section in the arena, ranging from 65.4 – 76.1 dBA, did not exceed the OSHA PEL of 90 dBA, with noise doses ranging from 3.3 – 14.6%. Similarly, the 8-hr TWA noise levels, ranging from 78.5 – 82.7 dBA (noise dose ranging from 40.6 72.7– %), did not exceed the ACGIH TLV of 85 dBA (Table 11).

Figure 20 shows a sample noise profile for Section 112. Some spikes for section 112 were found at 5:04pm during a siren sounding to lead players on to the ice, 5:32pm during a goal

for Hurricanes, 6:35pm during a huge goalie save, 7:16 during a goal for the Hurricanes, and 7:23 during score board pumping up the crowd.

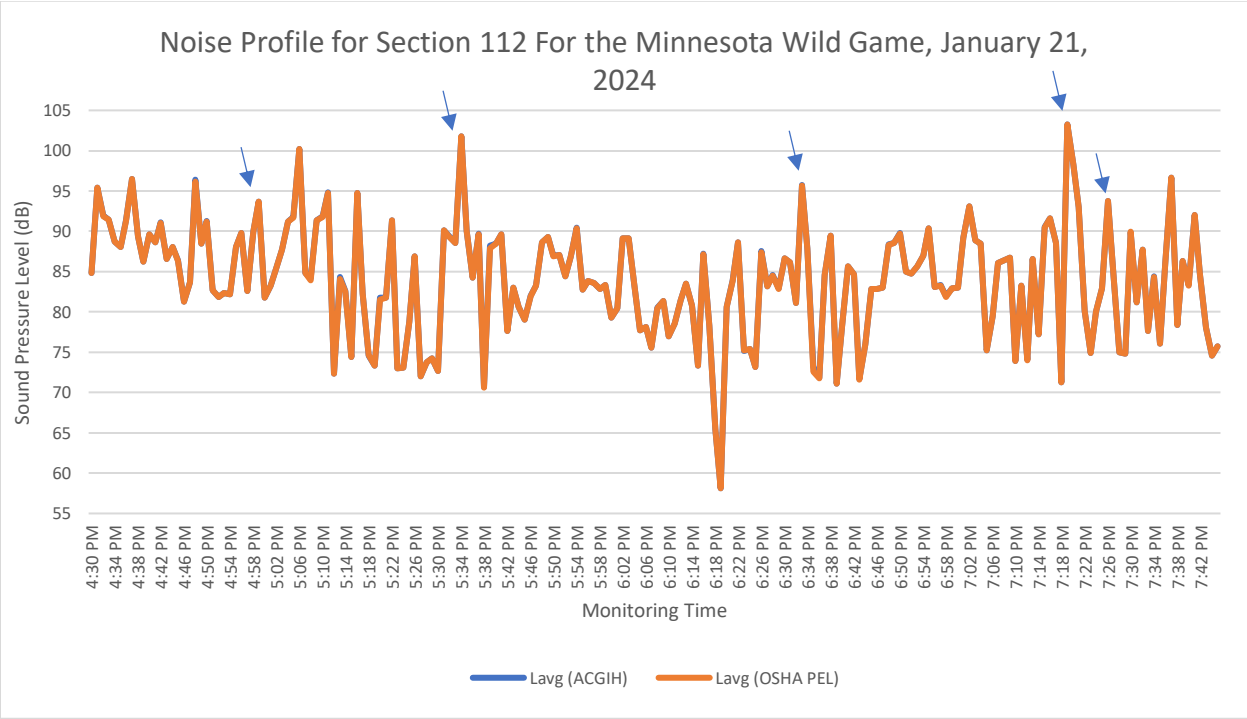

Figure 20. Time history of personal noise exposure of employee assigned at section 112, January 21, 2024. (Note: OSHA and ACGIH graphs lines overlap.)

The sound level meter in section 102 monitored noise for 3 hours and 15 minutes from 4:30 – 7:45 PM, from the start of warmups to the end of the game. Some of the spikes in this game for this section are: 5:04pm during a siren sounding for the players entering the ice, 5:29pm during a good series of plays, 5:32pm during a goal for the Hurricanes, and 7:17pm during the "Let's go Canes" chant. Figure 21 shows the noise profile that demonstrates the time history of area noise level at Section 102.

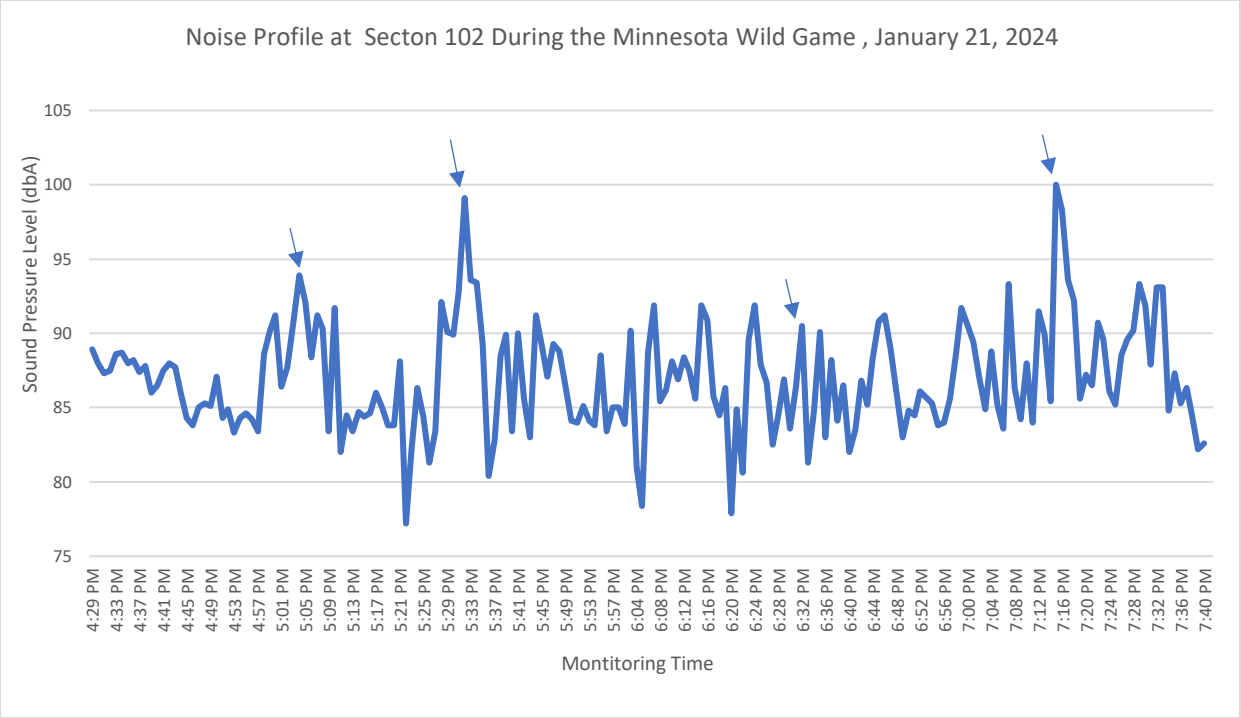

Figure 21. time history of area noise level at section 102, January 21, 2024.

Game #11: New Jersey Devils

The New Jersey Devils are a rival for the Carolina Hurricanes. This game was one of the loudest games of the rivals' games. Table 12 shows the averages (L_{avg} and 8-hr TWA), dose and maximum (LASmax) noise levels by dosimeter channel measured during the New Jersey Devils game at various locations in the arena.

Table 12. Averages (L_{avg}), 8-hr dose and time-weighted-average (TWA) and maximum noise levels by dosimeter channel and location during the New Jersey Devils Game, January 25, 2024.

Section #	Duration (h:mm)	ACGIH				OSHA PEL				Maximum (LASmax) (dBA)
		L_{avg} (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>85 dBA	L_{avg} (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>90 dBA	
112	3:15	92.8	119.8	86.3	Yes	86.3	24.3	79.8	No	109.6
119	3:15	90.3	84.7	83.8	No	80.1	10.3	73.6	No	108.9
125	3:15	103.3	513.5	96.8	Yes	93.4	65.1	86.9	No	103.3
1st level average		95.5 ± 6.9	239.3 ± 238.1	89.0 ± 6.9	Yes	86.6 ± 6.7	33.2 ± 28.5	80.1 ±?6.7	No	114.0 ± 8.3
229	3:15	89.9	80.1	83.4	No	80.9	11.5	74.4	No	108.9
2nd level average		89.9	80.1	83.4	No	80.9	11.5	74.4	No	108.9
301	3:15	88	61.6	81.5	No	80.5	10.9	74	No	100.3
311	3:15	88.9	80.1	83.4	No	79.9	10	73.4	No	104.1
321	3:15	91.2	96	84.7	No	83.9	17.4	77.4	No	109.6
327	3:15	88.7	67.9	82.2	No	81.0	11.7	74.5	No	101.9
3rd level average		89.2 ± 1.4	76.4 ± 15.2	83.0 ± 1.4	No	81.3 ± 1.8	12.5 ± 3.3	74.8 ± 1.8	No	104 ± 4.1
Office	3:15	86.9	52.9	80.4	No	76.1	5.9	69.6	No	100.5
Overall average		91.1 ± 4.9	128.5 ± 145.7	84.7 ± 4.8	No	82.5 ± 5.0	18.6 ± 18.2	76.0 ± 5.0	No	107.9 ± 6.9

The monitoring period was conducted for 3 hours and 15 minutes from 6:30 – 9:45 PM. For this game, the 3rd level is the quietest section (i.e., section 327 with an ACGIH Lavg of 88.7 dBA and an OSHA PEL Lavg of 81.0 dBA), with the 1st level being loudest (i.e., section 125 with an ACGIH Lavg of 103.3 dBA and an OSHA PEL Lavg of 93.4 dBA) and 2nd level had an ACGIH Lavg of 89.9 dBA and an OSHA PEL Lavg of 80.9 dBA. The first level had the loudest sections, with the north end slightly more than the south end and the middle end. For the third level, section 321 was louder (ACGIH Lavg of 91.2 dBA and OSHA PEL Lavg of 83.9 dBA) than the other sections.

The 8-hr TWA noise levels for each monitored section in the arena, ranging from 69.6 – 79.8 dBA, did not exceed the OSHA PEL of 90 dBA, which noise doses ranging from 5.9 –

24.3%. Similarly, the 8-hr TWA noise levels, ranging from 80.4 – 84.7 dBA (noise dose ranging from 52.9 – 96.0%), did not exceed the ACGIH TLV of 85 dBA, except in sections 112 and 125, wherein the 8-hr TWAs were 86.3 and 96.8 dBA and the noise doses were 119.8% and 513.5%, respectively (Table 12).

Figure 22 shows a sample noise profile for Section 112. Some spikes for section 112 would be at 7:00pm when warmups begin, 7:33pm during a siren for the players to come on to the ice, 7:38pm during the "Let's Go Canes" chant, 8:37pm during a Hurricanes goal, 9:00pm during a goalie save, 9:32 when players returned to the ice for the third period, and 9:58pm during Sweet Caroline.

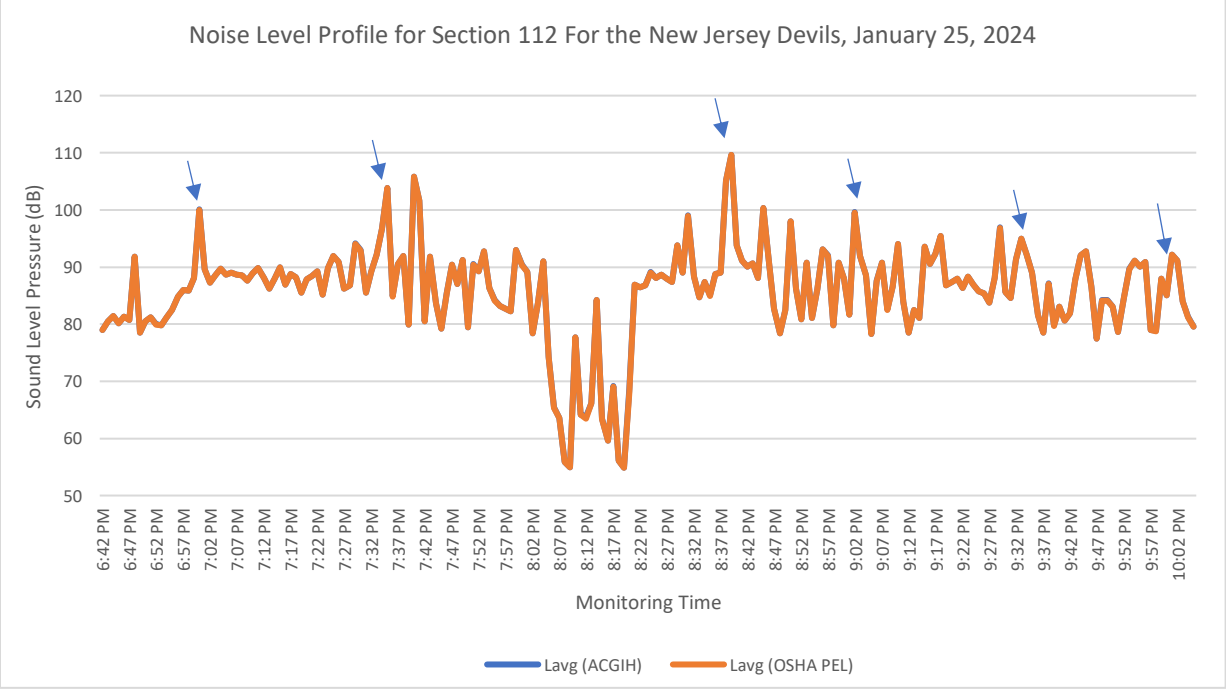

Figure 22. Time history of personal noise exposure of employee assigned at section 112, January 25, 2024. (Note: OSHA and ACGIH graphs lines overlap.)

The sound level meter in Section 102 monitored noise for 3 hours and 15 minutes from 6:30 – 9:45 PM, from the start of warmups to the end of the game. Some of the spikes in this

game for this section are: 7:33pm during a siren to lead the Hurricanes on to the ice for the start of the game, 7:40 during a goal, 8:36pm during a penalty, and 10:07pm at the end of game. Figure 23 shows the noise profile that demonstrates the time history of area noise level at Section 102.

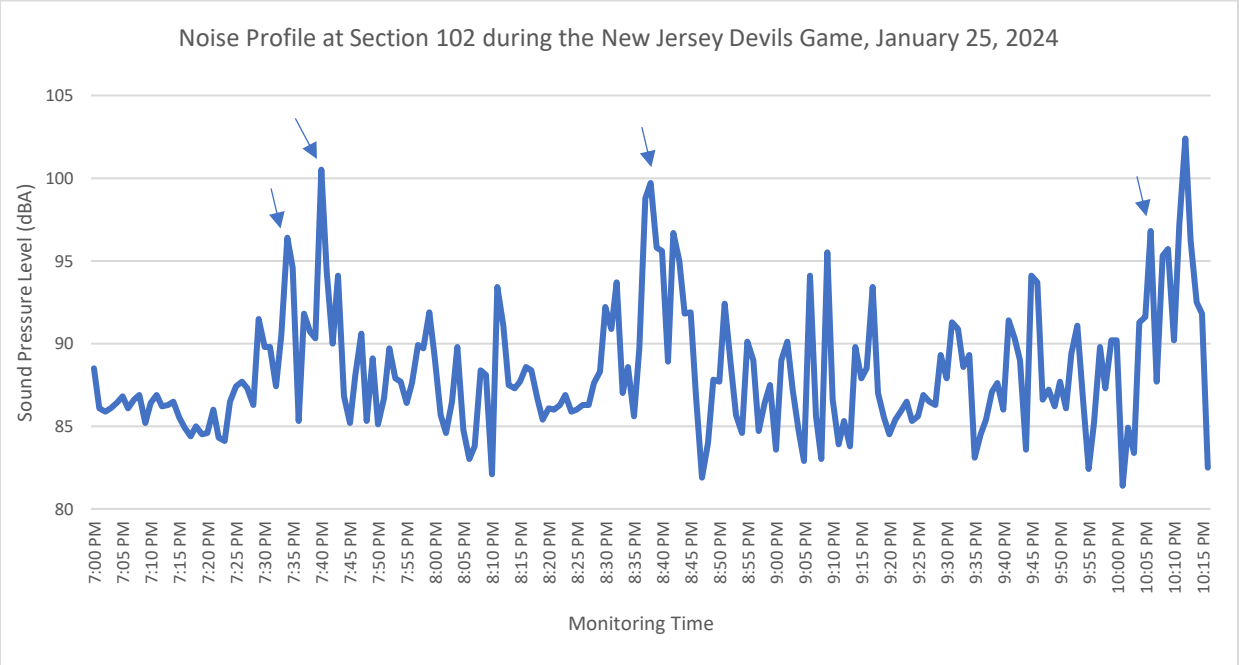

Figure 23. Time history of area noise level at section 102, January 25, 2024.

Game #12: Arizona Coyotes

The Arizona Coyotes are not a rival team for Carolina Hurricanes. Table 13 shows the averages (L_{avg} and 8-hr TWA), dose and maximum (LASmax) noise levels by dosimeter channel measured during the New Jersey Devils game at various locations in the arena.

Table 13. Averages (L_{avg}), 8-hr dose and time-weighted-average (TWA) and maximum noise levels by dosimeter channel and location during the Arizona Coyotes, January 27, 2024

		ACGIH	OSHA PEL	

Section #	Duration (h:mm)	L_{avg} (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>85 dBA	L_{avg} (dBA)	8-hr dose (%)	8-hr TWA (dBA)	>90 dBA	Maximum (LASmax) (dBA)
112	3:15	91.1	94.6	84.6	No	85.4	21.5	78.9	No	103.9
119	3:15	89.5	75.8	83.0	No	82.6	14.6	76.1	No	100.3
125	3:15	89.3	73.7	82.8	No	83.5	16.5	77	No	99.9
1st level average		90.0 ± 1.0	81.4 ± 11.5	83.5 ± 1.0	No	83.8 ± 1.4	17.5 ± 3.6	77.3 ± 1.4	No	101.4 ± 2.2
229	3:15	107.0	857.7	100.5	Yes	96.8	104.3	90.3	Yes	128.9
2nd level average		107.0	857.7	100.5	Yes	96.8	104.3	90.3	Yes	104
301	3:15	89.6	76.9	83.1	No	82.3	14	75.8	No	104
311	3:15	89.5	75.8	83.0	No	82.7	14.8	76.2	No	101.8
321	3:15	90.7	89.5	84.2	No	84.4	18.7	77.9	No	105.2
327	3:15	91.0	93.3	84.5	No	85.5	21.8	79	No	103.6
3rd level average		90.2 ± 0.8	83.9 ± 8.8	83.7 ± 0.8	No	83..7 ± 1.5	17.3 ± 3.6	77.2 ± 1.5	No	100.6 ± 7.4
Office	3:15	86.9	52.9	80.4	No	77.5	7.2	71	No	100.5
Overall average		91.6 ± 5.9	165.6 ± 259.9	85.1 ± 5.9	Yes	84.5 ± 5.2	25.9 ± 29.7	78.0 ± 5.2	No	104..0 ± 10.5

The monitoring period was conducted for 3 hours and 15 minutes from 6:30 – 9:45 PM. For this game, the 1st level was the quietest (i.e., section 125 with the ACGIH Lavg of 89.3 dBA and the OSHA PEL of 83.5 dBA), with the 3rd level having the 2nd loudest section (i.e., section 327 with the ACGIH Lavg of 91.0 dBA and the OSHA Lavg of 85.5 dBA. The second level had the loudest section, specifically section 229 wherein the ACGIH Lavg was 107.0 dBA, and the OSHA PEL Lavg was 96.8 dBA. The maximum noise levels, ranging from 99.9 - 128.9 dBA, were measured during the players' introduction, during goals or the announcement of goals and when fights break out.

The 8-hr TWA noise levels for each monitored section in the arena, ranging from 71.0 – 78.9 dBA, did not exceed the OSHA PEL of 90 dBA, with noise doses ranging from 7.2 – 21.5%. However, Section 229 exceeded the OSHA PEL of 90 dBA, wherein the 8-hr TWA was 90.3 and the noise dose was 104.3%. The 8-hr TWA noise levels, ranging from 80.4 – 84.6 dBA (noise dose ranging from 52.9 – 94.6%), did not exceed the ACGIH TLV of 85 dBA, except in

the section 229 wherein the 8-hr TWA was 100.5 dBA and the noise dose was 857.7% (Table 13).

Figure 24 shows a sample noise profile for Section 321. Some spikes for section 321 were found at 7:02pm when players come on to the ice, 7:41pm during almost goal, 8:16pm during a goal for the Hurricanes, 9:20pm during a series of great plays, 9:34pm during a goal, 9:36pm during another goal, and 9:42pm during player interview.

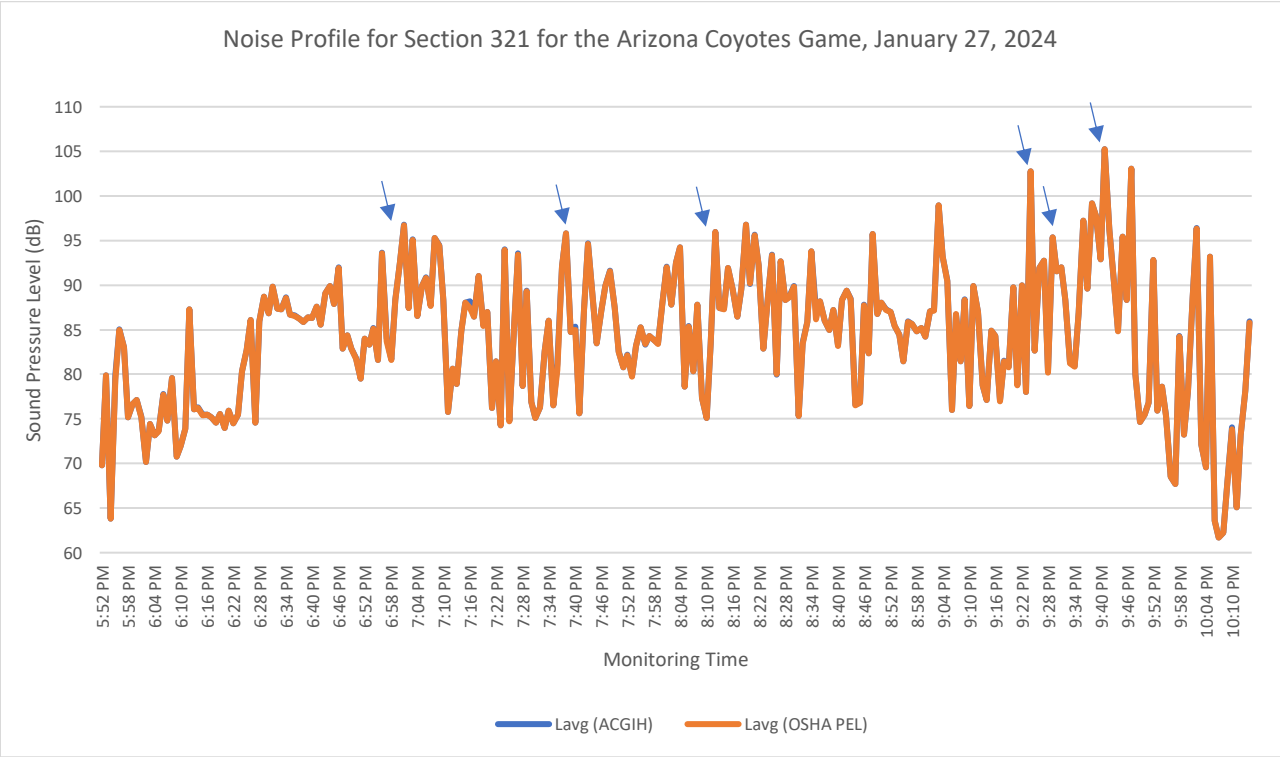

Figure 24. Time history of personal noise exposure of employee assigned at Section 321, January 27, 2024. (Note: OSHA and ACGIH graphs lines overlap.)

The sound level meter in section 102 monitored noise for a duration of 3 hours and 15 minutes from 6:30 – 9:45 PM. Some of the spikes in this game were found at 7:04pm during players introduction, 7:41pm during almost goal, 8:00pm during a siren sounding for the 2nd period start, 8:16pm during a goal for the Hurricanes, 9:24pm during a series of great plays, and

9:34pm during a game winning goal. Figure 25 shows the noise profile that demonstrates the time history of area noise level at Section 102.

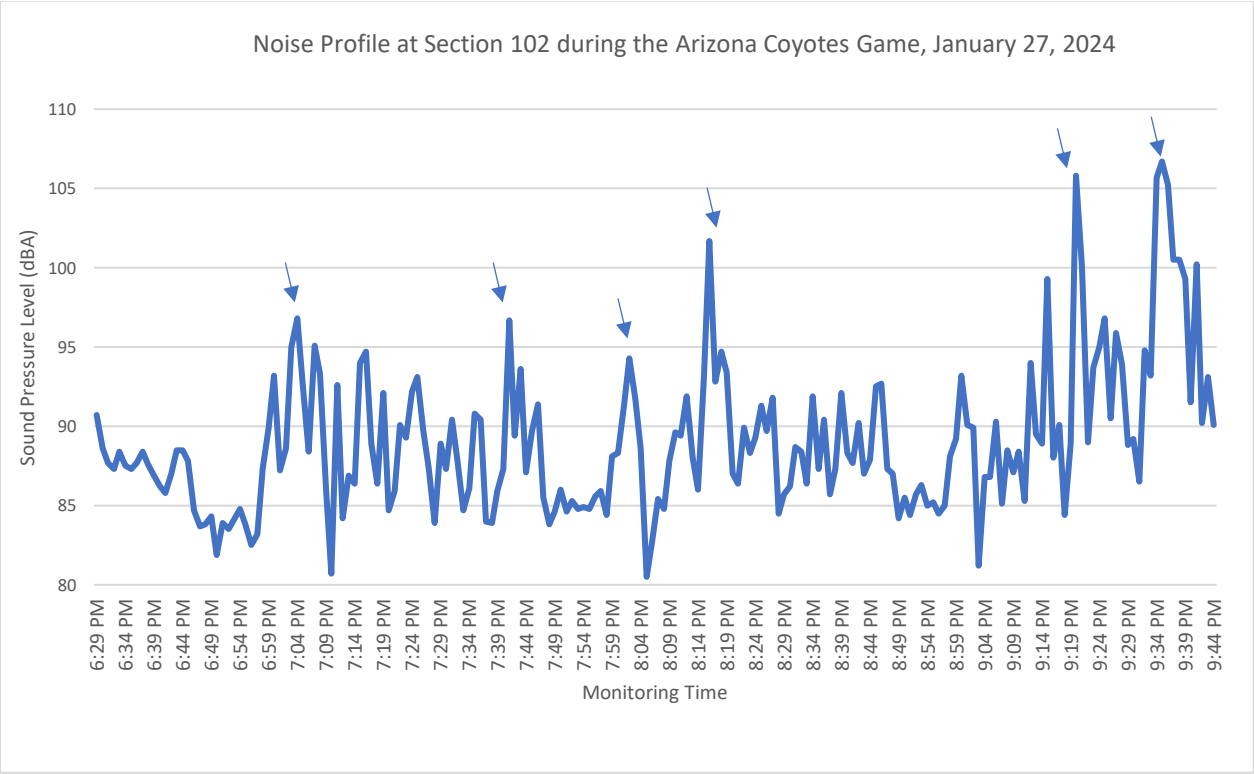

Figure 25. Time history of area noise level at Section 102, January 27, 2024.

Table 14 summarizes the average and maximum noise levels measured by the sound level meter at Section 102 for all monitored games. The game with the highest average was Game 1 (89.2 ± 5.3 dBA, while the lowest average game was Game 4 (83.2 ± 7.4 dBA, both of which are non-rival games. The highest peak was measured during Game 9 where the maximum (LASmax) was 120.1 dB.

Table 14. Average (L_{avg}) and maximum noise levels measured by sound level meter at section 102 by Game.

Game #	Rival/ non-rival	Date	Start Time	End Time	Monitoring Duration (h:mm)	Average (dBA)	SD (dBA)	Maximum* (dB)

1	Non- Rival	10/11/23	7:37pm	9:58pm	2:21	89.2	5.3	113.2
2	Non-Rival	10/26/23	6:30pm	7:45pm	1:15	84.5	3.6	109.5
3	Non-Rival	10/27/23	7:50pm	9:53pm	2:03	85.9	3.8	111.2
4	Non-Rival	12/2/23	6:30pm	9:40pm	3:10	83.2	7.4	115.4
5	Rivals	12/17/23	6:30pm	8:55pm	2:25	85.4	3.9	111.8
6	Rivals	12/23/23	7:00pm	10:15pm	3:15	86.4	4.9	116.3
7	Non-Rivals	1/6/24	8:00pm	10:50pm	2:50	86.2	4.6	115.4
8	Rivals	1/13/24	6:30pm	9:49pm	3:19	87.1	4.4	115.0
9	Non-Rivals	1/19/24	6:30pm	9:41pm	2:41	86.3	4.7	120.1
10	Non-Rivals	1/21/24	4;30pm	7:40pm	3:10	84.6	3.7	111.6
11	Rival	1/25/24	7:00pm	10:16pm	3:16	86.3	3.7	112.8
12	Non-Rivals	1/27/24	6:30pm	9:44pm	3:14	86.9	4.5	115.4

*Maximum- LASmax

Table 15 shows whether the 8-hr TWA by game exceeded the ACGIH TLV and the OSHA PEL. Results show that Game 1 (88.1 ± 2.0), Game 4 (85.1 ± 2.7), and Game 12 (85.1 ± 5.9) all had levels that had TWA that were over the ACGIH TWA of 85 dBA. It also showed that all the games did not exceed the OSHA PEL of 90 dBA.

Table 15. OSHA PEL and ACGIH TLV exceedances of 8-hr Time-Weighted-Average (TWA) by Game

Game #	**Rival/ non-rival**	**ACGIH**		**OSHA PEL**	
		TWA ± SD (dBA)	**>85 dBA?**	**TWA ± SD (dBA)**	**>90 dBA?**
Game 1	Non- Rival	88.1 ± 2.0	Yes	82.8 ± 2.9	No
Game 2	Non-Rival	83.4 ± 1.6	No	75.7 ± 2.7	No
Game 3	Non-Rival	82.4 ± 2.0	No	74.8 ± 3.0	No
Game 4	Non-Rival	85.1 ± 2.7	Yes	78.5 ± 3.7	No
Game 5	Rivals	80.9 ± 4.1	No	72.8 ± 6.0	No
Game 6	Rivals	82.3 ± 2.9	No	74.3 ± 3.2	No
Game 7	Non-Rivals	79.9 ± 4.5	No	72.0 ± 7.1	No
Game 8	Rivals	84.2 ± 2.2	No	77.3 ± 3.1	No
Game 9	Non-Rivals	83.6 ± 2.2	No	76.9 ± 3.0	No
Game 10	Non-Rivals	81.0 ± 1.6	No	72.1 ± 3.8	No
Game 11	Rival	84.7 ± 4.8	No	76.0 ± 5.0	No
Game 12	Non-Rivals	85.1 ± 5.9	Yes	78.0 ± 5.2	No

Table 16 shows the comparison of averages (Lavg and 8-hour TWA), dose and maximum noise levels between rivals and non-rival games. The 8-hr TWAs for non-rival games for both ACGIH and OSHA PEL (83.6 ± 2.6 dBA and 76.4 ± 3.6 dBA, respectively) were not significantly different (t= –0.72, p=0.48 and t= –1.26, p=0.21, respectively) from those of rival

games (83.0 ± 1.8 dBA and 75.1 ± 2.0 dBA, respectively). The greatest difference between the rival and non-rival games was observed on the dose% for both OSHA PEL and ACGIH, with the non-rival games having the OSHA dose% of 19.2% and the rival games having the OSHA dose % of 15.4%. Moreover, the ACGIH dose% for the non-rival games was 98.5% and that of the rival games was 89.7%. However, such differences for both ACGIH and OSHA PEL noise doses were not significant (t= –0.47, p=0.64 and t= –1.34, p=0.18, respectively). The ACGIH Lavg for the non-rival games (90.1 ± 2.0 dBA) was not significantly different (t= –0.81, p=0.42) from that of the rival games (89.6 ± 1.4 dBA). Similarly, the OSHA PEL Lavg for the rival games (81.7 ± 1.6 dBA) was not significantly different (t= –1.39, p=0.17) from that of the non-rival games (82.9 ± 3.0 dBA).

Table 16. Comparison of average (Lavg), 8-hr dose and time-weighted-average (TWA) and maximum noise levels between Rival vs Non-rival Games

Game #	ACGIH			OSHA PEL			Max ± SD (dB)
	Average ± SD (dBA)	Dose ± SD (%)	TWA ± SD (dBA)	Average ± SD (dBA)	Dose ± SD (%)	TWA ± SD (dBA)	
Rival							
Game 5	88.4 ± 2.1	64.7 ± 30.4	80.9 ± 4.1	80.3 ± 4.3	12.1 ± 8.2	72.8 ± 6.0	102.2 ± 2.5
Game 6	88.3 ± 1.9	73.3 ± 26.9	82.3 ± 2.9	80.4 ± 2.3	12.4 ± 5.2	74.3 ± 3.2	102.5 ± 4.0
Game 8	90.5 ± 2.2	92.3 ± 27.4	84.2 ± 2.2	83.6 ± 3.1	18.5 ± 8.0	77.3 ± 3.1	105.5 ± 4.3
Game 11	91.1 ± 4.9	128.5 ± 145.7	84.7 ± 4.8	82.5 ± 5.0	18.6 ± 18.2	76.0 ± 5.0	107.9 ± 6.9
Rival Average	89.6 ± 1.4	89.7 ± 28.3	83.0 ± 1.8	81.7 ± 1.6	15.4 ± 3.6	75.1 ± 2.0	104.5 ± 2.7
Non-Rivals							
Game 1	93.6 ± 2.0	158.8 ± 36.5	88.1 ± 2.0	88.3 ± 2.9	39.3 ± 11.9	82.8 ± 2.9	108.7 ± 3.0
Game 2	89.4 ± 1.6	82.4 ± 17.5	83.4 ± 1.6	81.7 ± 2.7	14.7 ± 5.0	75.7 ± 2.7	105.6 ± 1.8
Game 3	89.0 ± 1.9	72.1 ± 21.9	82.4 ± 2.0	81.4 ± 2.8	13.0 ± 5.5	74.8 ± 3.0	104.6 ± 3.9
Game 4	91.4 ± 2.7	107.1 ± 44.5	85.1 ± 2.7	84.9 ± 3.7	22.7 ± 12.1	78.5 ± 3.7	106.8 ± 4.5
Game 7	88.3 ± 2.2	57.2 ± 29.2	79.9 ± 4.5	80.3 ± 5.1	11.2 ± 7.6	72.0 ± 7.1	100.2 ± 3.3
Game 9	90.1 ± 2.2	86.1 ± 27.7	83.6 ± 2.2	83.4 ± 3.0	17.3 ± 5.6	76.9 ± 3.0	103.5 ± 4.9
Game 10	87.5 ± 1.6	58.5 ± 12.5	81.0 ± 1.6	78.6 ± 3.8	9.3 ± 4.0	72.1 ± 3.8	100.0 ± 1.9
Game 12	91.6 ± 5.9	165.6 ± 259.9	85.1 ± 5.9	84.5 ± 5.2	25.9 ± 29.7	78.0 ± 5.2	104.0 ± 10.5
Non-rival average	90.1 ± 2.0	98.5 ± 42.5	83.6 ± 2.6	82.9 ± 3.0	19.2 ± 9.9	76.4 ± 3.6	104.2 ± 3.0
t	-0.81	-0.47	-0.72	-1.39	-1.34	-1.26	0.39
p-value	0.42	0.64	0.48	0.17	0.18	0.21	0.70

Table 17 shows the overall average, 8-hr dose and TWA and the maximum noise levels by arena level. Level 2 has the highest ACGIH Lavg of 91.1 ± 5.8 dBA, but the TWA was not the highest (84.3 ± 6.6 dBA). The highest TWA was at level 1 (84.4 ± 3.6 dBA). The office has the lowest ACGIH Lavg at 86.5 ± 1.7 dBA. The ACGIH TWA for the office was 79.4 ± 3.7 dBA. For the OSHA PEL, level 1 has the highest Lavg level of 83.9 ± 3.9 dBA and a TWA of 77.4 ± 4.4 dBA. The office level was the lowest OSHA PEL Lavg of 76.4 ± 4.1 dBA with the lowest TWA of 69.3 ± 6.1 dBA. Level 2 had the highest maximum noise level of 106.7 ± 6.8 dB while the office had the lowest maximum level of 100.5 ± 3.2 dB.

Table 17. Overall, average (Lavg), 8-hr dose and time-weighted-average (TWA) and maximum noise levels by arena level

Parameter	Arena Level				F	*p*-value
	Level 1	Level 2	Level 3	Office		
ACGIH						
Average (Lavg) (dBA)	90.8 ± 3.1	91.1 ± 5.8	89.6 ± 2.3	86.5 ± 1.7	5.20	<0.01
Dose (%)	107.1 ± 83.4	152.2 ± 237.0	84.0 ± 35.2	50.5 ± 19.6	2.45	0.07
TWA (dBA)	84.4 ± 3.6	84.3 ± 6.6	83.2 ± 2.8	79.4 ± 3.7	4.47	<0.01
OSHA PEL						
Average (Lavg) (dBA)	83.9 ± 3.9	82.9 ± 6.3	82.5 ± 3.5	76.4 ± 4.1	7.97	<0.01
Dose (%)	20.9 ± 13.7	23.3 ± 28.8	16.6 ± 10.1	7.2 ± 4.2	2.88	0.04
TWA (dBA)	77.4 ± 4.4	76.0 ± 7.2	76.0 ± 3.9	69.3 ± 6.1	6.96	<0.01
Maximum (dB)	105.0 ± 5.1	106.7 ± 8.5	103.8 ± 4.7	100.5 ± 3.2	2.64	0.05

CHAPTER VIII: DISCUSSION

Hypothesis 1 of this study states that the 8-hr time-weighted-average (TWA) noise exposure of employees during the home games of Carolina Hurricanes exceeds the OSHA PEL of 90 dBA and the ACGIH TLV of 85 dBA. The findings of this study did not fully support this hypothesis because no game had an 8-hr TWA that exceeded the OSHA PEL of 90 dBA while majority (75%) of the games exceeded the ACGIH (TLV) of 85 dBA. Even with a large area, high seating capacity and big crowds, the noise exposure level of employees and attendees was generally acceptable. The findings of this study are similar to those in Cranston et al. (2013), which found that no workers or attendees were exposed to excessive amount of noise exposure for the eight-hour TWA of 90 A-weighted decibels and that 40% of the workers and 33% of attendees for Venue one were excessively exposed to noise. For Venue 2, 57% of workers and 90% of attendees were exposed to levels that exceeded the ACGIH TLV. The study by Engard et al. (2010) also had similar results wherein the attendees and workers were exposed to noise in excess of the OSHA permissible exposure limit of 90 dBA, with 96% of workers are exposed to ACGIH TLV of 85 dBA. This study had a different outcome than the study by Hodgetts and Liu (2006), wherein the average exposure in a game for 3 hours were 104.1 for game 1, 100.7 for game 2, 103.1 dB for game 3, whereas this study showed that the average exposure of workers did not exceed the OSHA PEL. In a study by Lee & Wooaje (2019), the LAeq of their 16 measures produced 91.7 dBA, which indicates that attendees of the baseball games had noise exposures over the OSHA PEL of 90 dBA, which is the opposite of this study showing that no workers or attendees were exposed over OSHA PEL.

Hypothesis 2 of this study states that the 8-hr TWA noise exposure of employees during home rival games for the Carolina Hurricanes is higher than that during home non-rival games. The findings of this study did not support this hypothesis since the TWA noise exposure during

the rival games was not significantly different from that during the non-rival teams. Although the difference is not significant, the non-rival games showed slightly higher TWA for both ACGIH and OSHA PEL. This may be due to the non-rival teams having the opening day game and having more games that brought up the average noise level compared to the rival games. This also could be that most of the rival games were a loss for the Carolina Hurricanes and that the team did not score as many times during the rival games compared to the non-rival games. In a study by Hodgetts and Liu (2006) during the playoffs of NHL games, results showed that the three games that had noise exposures over the OSHA PEL were playoff games that were more intense. A playoff game has more on the line than a rival game, causing the crowd to be more into the game than during a rival or a non-rival game being played. To the author's knowledge, no study that investigated the difference in noise exposures between rival and non-rival games for any sporting event has been published.

Hypothesis 3 of this study states that the 8-hr TWA noise exposure level on the higher seating level of the arena is less than that on the lower seating levels. Results showed that the 8-hr TWA generally decreased as the arena level increased, which supports the 3rd hypothesis. For the ACGIH, the second level, however, had the highest TWA, followed by the first level and then the third level. The office, which is on the fifth level of the arena, was found to be the least noisy of all the levels. This may be attributed to the fact that there are no fans surrounding the area and there are glass windows that serve as enclosures that blocks the noise from reaching the dosimeter that was placed in the office. A study by Lee and Han (2019) showed significant difference in noise levels for the different seating sections, where the red sections (94 dBA) and the navy sections (91.9 dBA) were significant different than the outfield level (87.1 dBA), which is the farthest section from the playing field. This current study compares to the Lee and Han (2019) study where the farther sections from the playing field can be quieter than the sections

closer to the playing field (Lee & Han, 2019). To the author's knowledge, no study that investigated the difference in noise exposures between arena levels for any sporting event has been published.

Since there were games wherein noise exposures exceeded the ACGIH TLV, recommended control measures to reduce noise exposures of employees and/or attendees may include worker rotation as an administrative control and wearing of hearing protection. To reduce the overall noise exposure, workers should be rotated. Specifically, workers may be rotated from the bowl area, where there is a large crowd, to the concourse or stairwells every other period to decrease the workers' overall exposure to excessive noise. Implement a rotation plan where workers are assigned to different areas. Workers may also be rotated from one shift to another, such as having one shift being in an area where the noise exposure is high (e.g., bowl area) and then having the next shift where they are working in less noisy areas (e.g., stairwells, concourse areas).

For future studies, it is recommended to conduct personal noise monitoring of both workers and attendees to get a broader range of data. Future studies should be conducted in other arenas that have different features and configurations to investigate their effects on noise exposure. It is also recommended to have a mixture of sound level meters and dosimeters for conducting area monitoring and to have dosimeters conducting personal noise monitoring to assess noise exposure of attendees and workers.

Strengths and Limitations of the Study

The strength of the project for the use of dosimeters would be that there were several dosimeters deployed in different locations in the arena, providing information on whether worker location is a significant factor affecting noise exposure. The study was successful in monitoring

several games that are either rival or non-rival. This is the first study to investigate noise exposure of workers during professional hockey games in PNC arena. This study compared rival vs. non-rival games whereas no study has explored this. This study also compared the noise exposure levels based on arena levels, whereas other studies did not explore this.

Some limitations of this project were the occasional malfunctioning of some dosimeters, wherein the dosimeters would stop working with no warning, even though they were not stopped by the computer or the phone application. This would cause the monitoring periods to be different during some games. The sound level meter battery would drain rather quickly causing the batteries to die, creating a difference in monitoring periods. With the sound level meter battery being a cause for concern, the sound level meter would often be the last equipment to be started and was often started either after warmups or during the game, resulting in different monitoring periods. The results of this study may not be a representation of other arenas, due to the other arenas having different sizes and shapes. Arenas differ in crowd capacity and functionality. For example, there are arenas that are multi-functional (e.g., used as a concert venue and different sporting events) while others have limited use (e.g., only for hockey games and concerts).

Some things I would do differently for this study would be how I would monitor the dosimeters to see if they were working. Testing was conducted during the study to ensure the proper functioning of the dosimeters before calibration prior to each session. The performance of the dosimeters was assessed, and it was observed that the application on the phone exhibited intermittent behavior.I would have gone to each individual worker and checked to see if their dosimeter was working at the end of each period of the game. If the dosimeters were not working, then I would have taken the dosimeters to a location to have restarted, calibrated, and then replaced on the worker. For the sound level meter, I would change how I would start and

monitor it for battery usage. I would start the sound level meter at the start of the game only to make sure the sound level meter would be able to completely cover the entire game.

CHAPTER IX: CONCLUSION

Workers and attendees of sporting events are exposed to higher levels of noise.. This study showed that the workers and attendees may be exposed to noise higher than the recommended limit, as the study showed noise exposure higher than the ACGIH TLV for three games but were not above the OSHA PEL during any games. Different arena levels vary in noise exposures. Attendees that are on the second level have a higher noise exposure than the other levels in the PNC arena. The noise exposure for the first level was higher than the third and the office level of PNC arena. This did not support the hypothesis, because the first level was not louder than the second level. The noise exposures between the non-rival and rival games were not significantly different, which did not support the hypothesis.

The results of this study are representative of the noise exposure of attendees and workers for PNC arena but may not be applied to other NHL arena or other sporting events that take place in arenas due to arenas having their own distinct shapes, sizes and maximum crowd attendance.

Recommended controls would be administrative controls and personal protective equipment (PPE) for the workers. The administrative controls that the company could use would be trading positions for the workers during intermission and other breaks to give the workers a rest from noise exposure. Workers could also have a rotation between arena levels to reduce overall noise exposure. The PPE-related measure that a company could implement would be handing out ear plugs or earmuffs with appropriate noise reduction rating (NRR) for the workers to wear during the higher noise levels to protect their hearing. For attendees of games, they could bring in their own ear plugs to wear when the noise levels are harmful. Attendees also could find quieter areas where they can take a break from the higher noise levels that they are exposed to during game play.

Future study recommendations would be to set up noise exposure studies for each game of a season and during the playoffs to determine the noise exposures of attendees and workers. It is also recommended to monitor noise exposure of actual attendees and more workers to gather more data points and a broader picture of the noise exposure. I would recommend deploying sound level meters to each arena level. Similar studies in other arenas with different features are also recommended to compare noise exposure differences during games and determine the influence of such features on noise exposure.

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APPENDIX A: ECU Institutional Review Board (IRB) Initial Letter of Approval

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board
4N-64 Brody Medical Sciences Building· Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** ·
rede.ecu.edu/umcirb/

Notification of Initial Approval: Expedited

From: Biomedical IRB
To: Samantha Curtis
CC: Jo Anne Balanay
Date: 5/19/2023
Re: UMCIRB 23-000763
Occupational and Recreational Noise Levels during National Hockey League Games

I am pleased to inform you that your Expedited Application was approved. Approval of the study and any consent form(s) occurred on 5/18/2023. The research study is eligible for review under expedited category # 4. The Chairperson (or designee) deemed this study no more than minimal risk.

As the Principal Investigator you are explicitly responsible for the conduct of all aspects of this study and must adhere to all reporting requirements for the study. Your responsibilities include but are not limited to:

1. Ensuring changes to the approved research (including the UMCIRB approved consent document) are initiated only after UMCIRB review and approval except when necessary to eliminate an apparent immediate hazard to the participant. All changes (e.g. a change in procedure, number of participants, personnel, study locations, new recruitment materials, study instruments, etc.) must be prospectively reviewed and approved by the UMCIRB before they are implemented;

2. Where informed consent has not been waived by the UMCIRB, ensuring that only valid versions of the UMCIRB approved, date-stamped informed consent document(s) are used for obtaining informed consent (consent documents with the IRB approval date stamp are found under the Documents tab in the ePIRATE study workspace);

3. Promptly reporting to the UMCIRB all unanticipated problems involving risks to participants and others;

4. Submission of a final report application to the UMICRB prior to the expected end date provided in the IRB application in order to document human research activity has ended and to provide a timepoint in which to base document retention; and

5. Submission of an amendment to extend the expected end date if the study is not expected to be completed by that date. The amendment should be submitted 30 days prior to the UMCIRB approved expected end date or as soon as the Investigator is aware that the study will not be completed by that date.

The approval includes the following items:

Name	Description
Assignment 8 - Proposal.docx	Study Protocol or Grant Application
Informed-Consent-Document-No-More-Than-Minimal-Risk (Curtis 5-8-23) (1) (2) (1).docx	Consent Forms
Informed-Consent-Document-No-More-Than-Minimal-Risk (Curtis 5-8-23) (1) (2) (1).docx	Recruitment Documents/Scripts

For research studies where a waiver or alteration of HIPAA Authorization has been approved, the IRB states that each of the waiver criteria in 45 CFR 164.512(i)(1)(i)(A) and (2)(i) through (v) have been met. Additionally, the elements of PHI to be collected as described in items 1 and 2 of the Application for Waiver of Authorization have been determined to be the minimal necessary for the specified research.

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

APPENDIX B: Informed Consent Form

Informed Consent to Participate in Research
Information to consider before taking part in research that has no more than minimal risk.

Title of Research Study: Assessing Occupational and Recreational Noise levels during National Hockey League Games and its Impact on Employees and Attendants

Principal Investigator: Samantha Curtis (Person in Charge of this Study)
Institution, Department or Division: Health Education and Promotion
Address: 943 E 14th St, Greenville, NC 27858
Telephone #: 920 222 2263
Study Coordinator: Dr. Jo Anne Balanay
Telephone # 252 737 1474

Researchers at East Carolina University (ECU) study issues related to society, health problems, environmental problems, behavior problems and the human condition. To do this, we need the help of volunteers who are willing to take part in research.

Why am I being invited to take part in this research?
This research study will measure the noise exposure of employees during home games of the National Hockey League team Carolina Hurricanes and compare these noise exposure levels to occupational exposure limits. You are being invited to take part in this research because you are an employee of PNC arena. The decision to take part in this research is yours to make. By doing this research, we hope to learn what the noise exposure of employees in the PNC arena during a National Hockey League non-rival game and how it compares to a rival game, and if the noise exposure will be different in each seating levels in PNC arena during a National Hockey League game.
If you volunteer to take part in this research, you will be one of about 30 people to do so.

Are there reasons I should not take part in this research?
There are no health or ethical reasons that should prevent you from participating in this research.

What other choices do I have if I do not take part in this research?
You can choose not to participate.

Where is the research going to take place and how long will it last?
The research will be conducted at PNC arena in Raleigh, North Carolina. You will need to come to PNC arena 14 times during the study. The total amount of time you will be asked to volunteer for this study is 14 games over the next 4 months.
The games that will be part of the study are:

- September 26th
- October 6th
- October 11th
- October 26th
- October 27th

- November 18th
- December 2nd
- December 17th
- December 23rd
- January 6th
- January 19th
- January 21st
- January 25th
- January 27th

What will I be asked to do?
You will be asked to attend 14 mandatory start of the workday meetings. You will be asked to attend each mandatory shift meeting for each of the 14 games you are wearing the noise dosimeter. At this meeting you will be asked to wear a noise dosimeter that will be placed on your dominant shoulder during the entire work shift. These noise dosimeters will not record any audio or video. The noise dosimeters will be used to monitor personal noise exposure during the shift. Your job title for the day will be recorded and no personal information such as name, age, etc. will be collected during the monitoring. You will also be asked to sign this form, at the beginning of the workday meetings. You will be asked to wear the noise dosimeter for 14 shifts. You will be asked to fill out a daily activity log during the work shift to indicate location within the arena and associated time.

What might I experience if I take part in the research?
We do not know of any risks (the chance of harm) associated with this research. Any risks that may occur with this research are no more than what you would experience in everyday life. Taking part in this study may be of personal benefit to you by knowing your occupational noise exposure during your work shift. The information gained by doing this research may also help others in the future in terms of noise exposure prevention and hearing conservation.

Will I be paid for taking part in this research?
We will not be able to pay you for the time you volunteer while being in this study.

Will it cost me to take part in this research?
It will not cost you any money to be part of the research.

Who will know that I took part in this research and learn personal information about me?
ECU and the people and organizations listed below may know that you took part in this research and may see information about you that is normally kept private. With your permission, these people may use your private information to do this research:

- Principal investigator (Samantha Curtis) from East Carolina University
- Any agency of the federal, state, or local government that regulates human research. This includes the Department of Health and Human Services (DHHS), the North Carolina Department of Health, and the Office for Human Research Protections.
- The University & Medical Center Institutional Review Board (UMCIRB) and its staff have responsibility for overseeing your welfare during this research and may need to see research records that identify you.

How will you keep the information you collect about me secure? How long will you keep it?

Physical data collected from this study (i.e., data sheet) will be converted to electronic data, and then discarded immediately. Electronic data will be retained indefinitely in password-protected computers of the research investigators. A participant ID number (#01 to #07) will be assigned to each participant per day and will be used to code all study info (e.g., noise exposure profiles, time log). No personal identifiers (i.e., name) will be linked to participant ID numbers. Thus, there will be no way to trace responses and other data back to a particular participant.

What if I decide I don't want to continue in this research?
You can stop at any time after it has already started. There will be no consequences if you stop, and you will not be criticized. You will not lose any benefits that you normally receive.

Who should I contact if I have questions?
The people conducting this study will be able to answer any questions concerning this research, now or in the future. You may contact the Principal Investigator at 920-222-2263 (days, between Monday-Friday 9am-5pm).

If you have questions about your rights as someone taking part in research, you may call the University & Medical Center Institutional Review Board (UMCIRB) at phone number 252-744-2914 (days, 8:00 am-5:00 pm). If you would like to report a complaint or concern about this research study, you may contact the Director for Human Research Protections, at 252-744-2914.

I have decided I want to take part in this research. What should I do now?
If you have decided to take part in this research, express interest by emailing the principal investigator at curtiss17@students.ecu.edu. The Principal Investigator will then follow up with you with further instructions.
The person obtaining informed consent will ask you to read the following and if you agree, you should sign this form:

- I have read (or had read to me) all of the above information.
- I have had an opportunity to ask questions about things in this research I did not understand and have received satisfactory answers.
- I know that I can stop taking part in this study at any time.
- By signing this informed consent form, I am not giving up any of my rights.
- I have been given a copy of this consent document, and it is mine to keep.

_____ _____

Participant's Name (PRINT) **Signature** **Date**

Person Obtaining Informed Consent: I have conducted the initial informed consent process. I have orally reviewed the contents of the consent document with the person who has signed above, and answered all of the person's questions about the research.

_____

Person Obtaining Consent (PRINT) **Signature** **Date**

APPENDIX C: Tables of Raw Data on Noise Measurements:

Game #1: October 11, 2023; vs. Ottawa Senators

Location	Serial Number	Duration HR:MIN	ACGIH LAVG	OSHA PEL LAVG	Min	Max	Max-Time	What was Occurring during Max
Section 112	MK501322	3:45	95.2	90.8	59.2	111.1	8:48	Announcement of Goal
Section 119	M501301	3:45	94.4	90.3	66.9	107.2	9:54	Three Stars of the Game
Section 125	MK501326	3:45	95.6	89.5	62.1	111.9	9:31	Good Play
Section 229	MK501300	3:45	94.0	89.1	66.8	106.5	7:06	Players Introductions
Section 311	MK501311	3:45	94.2	90.2	52.7	111.1	7:12	Players Introductions
Section 301	MK501289	3:45	93.8	89.0	53.3	111.7	9:33	Goal
Section 321	MK501296	3:45	94.1	88.3	59.2	109.7	8:20	Good Play
Section 327	MK501298	3:45	91.9	86.0	61.4	105.2	7:28	Good Play
Production	MK501303	3:45	89.1	81.7	54.5	104.2	7:11	Players Introductions

Game #2: October 26, 2023; vs. Seattle Kracken

Location	Serial Number	Duration HR:MIN	ACGIH LAVG	OSHA PEL LAVG	Min	Max	Max-Time	What was Occurring during Max
Section 112	MK501322	Did not record	-	-	-	-	-	-
Section 119	M501301	3:30	89.2	81.2	72.6	103.6	9:33	Goal Announcement
Section 125	MK501326	3:30	90.7	84	57.6	106.5	7:46	Goal Announcement
Section 229	MK501300	3:30	90.7	83.6	72.9	108.2	9:42	Good Plays
Section 311	MK501311	3:30	91.3	85.1	69	106.4	7:46	Goal Announcement
Section 301	MK501289	3:30	86.9	78.1	51.7	105.6	7:44	Goal
Section 321	MK501296	3:30	89	81.9	62.3	103.9	7:04	Players Introductions
Section 327	MK501298	3:30	90.2	82.4	69	107.3	7:46	Goal Announcement

Production	MK501303	3:30	87.3	77.6	69	104	9:33	Fight

Game #3 October 27, 2023; vs. San Jose Sharks

Location	Serial Number	Duration HR: MIN	ACGIH LAVG	OSHA PEL LAVG	Min	Max	Max-Time	What was Occurring during Max
Section 112	MK501322	Did not record	-	-	-	-	-	-
Section 119	M501301	3:20	92.3	85.7	68.5	108	9:17	Goal Announcement
Section 125	MK501326	3:20	90.1	81.3	62.3	106.4	7:38	Goal
Section 229	MK501300	3:20	94.0	83.7	60.8	103.7	7:16	Good Play
Section 311	MK501311	3:20	86.4	76.7	72.6	99.9	9:17	Good Play
Section 301	MK501289	3:20	88.5	81.2	51.9	109	7:16	Good Play
Section 321	MK501296	3:20	87.5	79.8	73.7	98.8	7:02	Player Introduction
Section 327	MK501298	3:20	88.9	81.1	75.4	106.3	7:38	Goal
Production	MK501303	Did not Record	-	-	-	-	-	-

Game #4 December 2, 2023; vs. Buffalo Sabers

Location	Serial Number	Duration HR: MIN	ACGIH LAVG	OSHA PEL LAVG	Min	Max	Max-Time	What was Occurring during Max
Section 112	MK501322	Did not Record	-	-	-	-	-	-
Section 119	M501301	3:20	91	84.3	69.6	106.9	8:07	Goal Announcement
Section 125	MK501326	3:20	88.7	82	52.2	100	8:44	Goal Announcement
Section 229	MK501300	Did not Record	-	-	-	-	-	-
Section 311	MK501311	3:15	88.9	80.2	68	105.4	8:07	Goal Announcement
Section 301	MK501289	3:20	92.7	87.5	69.6	108.2	7:38	Goal
Section 321	MK501296	3:15	91.3	84.9	65.4	106.7	7:40	Goal
Section 327	MK501298	3:20	95.9	90.3	71.7	113.8	7:38	Goal

Production	MK501303	Did not Record	-	-	-	-	-	-

Game #5: December 17 2023, vs. Washington Capitals

Location	Serial Number	Duration HR: MIN	ACGIH LAVG	OSHA PEL LAVG	Min	Max	Max-Time	What was Occurring during Max
Section 112	MK501322	3:3091.2	86.1	62.3	105.3	6:25	Refs calling off a goal	
Section 119	M501301	3:30	91.4	85.3	76.9	103.9	6:25	Refs calling off a goal
Section 125	MK501326	3:30	89.3	82.4	72.9	102.3	6:25	Refs calling off a goal
Section 229	MK501300	1:12	87.4	78.3	65.4	102.1	6:25	Refs calling off a goal
Section 311	MK501311	3:30	86.9	78.5	64.7	97.5	6:10	Good Plays
Section 301	MK501289	3:30	89.3	82.4	72.9	102.3	6:05	Good Plays
Section 321	MK501296	3:30	87.8	78.2	67.9	104.9	7:30	Good Plays
Section 327	MK501298	2:19	87.9	79.5	55.3	103	6:05	Good Plays
Production	MK501303	2:19	84.8	71.9	68.5	99.3	6:25	Ref calling off a goal

Game #6: December 23, 2023, vs New York Islanders

Location	Serial Number	Duration HR: MIN	ACGIH LAVG	OSHA PEL LAVG	Min	Max	Max-Time	What was Occurring during Max
Section 112	MK501322	3:45	90.1	83.9	54.1	104.3	8:57	Aftermath of a fight
Section 119	M501301	3:45	89.3	81.8	54.1	103.8	7:36	Player Introductions
Section 125	MK501326	3:45	92.1	84	58.5	111.2	9:56	Good Plays
Section 229	MK501300	3:45	88.1	79.3	67.6	103.3	8:02	Bad Plays
Section 311	MK501311	3:45	87.6	79.6	55.3	103.4	8:57	Aftermath of a fight
Section 301	MK501289	1:50	86.8	78.8	54	98,2	7:09	Good plays
Section 321	MK501296	3:45	87.7	79.7	67	98.8	8:03	Bad Plays

Section 327	MK501298	3:45	87.1	78.9	62.3	100.7	8:57	Aftermath of a Fight
Production	MK501303	3:45	86.1	77.4	65.5	98.9	7:53	Good Plays

Game #7: January 6, 2024, vs. St. Louis Blues

Location	Serial Number	Duration HR: MIN	ACGIH LAVG	OSHA PEL LAVG	Min	Max	Max-Time	What was Occurring during Max
Section 112	MK501322	1:57	88.1	81	59.5	98.3	8:05	Player's introduction
Section 119	M501301	3:20	91	85.6	68.1	103.9	10:48	End of game
Section 125	MK501326	1:57	88.1	81	59.5	98.3	9:23	Bad Play
Section 229	MK501300	3:20	89.3	82.1	64.1	103.4	10:45	End of game
Section 311	MK501311	3:20	88	80.9	67.6	101.4	9:30	Good Plays
Section 301	MK501289	3:20	91	85.6	68.1	103.9	10:48	End of game
Section 321	MK501296	3:20	88.4	80.8	62.7	100.9	10:45	End of game
Section 327	MK501298	1:43	87.8	80	72.1	98.2	8:29	Penalty
Production	MK501303	1:28	83.5	68.4	70.2	94.6	8:05	Players Introduction

Game #8: January 13, 2024, vs. Pittsburgh Penguins

Location	Serial Number	Duration HR: MIN	ACGIH LAVG	OSHA PEL LAVG	Min	Max	Max-Time	What was Occurring during Max
Section 112	MK501322	Did not Record	-	-	-	-	-	-
Section 119	M501301	3:20	91.8	85.9	69.2	105.8	7:22	Goal announced
Section 125	MK501326	3:20	87.7	79.9	59.9	100	7:09	Puck Drop
Section 229	MK501300	3:20	92.6	84.9	52.3	111.9	8:01	Canes Coming on to Ice for second period
Section 311	MK501311	3:20	88.7	81.4	63.6	100.9	7:06	Players Introduction
Section 301	MK501289	3:20	93.2	88.2	74.7	108.7	7:22	Goal Announcement

Section 321	MK501296	3:20	90.7	84.2	66.8	107.8	9:39	Start of overtime
Section 327	MK501298	3:20	88.5	80.5	68.3	103.3	9:48	End of Game
Production	MK501303	Did not Record	-	-	-	-	-	-

Game#9: January 19, 2024, vs. Detroit Red Wings

Location	Serial Number	Duration HR: MIN	ACGIH LAVG	OSHA PEL LAVG	Min	Max	Max-Time	What was Occurring during Max
Section 112	MK501322	3:15	91.1	85.5	52.5	103.2	7:40	Good plays
Section 119	M501301	3:15	90.4	84.5	55.8	104.9	9:43	End of game
Section 125	MK501326	3:15	90.2	83.5	71.4	105.8	9:38	End of game
Section 229	MK501300	3:15	88.3	81.2	66.2	99.2	8:46	Score board announcement
Section 311	MK501311	3:15	90	84	72	101.1	9:38	End of Game
Section 301	MK501289	3:15	90.3	83.8	68	103.8	9:37	Three stars of the game
Section 321	MK501296	3:15	90.3	83.8	68	101.5	8:43	Score Board announcement
Section 327	MK501298	3:15	94.4	86.7	69.8	114.6	9:19	Good Plays
Production	MK501303	3:15	86	76.5	70.5	98	8:37	End of Period

Game #10: January 21, 2024, vs. Minnesota Wild

Location	Serial Number	Duration HR: MIN	ACGIH LAVG	OSHA PEL LAVG	Min	Max	Max-Time	What was Occurring during Max
Section 112	MK501322	3:15	89.1	81.6	58.1	103.3	7:19	Opponents goal
Section 119	M501301	3:15	89.1	81.6	58.1	99.3	5:34	Penalty
Section 125	MK501326	3:15	88	80	58.4	99.4	5:34	Penalty
Section 229	MK501300	3:15	85	71.9	68.7	97.8	7:20	Good Plays
Section 311	MK501311	3:15	89.2	82.6	60.3	100.8	7:37	Good Plays
Section 301	MK501289	3:15	89.2	81.5	71.2	102.3	5:04	Siren
Section 321	MK501296	3:15	86.9	77.2	70	98.8	5:32	Goal
Section 327	MK501298	3:15	86.3	77.9	65.7	97.6	5:05	Players Introductions
Production	MK501303	3:15	88	80.9	69.2	101.4	7:36	Good Plays

Game #11: January 25, 2024, vs. New Jersey Devils

Location	Serial Number	Duration HR: MIN	ACGIH LAVG	OSHA PEL LAVG	Min	Max	Max-Time	What was Occurring during Max
Section 112	MK501322	3:15	92.8	86.3	54.9	109.6	8:39	Goal
Section 119	M501301	3:15	90.3	80.1	53.1	108.9	8:39	Goal
Section 125	MK501326	3:15	103.3	93.4	73.7	123.6	8:40	Challenge of Goal
Section 229	MK501300	3:15	89.9	80.9	61	108.9	8:39	Goal
Section 311	MK501311	3:15	88.9	79.9	68.8	104.1	9:08	Goalie Save
Section 301	MK501289	3:15	88	80.5	57.8	100.3	8:12	Big Plays
Section 321	MK501296	3:15	91,2	83.9	70.4	109.6	7:40	Goal
Section 327	MK501298	3:15	88.7	81	72	101.9	8:40	Challenge of Goal
Production	MK501303	3:15	86.9	76.1	70;4	104.4	7:40	Goal

Game #12: January 27, 2024, vs. Arizona Coyotes

Location	Serial Number	Duration HR: MIN	ACGIH LAVG	OSHA PEL LAVG	Min	Max	Max-Time	What was Occurring during Max
Section 112	MK501322	3:15	91.1	85.4	52.2	104	7:05	Players Introduction
Section 119	M501301	3:15	89.5	82.6	63.9	100.5	9:38	End of Game
Section 125	MK501326	3:15	73.7	83.5	53.5	99.9	9:24	Penalty
Section 229	MK501300	3:15	107	96.8	54.1	128.9	9:42	Player Interview/ Player's Name chant
Section 311	MK501311	3:15	89.5	82.7	69.9	101.8	9:38	End of Game
Section 301	MK501289	3:15	89.6	82.3	66.7	104	9:42	Player interview name chant
Section 321	MK501296	3:15	90.7	84.4	74.3	105.2	9:41	Three Stars
Section 327	MK501298	3:15	91	85.5	74.5	103.6	9:42	Player Interview name Chant
Production	MK501303	86.9	77.5	70.6	77.5	100.5	9:41	Three Stars

APPENDIX D: SPSS Statistical Output for T-Tests

Group Statistics

	Rival Stat	N	Mean	Std. Deviation	Std. Error Mean
ACGIH Lavg	Rival	34	89.532	3.1898	.5471
	Nonrival	66	90.095	3.3530	.4127
ACGIH Dose	Rival	34	89.544	79.6155	13.6540
	Nonrival	66	99.127	103.1570	12.6977
ACGIH TWA	Rival	34	82.953	3.8686	.6635
	Nonrival	66	83.545	3.9567	.4870
OSHA Lavg	Rival	34	81.562	3.9328	.6745
	Nonrival	66	82.856	4.6532	.5728
OSHA Dose	Rival	34	15.191	11.1922	1.9194
	Nonrival	66	19.274	15.7735	1.9416
OSHA TWA	Rival	34	74.953	4.6684	.8006
	Nonrival	66	76.306	5.3152	.6543
Max	Rival	34	104.471	5.1094	.8763
	Nonrival	66	104.024	5.5613	.6846

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
ACGIH Lavg	Equal variances assumed	.052	.819	-.809	98	.210	.421	-.5631	.6964	-1.9451	.8189
	Equal variances not assumed			-.822	69.780	.207	.414	-.5631	.6853	-1.9299	.8037
ACGIH Dose	Equal variances assumed	.231	.632	-.473	98	.318	.637	-9.5832	20.2397	-49.7483	30.5820
	Equal variances not assumed			-.514	83.177	.304	.609	-9.5832	18.6457	-46.6676	27.5013
ACGIH TWA	Equal variances assumed	.031	.861	-.715	98	.238	.476	-.5925	.8290	-2.2377	1.0527
	Equal variances not assumed			-.720	68.108	.237	.474	-.5925	.8230	-2.2348	1.0498
OSHA Lavg	Equal variances assumed	.506	.479	-1.386	98	.084	.169	-1.2943	.9339	-3.1475	.5589
	Equal variances not assumed			-1.463	77.340	.074	.148	-1.2943	.8849	-3.0561	.4676
OSHA Dose	Equal variances assumed	1.437	.234	-1.344	98	.091	.182	-4.0831	3.0387	-10.1133	1.9471
	Equal variances not assumed			-1.496	88.200	.069	.138	-4.0831	2.7302	-9.5086	1.3425
OSHA TWA	Equal variances assumed	.264	.608	-1.255	98	.106	.212	-1.3531	1.0780	-3.4924	.7861
	Equal variances not assumed			-1.309	74.844	.097	.195	-1.3531	1.0339	-3.4129	.7067
Max	Equal variances assumed	.101	.751	.391	98	.348	.697	.4463	1.1428	-1.8214	2.7141
	Equal variances not assumed			.401	71.964	.345	.689	.4463	1.1119	-1.7703	2.6630

APPENDIX E: SPSS Statistical Output for ANOVA

Report

Arena level		ACGIH Lavg	ACGIH Dose	ACGIH TWA	OSHA Lavg	OSHA Dose	OSHA TWA	Max
Level 1	Mean	90.822	107.084	84.391	83.856	20.894	77.425	104.963
	N	32	32	32	32	32	32	32
	Std. Deviation	3.1475	83.4008	3.6274	3.8612	13.6666	4.3685	5.1470
	Maximum	103.3	513.5	96.8	93.4	65.1	86.9	123.6
Level 2	Mean	91.127	152.245	84.255	82.891	23.264	76.018	106.718
	N	11	11	11	11	11	11	11
	Std. Deviation	5.8055	236.9712	6.6491	6.3200	28.7889	7.2455	8.4510
	Maximum	107.0	857.7	100.5	96.8	104.3	90.3	128.9
Level 3	Mean	89.648	83.973	83.179	82.467	16.648	75.977	103.752
	N	48	48	48	48	48	48	48
	Std. Deviation	2.3386	35.2495	2.8289	3.4750	10.0579	3.9021	4.6999
	Maximum	95.9	188.8	89.6	90.3	48.2	84.7	114.5
Office	Mean	86.511	50.533	79.389	76.444	7.222	69.322	100.533
	N	9	9	9	9	9	9	9
	Std. Deviation	1.6684	19.5832	3.6567	4.1280	4.2255	6.1282	3.2357
	Maximum	89.1	82.8	83.6	81.7	14.8	76.2	104.4
Total	Mean	89.904	95.869	83.344	82.416	17.886	75.846	104.176
	N	100	100	100	100	100	100	100
	Std. Deviation	3.2931	95.5010	3.9175	4.4443	14.4530	5.1214	5.3901
	Maximum	107.0	857.7	100.5	96.8	104.3	90.3	128.9

ANOVA Table

			Sum of Squares	df	Mean Square	F	Sig.
ACGIH Lavg * Arena level	Between Groups	(Combined)	150.173	3	50.058	5.204	.002
	Within Groups		923.465	96	9.619		
	Total		1073.638	99			
ACGIH Dose * Arena level	Between Groups	(Combined)	64277.170	3	21425.723	2.453	.068
	Within Groups		838647.164	96	8735.908		
	Total		902924.334	99			
ACGIH TWA * Arena level	Between Groups	(Combined)	186.264	3	62.088	4.471	.006
	Within Groups		1333.103	96	13.886		
	Total		1519.366	99			
OSHA Lavg * Arena level	Between Groups	(Combined)	389.918	3	129.973	7.970	<.001
	Within Groups		1565.477	96	16.307		
	Total		1955.394	99			
OSHA Dose * Arena level	Between Groups	(Combined)	1704.621	3	568.207	2.875	.040
	Within Groups		18975.500	96	197.661		
	Total		20680.120	99			
OSHA TWA * Arena level	Between Groups	(Combined)	463.972	3	154.657	6.962	<.001
	Within Groups		2132.637	96	22.215		
	Total		2596.608	99			
Max * Arena level	Between Groups	(Combined)	218.931	3	72.977	2.636	.054
	Within Groups		2657.371	96	27.681		
	Total		2876.302	99			