Halifax Noise Study: Resident Perceptions into Noise Annoyance

by

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Abstract

As the population of Halifax, N.S. continues to grow and urbanization continues, as does the issue of urban noise. Experiencing noise at home or in urban environments is shown to have a myriad of negative health and psychological impacts. Natural species such as songbirds are especially vulnerable to the impact of increased noise due to their reliance on acoustic communication. The purpose of this study being to *1) Explore the level of annoyance associated with noise in Halifax and 2) to investigate the sources of noise residents of Halifax find to be most annoying***.** To provide a representative sample of the population, it was determined that 384 study participants would be sufficient, based on Halifax's 2016 population count of 403,390, calculated with a 95% confidence level and 5% margin of error. Participants (18 years or older) were recruited via targeted ads on social media and asked to complete the anonymous online survey consisting of questions discussing levels of noise annoyance and noise sources while in their home or in their neighbourhood over the last 12 months. Sociodemographic questions were also included in the survey asking for resident postal codes for relative location, ages, and other similar indicators. The survey took 8–10-minutes to complete and was available in the early months of 2022. A total of 468 residents completed the survey. Data analysis consisted of finding measures of central tendency, counts, as well as the proportion of annoyance from scaling questions. Pattern and focused coding analysis was conducted for open-ended responses to understand the most significant source of noise annoyance. The research found that residents of Halifax were moderately to highly annoyed with noise that was outside in their neighbourhood over the last 12 months or so. Both road traffic and fireworks were found to be sources of significant noise annoyance. Road traffic was identified as the most annoying noise source at any time, and fireworks were found to be the most common nighttime noise annoyance source that interfered with residents' ability to sleep.

Keywords: Urban Noise, Noise Annoyance, Noise Pollution, Anthropogenic Noise, Noise Annoyance Scales, Built Environment, Noise Annoyance Survey, Traffic, Neighbourhood, Fireworks, Halifax Regional Municipality

CHAPTER 1: INTRODUCTION

1.1 Background

Noise has been shown to have impacts to both physical and mental health, and has been shown to interfere with communication patterns in other species (Mohamed et al., 2021; Rosa & Koper, 2018). Urban noise, especially from road traffic, has been shown to negatively affect sleep patterns at night (Perron et al., 2016). The World Health Organization (WHO) has also noted traffic noise as the second worst environmental stressor affecting human health after air pollution (Münzel et al., 2020). Research quantifying the effect of noise on an individual's perception has identified traffic as a common source of annoyance across many demographics (Michaud et al., 2005). Noise annoyance is defined as feelings of displeasure, brought on by acoustic factors, which affect an individual's mind and/or mood in a negative way (Stallen, 1999).

Within Canada, Halifax now has the fastest rate of population growth in the downtown core and with this growth comes an increase in infrastructure, traffic, and other sources of anthropogenic noise (Mohamed et al., 2021; Statistics Canada, 2022). Previous research studies conducted solely on the topic of noise annoyance have been completed. Research by Michaud and colleagues has focused on noise annoyance within Canada as a whole and was completed over fifteen years ago (2005). Research into resident perceptions on noise annoyance, however, has not yet been conducted within the city of Halifax. Therein lies a knowledge gap this research study is seeking to fill.

1.2 Purpose of the Study

The purpose of this study is to achieve a better understanding of the level of annoyance associated with noise levels and what sources of noise annoyance are most significant to residents of Halifax. The research builds upon similar noise annoyance surveys which seek to understand the level of annoyance residents are experiencing due to noise in their neighbourhood. Understanding subjective perceptions of noise annoyance across a variety of neighbourhoods is necessary to develop noise abatement solutions and assist in expanding knowledge within the intersecting fields of environmental health, and sustainability

1.3 Research Objectives

The objectives of this research are:

1) To explore the level of annoyance associated with noise in Halifax.

2) To investigate the sources of noise residents of Halifax find to be most annoying.

1.4 Theoretical perspective

The phenomena of noise annoyance regarding ‘mind and mood’ is nuanced because it is subjective to the individual (Stallen, 1999). Stallen describes noise annoyance as a type of psychological stress that can lead to disturbances through the night, anxiety, stress, or impediment to focus (1999). The theoretical framework of noise annoyance is determined by an individual’s perceived disturbance and perceived control over the circumstance. Generally, a low

level of perceived control over the source of noise disturbance will result in a higher level of psychological stress for an individual (Stallen, 1999). To accurately assess the degree of noise annoyance in the study population, the survey design has focused on what levels of annoyance, stress, or disturbance the participants have felt from noise around their home and within their neighbourhood.

1.5 Significance of the Study

The issue of noise annoyance is of great significance for both human health and the natural environment. Noise has been shown to be a significant issue with implications for both human health and other species, however, the level of psychological stress which noise annoyance can produce has not received much study in the city of Halifax. Currently the city of Halifax is reviewing By-law N-200 ‘Respecting Noise’. Councillors are ideally looking for a noise standard that is more subjective and are unsure if a decibel measurement is the best way to interpret excessive noise (Berman, 2021; D’entremont, 2021). Understanding the levels of noise annoyance and significant sources of noise in Halifax may influence the decision making in this process.

In better understanding sources of noise pollution within Halifax, and how they affect the local population, there is a broadening of understanding towards what anthropogenic activities may create greater negative impacts within the local built environment. In doing so, this research may assist in finding recommendations to abate the presence of high noise annoyance sources in the city of Halifax, and therefore benefit the city in working to attain key sustainable development goals such as sustainable cities and communities.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The use of the Dalhousie Novanet online library was the primary search engine for this literature review. The approach to review significant literature for the research study was through the use of keywords and phrases such as ‘urban noise’, ‘noise annoyance’, ‘noise annoyance and health’, ‘noise pollution and health’, ‘noise and health’, ‘anthropogenic noise and effects’, ‘noise annoyance and scale’, ‘built environment and noise’, and lastly ‘noise and surveys’. The chosen search terms and phrases were carefully selected as they were directly related to the chosen area of research. Only peer-reviewed literature published from 1999 to present and produced in the English language were included in the search.

2.2 Noise & The Built Environment

As of 2021, 73.7% of Canadians live within a large urban centre, and the trend of rapid population growth continues, leading to an increase in urban infrastructure (Statistics Canada, 2022). This type of urban sprawl and habitat fragmentation have decreased species diversity, but as outlined by Proppe and colleagues, what is lesser known is the contribution of anthropogenic noise to reduced species diversity (2013). The authors found songbirds to be a great species of study due to their reliance on acoustic communication. A strong relationship was found between lower diversity in songbirds and noisier anthropogenic areas, independent of vegetation. The ambient noise levels ranged from 30 to 60 dB(A), and higher noise levels were associated with closer proximity to roadways. The knowledgeable outcome of this study being that there is a

possibility to better manage the diversity of songbird populations by identifying and mitigating high levels of anthropogenic noise (Proppe et al., 2013).

The cascading environmental effects of anthropogenic noise to natural biota is of great significance in the fields of environmental science and sustainability. More than ever researchers are drawing this connection, and the recognition of pollution extending past just physical realms to the acoustic realms of free-living animals is finally being explored. A recent study published by Grunst and colleagues in 2021 followed sleep behaviour of the great tit songbird in their nesting boxes to see how their behaviour may change over a series of nights with variability and amplitude of traffic noise. The study used nesting boxes for the songbirds, and placed noise playback devices nearby. They starting at a baseline with no playback noise, then the following night increased to variable traffic noise measuring at 70 dB(A), and then 80 dB(A) the following night. The variability of noise had periods of quiet, and increasing amplitude through varying times of the night, and early morning to mimic that of usual road traffic. It was found that sleep was shorter lived and more fragmented for the songbirds who experienced 80 dB(A) of traffic noise through the night. A recommendation coming from this study is reducing or mitigating the presence of high amplitude traffic and variable noise at night with buffers may help both wildlife and human populations' sleep patterns and therefore lead to greater physiological health outcomes (Grunst et al., 2021). Both studies reveal that mitigation of high amplitude (loud) anthropogenic noise is necessary to assist the environmental health of free-living animals whom we share our urban environment with.

Noise levels vary spatially in the urban environment. In a large-scale study by McAlexander and colleagues, geospatial modelling of street-level noise measurements showed

that most locations throughout the city, even within pocket parks, exceeded or were equal to 70 dB(A). Regularly exceeding this level of noise is found to have negative implications for human health (McAlexander et al., 2015). Most significant noise levels were found to be around evening and early morning commuting time frames from traffic, but also at times when there were sirens, busy pedestrian traffic, and construction present (McAlexander et al., 2015).

However, there are still some elements of the relationship between noise and the urban environment that are still unclear. A knowledge gap that has been identified as per a systematic review of literature by Dzhambov and Dimitrova (2014) is that of green buffer zones, and how they may reduce some psychological health impacts of noise. Through examining the broad categories of interventional and observational studies in the systematic review, there was encouraging evidence found that green buffer zones such as zones of vegetation on roadsides or roof installations may help reduce the negative perceptions of noise. Further study is needed to understand the volume and types of vegetation that would play a role in the propagation of noise for the purpose of noise abatement and reductions in psychological stress induced by excess noise in the urban environment (Dzhambov & Dimitrova, 2014).

2.3 Noise Annoyance on Human Health & Well-Being

In a 2006 study published by Bjork and colleagues in Sweden, road traffic noise and its disturbance on participants' daily activities and health were examined. Participants reported increased levels of noise annoyance from road traffic. It was also found that road traffic exposure of <50 dB(A), 50-54 dB(A), and ≥55 dB(A) had positive associations with disturbance of participants' daily activities, concentration, and insufficient sleep. Levels of stress and

hypertension were also reported from traffic noise at these levels, creating greater potential for adverse health and financial outcomes (Bjork et al., 2006).

A cross-national study published by Stansfield and colleagues in 2005 analyzed the effect of aircraft and road traffic noise on children's mental cognition and health. They utilized on-site measurements for relative traffic noise, and noise contouring maps to match schools that were nearby major airports across the Netherlands, Spain, and the United Kingdom. Standardized testing and questionnaires were given to a total of 2844 children, aged 9-10 years old. A linear exposure-effect association was found between impaired memory recognition and aircraft noise. There was also a positive association found between road traffic noise and annoyance levels in children. The authors' findings indicate that the unpredictability of noise associated with sudden aircraft flyovers to be the likely reason for distraction from tasks leading to impaired memory recognition (Stansfield et al., 2005).

In a newly published article in the journal of *Cities & Health,* (2021), Mayes found that non-occupational exposure to urban noise levels today is high enough to cause auditory impairment in individuals. Defined within as irreversible auditory sensorineural damage, auditory impairment includes, but is not limited to issues such as accelerated age-related hearing loss and tinnitus. They express how it can greatly impact quality of life and interpersonal communication. The article calls for new immediate auditory safe listening limits to be set for public health. They note that the WHO has recommended noise levels to be a daily average of ≤70 dB(A), however, worldwide urban noise levels are frequently higher than this on average (Mayes, 2021).

The urgency in this regard for new public health guidelines on noise is especially dire for neurodiverse persons such as autistic adults and children, as there is a higher prevalence of noise sensitivity attributed to autistic adults in a community (Landon et al., 2016). As adults on the autism spectrum were interviewed, a common theme of anxiety, a level of annoyance that felt almost painful, and avoidant behaviours were followed in what participants described as high noise environments. High noise environments and sources varied for participants. Some noted noise from urban environments including cars, others mentioned indoor noise such as the buzzing from fluorescent lighting, but avoidant behaviours were often a result of sudden high-pitched noises in the urban environment such as children screaming or the stop bell from a bus. Avoidant behaviours included moments of intense desire to flee the occurring noise as well as issues with problem focusing when in a high noise environment (Landon et al., 2016).

2.4 Earlier Studies on Noise Annoyance Levels

There is good evidence to suggest noise annoyance as being a great indicator of noise levels in the urban environment. For example, Jackovljevic and colleagues found that there was a strong correlation between actual noise levels and self-reported perceived levels of noise annoyance (2009). Earlier literature on the phenomenon of noise annoyance suggests that noise annoyance is only partly brought on by acoustic factors, and is determined more by an individual's attitude (Stallen, 1999). At that time, however, research did not indicate a strong enough relationship between ambient noise levels and self-reported noise annoyance levels.

The International Commission on the Biological Effects of Noise highlights the importance of using comparable annoyance scales in quantitative studies surrounding levels of

community noise annoyance. With over 300 different surveys of community noise annoyance over 35 years, the authors point to the fact that there is no definitive way to compare communities past or present because of fluctuating noise annoyance scales within surveys. Phrase words such as “bother, annoy, or disturb” (p. 650), are examined and recommended to be back translated for languages other than English as they may take on different meaning (Fields et al., 2001). Ultimate recommendations from ICBEN’s Community Response to Noise Team (Team 6) as provided by Fields and colleagues (2001) are to use the following two questions in each survey forward in levels of community noise annoyance;

> “Q.V “Thinking about the last (..12 months or so..), when you are here at home, how much does noise from (..noise source..) bother, disturb, or annoy you; Extremely, Very, Moderately, Slightly or Not at all?"
>
> Q.N “Next is a zero to ten opinion scale for how much (..source..) noise bothers, disturbs or annoys you when you are here at home. If you are not at all annoyed choose zero, if you are extremely annoyed choose ten, if you are somewhere in between choose a number between zero and ten. Thinking about the last (..12 months or so..), what number from zero to ten best shows how much you are bothered, disturbed, or annoyed by (..source..) noise?”" (p. 651)

Building from the study by Team 6 above, Schreckenberg and colleagues have listed three psychometric item properties as a second-order construct to better assess multi-item annoyance scales from various sources of noise (2018). These three elements are as follows.

> “(1) the experience of repeatedly occurring noise-related disturbances and the behavioural response to cope with it, (2) an emotional/attitudinal response to the sound

and its disturbing impact, (3) the perception of loss of control of the noise situation, or in other words, the perceived lack of capacity to cope with noise" (pp. 2-3).

This second order construct as described by Schreckenberg and colleagues, helps the researcher attain greater depth and insight into the level of noise annoyance or disturbance-related event (2018).

In 2005, a study published by Michaud and colleagues examined noise annoyance in Canada. A popular method called the Schultz's original curve was used with the data as well as the two standardized questions in the study survey as outlined by Fields and colleagues (2001), which allow the data to be comparable to other similar studies surrounding levels of perceived noise annoyance. This was a very broad survey, gathering information on noise annoyance throughout the country over a series of telephone surveys. The results of the study affirmed at the time, that traffic noise was above all the most selected source of noise annoyance for Canadians and grouped individuals as more or less affected by the noise based on age, education, and community size (Michaud et al., 2005).

Sources of noise associated with sleep disturbances were analyzed in a study published by Perron and colleagues in 2016. Telephone surveys were also employed, similar to the Canadian-wide study produced by Michaud and colleagues in 2005, and focused on the city of Montréal, Québec. The researchers obtained postal codes from study participants and utilized land use regression modelling in their methods to better understand the sources of noise disturbances. Road traffic, railways, and airplanes were among the sources of noise examined, with road traffic being found to be the most significant source of noise disturbance (Perron et al., 2016).

2.5 Conclusion

The literature review has confirmed that noise can have a myriad of negative impacts on both the physical health and well-being of individuals living in urban areas such as stress, loss of income, trouble sleeping, and hypertension (Bjork et al., 2006; Landon et al., 2016). Even average noise levels in the urban environment have been found to exceed acceptable limits of ≥70 dB(A), which can cause irreversible damage to hearing (Mayes, 2021; McAlexander et al., 2015). Free-living animals such as birds have also shown sleep disturbance to night-time urban noise reducing their overall quality of life (Grunst et al., 2021). Species diversity in urban songbirds is greatly decreased from anthropogenic noise in the built environment (Proppe et al., 2013), and neurodiverse persons suffer extreme anxiety from everyday interactions due to urban noise (Landon et al., 2016). Most recent studies identify traffic as playing a significant role in noise annoyance and noise disturbances (Michaud et al., 2005; Perron et al., 2016). The use of noise annoyance scales and specific keywords in noise annoyance surveys are important. Integrating them into the research design allows survey response data to be easily compared or contrasted to other noise annoyance surveys of similar scale (Fields et al., 2001). Green buffers such as live vegetation can be a valuable means of reducing noise annoyance in urban environments (Dzhambov & Dimitrova, 2014).

CHAPTER 3: METHODS

3.1 Research Design

3.1.1 Main Objective The research design is based on the two main study objectives; *1) To explore the level of annoyance associated with noise in Halifax. 2) To investigate the sources of noise residents of Halifax find to be most annoying.* Using an online survey as the research instrument (see Appendix C), participants responded to questions surrounding their levels of noise annoyance while at home or in their neighbourhood over the last 12 months, and the main sources of their identified noise annoyance. The survey design parallels noise annoyance studies such as those conducted by Michaud and colleagues' (2005) telephone survey, utilizing multi-item annoyance scales (Schreckenberg et al., 2018), and following recommendations from the International Standards Organization (ISO) on acoustic assessment surveys of noise annoyance (Fields et al., 2001).

3.1.2 Recruitment Participants who reside in Halifax had the opportunity to voluntarily complete the anonymous online survey. The surveys were completed with data collected through Opinio, a secure online survey portal. The survey took 8-10 minutes to complete and consisted of demographic questions related to age, sex, gender, participant postal codes, as well as perspectives on levels and sources of noise annoyance. Recruitment for the survey occurred primarily over social media platforms Facebook and Instagram. A small online posting with the title of the study, the incentive given to participants and an image identifying the survey as related to noise can be found on the recruitment document in Appendix D, Figure 11. Targeted ads were used upon these platforms to recruit Halifax residents aged 18 years and older. As

recently identified in the *BMC Medical Research Methodology* journal, social media advertisements have proven to be an effective tool in collecting responses from web-based surveys quickly and efficiently (Ali et al., 2020).

3.1.3 Incentive Incentive to participate in the study, as noted on the recruitment document in Appendix D, came with a chance to win a pair of noise-reducing LOOP ear plugs (https:// www.loopearplugs.com/), following research data collection and analysis. Non-financial incentive to participants included, but was not limited to, being a part of a research study, which may positively affect the future health and viability of the Halifax community. Participants were notified of this non-financial incentive within the consent form (see Appendix B). Participants were also briefed on how data from the research study would afterwards be stored in a public research database and have the potential for research findings to be published within a scientific journal to expand scientific knowledge on the topic of noise annoyance.

3.1.4 Research Ethics Upon the survey's landing page, the consent script (see Appendix B), had to be acknowledged before the participant was able to continue to the survey questions. The consent script was imperative to ensure participants understood the purpose of the study, what they could expect from providing their data, the types of questions asked, and how their data would be safely and securely stored thereafter. The information surrounding the study within the consent form (Appendix B), was exhaustive and ensured the participant was comfortable with the risks associated with the study before taking part. The research participant initiated their consent into the study by clicking the 'continue to survey' link at the bottom of the

survey landing page. The research study was given approval to proceed from Dalhousie's research ethics board on January 20, 2022, with REB # 2022-5962 (see Appendix A).

3.2 Sample Population

The target study population consisted of residents of Halifax including the urban geographic areas of Bedford, Rockingham, Fairview, Spryfield, Dartmouth, and other urban areas encompassed generally as Halifax Regional Municipality (HRM). Previous research has illuminated a relatively strong relationship between urban form and ambient noise levels, particularly from land uses associated with commercial and truck transportation activities (Jackovljevic et al., 2009; Perron et al., 2016). According to population data from the 2016 Canadian census, approximately 403,390 people reside in Halifax (Statistics Canada, 2017). To provide a representative population, it was determined that 384 participants would be required to detect statistically significant differences in self-reported measures of annoyance based on prevalence rates from similar studies (Michaud et al., 2005), using a level of confidence (Z) of 95%: $n = \frac{Z^2\, P(1-P)}{d^2}$ where P is the expected prevalence.

3.3 Instrumentation & Materials

Survey questions were logged and acquired through Dalhousie's Opinio secure survey service. Data logged into the secure Opinio server were exported directly into the Microsoft Excel platform to perform data analysis. Aggregated data were also geocoded based on the postal code of respondents and mapped in ArcGIS Pro (Esri Inc., 2020).

3.4 Variables in the Study

The variables in the study follow similar research into noise annoyance levels (Michaud et al., 2005; Perron et al., 2016), including questions related to sociodemographic indicators such as age, sex, gender, postal codes, and various living/income levels as shown in Appendix C, questions (1) and (17)-(21). Question (21) sought to explore the income of the participants relative to their neighbours by asking whether their income was the same, higher, or lower than that of their neighbouring households (see Appendix C). Question (20) in Appendix C asked what type of housing the participant occupied, such as detached, semi-detached, townhouse, high rise apartment building, low rise apartment building (<5 floors), or other, to understand if noise annoyance levels may differ according to housing type. Specific five-point and ten-point scaling questions (questions (4), (5) and (7) in Appendix C) focused on how much noise bothers, disturbs, or annoys respondents have been developed into the survey following the recommendations from the International Standards Organization (ISO) on acoustic assessment surveys of noise annoyance (Fields et al., 2001). Following the literature review, the ISO released a two-decade review for both scaling type questions in community noise annoyance surveys deeming them still as relevant and acceptable with room for minor changes in wording for location and time frames (Clark et al., 2021). Further deliberation was done and the wording ‘here at home’ was removed to be replaced with ‘at home’ in many of the scaling questions to ensure accuracy and avoid confusion as many participants may not be presently at home when taking the survey on for example, from their personal devices. Question (15) in Appendix C uses the clarity of a five-point scaling question as well to gage respondents' sensitivity to noise. Understanding potential co-determinants of annoyance such as sensitivity to noise and the ability

to cope with noise (see Appendix C, questions (5) and (10)) are valuable data to gather for use in future analysis or study extending past this research (Schreckenberg et al., 2018). Other variables included in the survey that have been derived from previous studies are open-ended responses to questions (9) and (11) which allow the respondent to identify their most common sources of noise annoyance (Michaud et al., 2005).

3.5 Data Analysis

3.5.1 Statistical Analysis The data were exported from Opinio to Microsoft Excel where descriptive statistics were conducted. There, simple statistics such as counts, and percentages were calculated for survey questions relating to level of noise annoyance (see questions (7) and (8) in Appendix C), as well as demographic indicators (see questions (17-18) to (20-21) in Appendix C). For the ten-point scaling questions such as question (7) in Appendix C on levels of noise annoyance, responses with a value of 7 or higher were deemed as high annoyance. This is in accordance with the ISO on acoustic assessment surveys of noise annoyance (Fields et al., 2001). Medium annoyance was then characterized as 4-6 on the scale, and low annoyance levels as 1-3. The noise annoyance scale has been reduced from the prescribed eleven-point to a ten-point scale in the process of survey design as it was found to be more visually concise for the respondent based on limitations encountered on the chosen survey platform. Measures of central tendency such as mean and median, were auto reported through the secure Opinio service and captured for the ten-point scaling question such as question (7) (see Appendix C).

3.5.2 Coding Analysis The open-ended survey response data from questions (9) and (11) as seen in Appendix C were run through Microsoft Excel for manual coding analysis. Initial

stages of analysis with this qualitative data consisted of a mixture of in vivo and emergent coding analysis. As common themes emerged through these data, both pattern and focused coding were performed to understand the most significant noise annoyance source(s) from participants' open-ended responses. This last stage of coding was pertinent to ensure the categories identified in the first stage of qualitative analysis were not repetitive or overlapping, but instead exhaustive of all described noise annoyance sources.

3.5.3 Spatial Representation The relative locations of survey respondents were geocoded and mapped through ArcGIS Pro (ESRI Inc., 2020). This was done to display the approximate spatial distribution of responses from urban, suburban, and/or rural areas. A symbolized representation was used to display the frequency of total survey responses per postal code.

CHAPTER 4: RESULTS

The target response quota for the research study was exceeded, reaching a total of 468 completed survey responses. All 468 participants were identified as Halifax residents as verified by the geocoded data. Below in Table 1, the overall count (#) and proportion (%) of survey respondents are shown with the sociodemographic indicators included.

Table 1

Total count and percentage of survey respondents and their corresponding sociodemographic criteria, n=468

Age Groups	Frequency	Proportion
22-39	151	32%
40-59	195	42%
60-85	114	24%
Undisclosed	8	2%
Sex		
Female	358	76%
Male	89	19%
Undisclosed	8	5%
Income Relative to Neighbourhood		
Same	278	59%
Lower	110	24%
Higher	73	16%
Undisclosed	7	1%
Housing Type		
Detached	252	54%
Semi-Detached	33	7%
Townhouse	29	6%
High Rise Apartment	49	10%
Low-Rise Apartment (<5 Floors)	74	16%
Other	24	5%
Undisclosed	7	2%

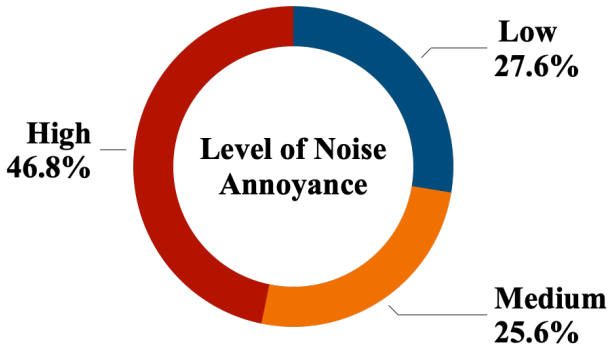
4.1 Level of Annoyance

As shown in Figure 1, the largest proportion of responses for question (7) understanding how bothered, annoyed, or disturbed residents were with outdoor noise over the last 12 months or so, was 46.8% in the high annoyance category. Overall, 129 out of 468 respondents (27.6%) were within the low category, 120 out of 468 respondents (25.6%) were in the medium category,

and 219 out of 468 respondents (46.8%) resonated with the high annoyance category. Both the median and mean number on the scale for the response was 6.

Figure 1

Proportion of Responses for Level of Noise Annoyance



Note. The greatest proportion of survey respondents were found to be in the high annoyance category regarding outdoor noise while at home over the last 12 months or so.

To better understand the relationship between level of noise annoyance and the study population, demographic variables such as sex (Tables 2 and 5), age (Tables 3 and 6), and household income (Tables 4 and 7) were analyzed alongside question (7)'s response categories of low, medium, and high annoyance. As shown in Table 2 below, within the low annoyance category 28 out of 129 (21.7%) respondents were male, 97 out of 129 (75.2%) were female, and 4 out of 129 (3.1%) did not disclose their sex. Within the medium annoyance category, 21 out of

120 (17.5%) respondents were male, 94 out of 120 (78.3%) were female, and 5 out of 120 (4.2%) did not disclose their sex. A total of 219 residents were within the high annoyance category, 40 (18.3%) male, 167 (76.2%) female, and 12 (5.5%) undisclosed.

Table 2

Noise Annoyance Scale Associated with Sex (counts)

Sex	Low annoyance	Medium annoyance	High annoyance
Male	28	21	40
Female	97	94	167
Undisclosed	4	5	12
Total	129	120	219

Study participants' ages ranged from 22 to 85 years as defined by the input of their birth year from question (17) in the survey (see Appendix C). Age categories were broken up from ages 22 to 39 (1983-2000), 40 to 59 (1963-1982), and ages 60 to 85 (1937-1962) respectively. 1972 was found to be the median birth year, and 1976 the overall average.

Table 3

Noise Annoyance Scale Associated with Age (counts)

Age	Low annoyance	Medium annoyance	High annoyance
22-39	51	38	62
40-59	58	50	87
60-85	19	31	64
Undisclosed	1	1	6
Total	129	120	219

Table 4

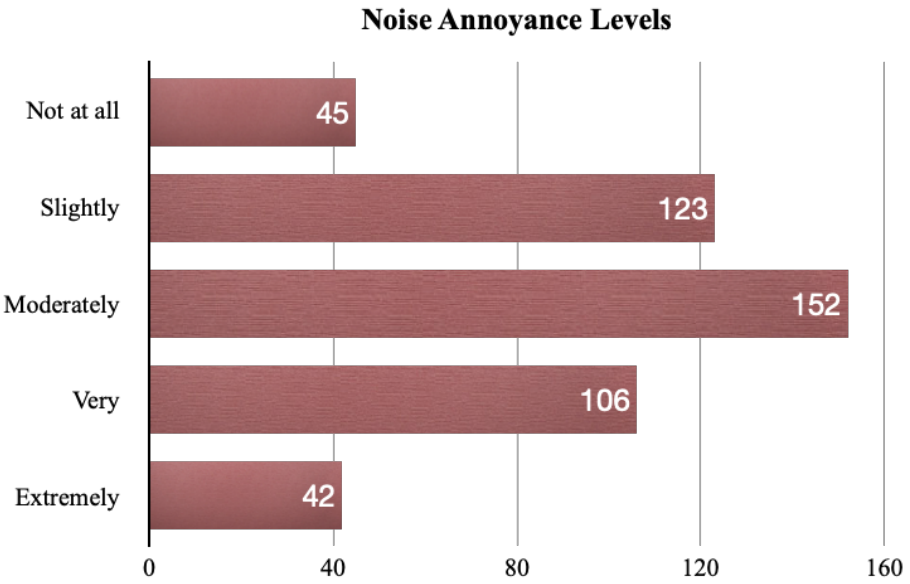
Noise Annoyance Scale Associated with Relative Neighbourhood Income (counts)

Income	Low annoyance	Medium annoyance	High annoyance
Same	82	68	128
Lower	22	35	53
Higher	24	16	33
Undisclosed	1	1	5
Total	129	120	219

Question (8) within the study survey (Appendix C) provides a descriptive rating for the respondents' perceived level of noise annoyance they experience when outside their home and in their neighbourhood. As displayed in Figure 2, the largest proportion of responses considered themselves as 'moderately' annoyed by outdoor noise. Overall, 152 out of 468 respondents (32.5%) chose moderately annoying, 45 out of 468 respondents (9.6%) chose 'not at all', 123 (26.3%) individuals chose 'slightly', 106 (22.7%) chose 'very', and lastly 42 (8.9%) selected their outdoor noise they experience as being 'extremely' annoying, bothersome or disturbing.

Figure 2

Proportion of Responses for Perceived Noise Annoyance Level



Note. Proportion of responses for noise annoyance levels (from question (8) when outside in their neighbourhood) are favourable towards the 'moderately' annoying category.

Table 5

Noise Annoyance Level Associated with Sex (counts)

Sex	Not at all	Slightly	Moderately	Very	Extremely
Male	10	27	26	17	9
Female	34	90	122	80	32
Undisclosed	1	6	4	9	1
Total	45	123	152	106	42

Table 6

Noise Annoyance Level Associated with Age (counts)

Age	Not at all	Slightly	Moderately	Very	Extremely
22-39	20	46	47	28	10
40-59	19	60	57	40	19
60-85	6	16	46	35	11
Undisclosed	0	1	2	3	2
Total	45	123	152	106	42

Table 7

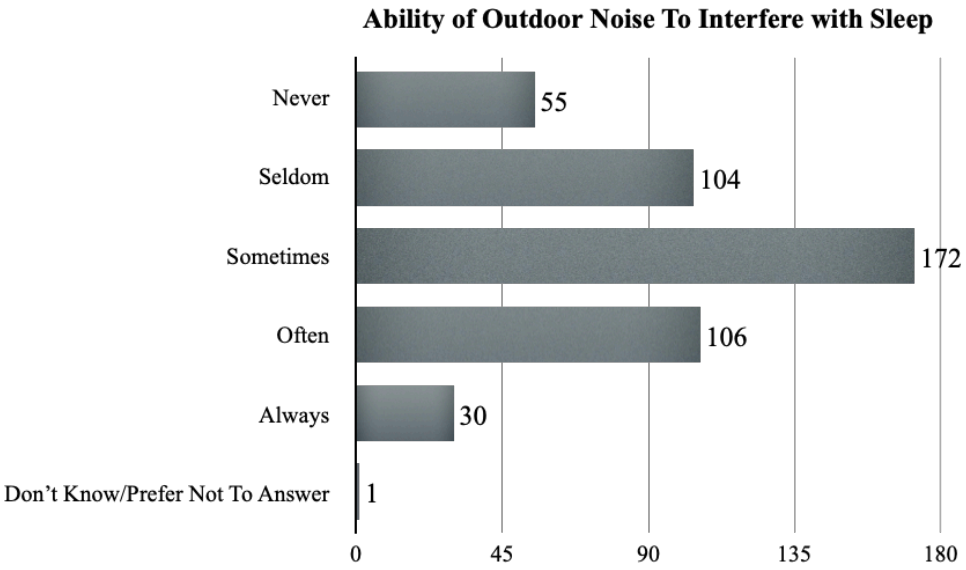
Noise Annoyance Level Associated with Relative Neighbourhood Income (counts)

Income	Not at all	Slightly	Moderately	Very	Extremely
Same	30	72	87	63	26
Lower	7	30	45	20	8
Higher	8	20	18	20	7
Undisclosed	0	1	2	3	1
Total	45	123	152	106	42

4.1.2 Ability to Cope with Noise Annoyance

Figure 3

Proportion of Responses for question (10) in Appendix C; "Over the past 12 months or so, while you were at home, did outdoor noise never, seldom, sometimes, often, or always interfere with your ability to sleep?"

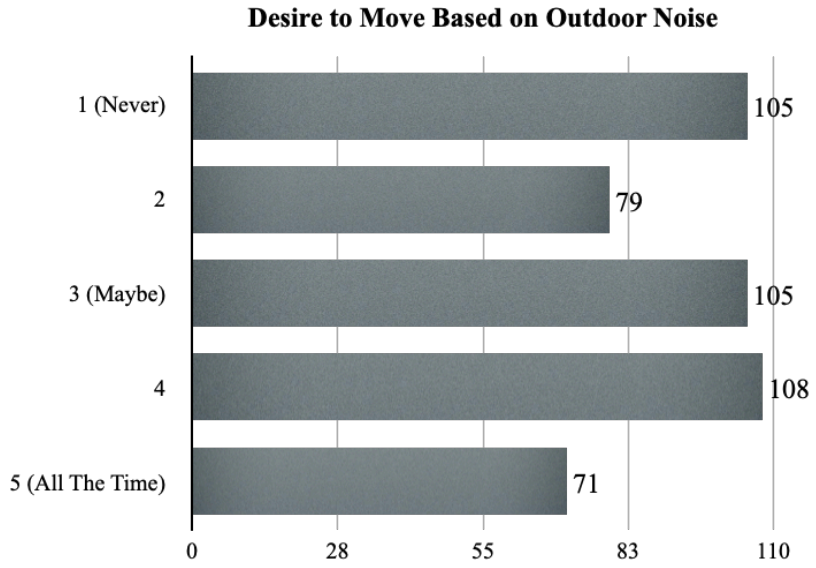


Note. Results were mixed in Fig 3, with the largest count identifying outdoor noise as 'sometimes' interfering with residents' ability to sleep.

One of the three second order constructs as defined by Schreckenberg and colleagues to better understand annoyance scales were with the ability to cope with noise (2018). The survey questions (10), asking if noise interferes with sleep, and (5) asking if noise has ever influenced a desire to move locations (see Appendix C) were examined for their total counts. Figure 3 above shows the result of total counts relating to survey question (10).

Figure 4

Proportion of Responses for question (5) in Appendix C; "Has noise in your neighbourhood/ outside your home ever made you feel that you should move to another location?"



Note. Results were mixed in Figure 4, with the largest count identifying outdoor noise as influencing an often desire to move locations because of it.

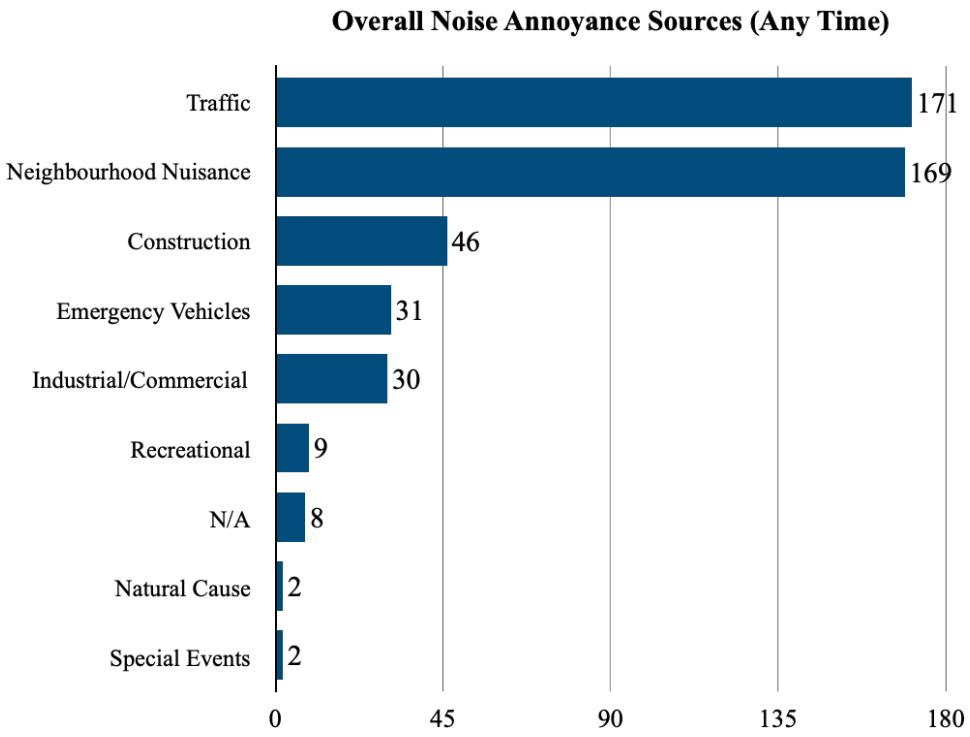
The results from survey question (5), as shown in Figure 4 above indicate a mixed form of responses again, but the largest proportion of residents selected a number (4) on the scale, revealing a relative desire to move locations based on noise outside their dwelling and in the neighbourhood. Mean and median values were also analyzed, giving a value of (3) on the scale.

4.2 Noise Annoyance Sources

Noise annoyance sources are analyzed below from the participant responses of open-ended survey questions (9), and (11) (see Appendix C). Question (9) asked what the most annoying sources of noise were from outside the home when at home, and question (11) asked what the primary source of noise was coming from outside the home that interferes with sleeping. Respondent data from these questions were coded qualitatively by analyzing overall trends in the data, and then breaking them down categorically and sub-categorically by most significant trends found.

Figure 5

Proportion of responses for any-time noise annoyance sources from survey question (9)

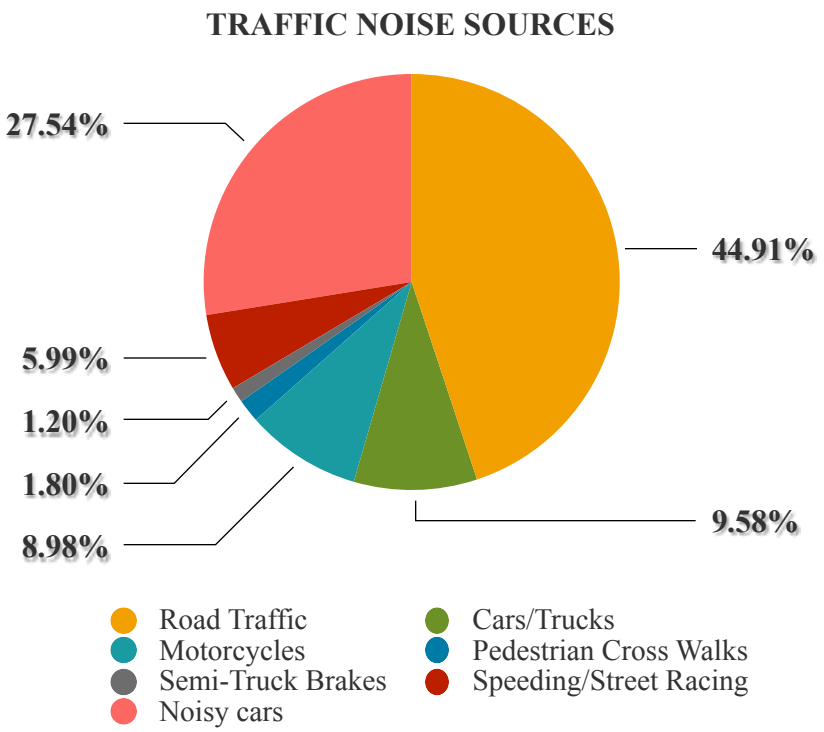


Note. Proportion of responses towards greatest noise annoyance sources show traffic as the dominant category followed by neighbourhood nuisance. Only the first noise source identified on the respondents' list (most significant source) was codified for this analysis.

As shown in Figure 5 above, the most annoying source of noise overall at any time coming from outside the home when at home is traffic followed by neighbourhood nuisance. To better understand the subcategories within the two most significant categories, they have been displayed below in Figure 6, and Figure 7.

Figure 6

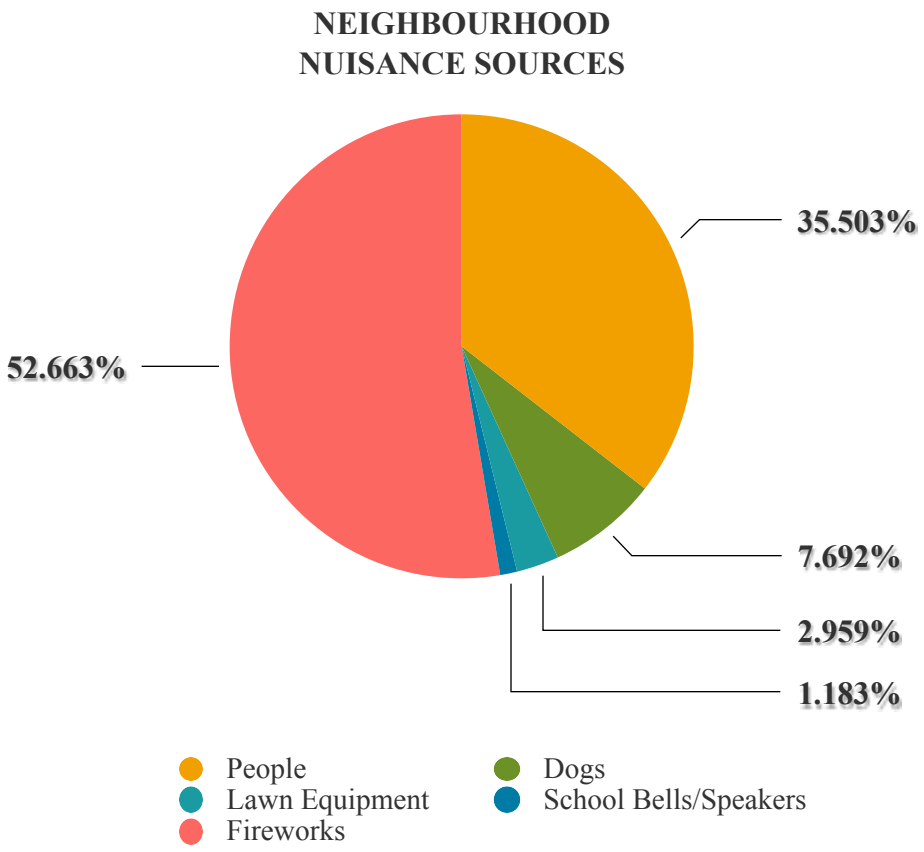
Proportion of responses divided into subcategories within the larger general traffic category



Note. Proportion of responses towards greatest noise annoyance sources identified road traffic explicitly as the dominant source followed by what was noted as 'noisy' cars. Respondents identified 'noisy' cars implicitly and explicitly. Implicit responses were identified within the 'noisy' subcategory with language such as 'modified exhaust systems', 'purposefully loud', 'loud engines', and/or 'revving engines.

Figure 7

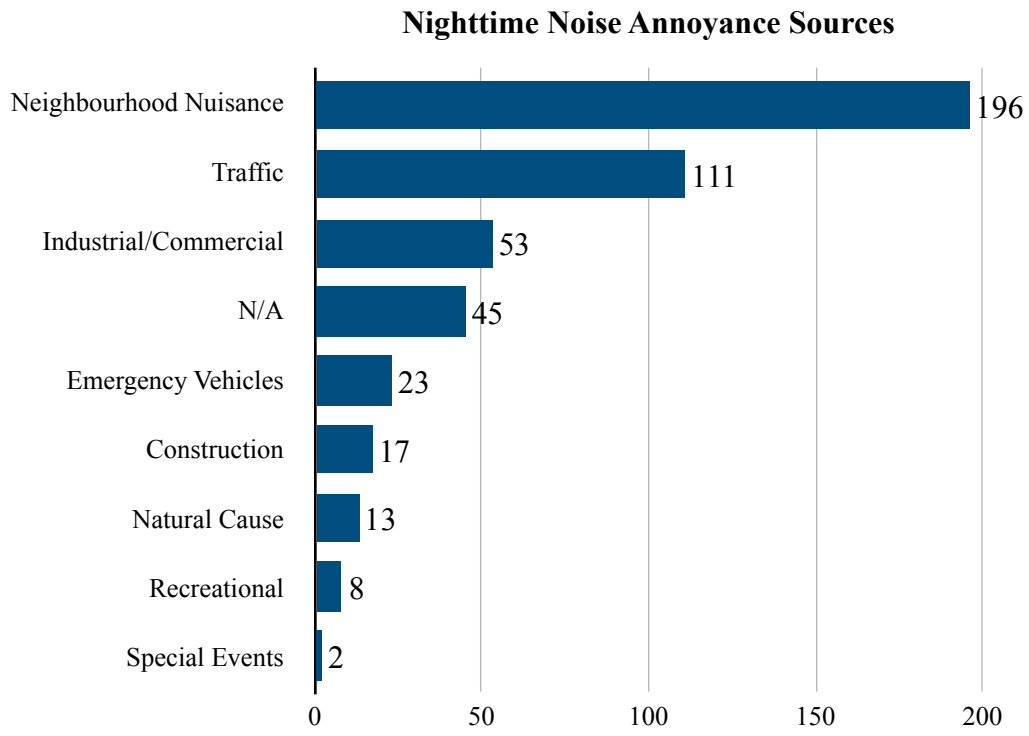
Proportion of responses from neighbourhood nuisance category shown within their noise annoyance source subcategories



Note: Proportion of responses towards greatest noise annoyance sources identified fireworks explicitly as the dominant neighbourhood nuisance source by stating they were ‘random’ or in their backyard, and/or frequently at unusual times. followed by what was noted generally as people. Respondents identified people often explicitly in their responses. Explicitly responses were identified within the ‘people’ subcategory with language such as ‘people next door’, ‘people across the street’, ‘partying next door’, and/or ‘people shouting loudly’.

Figure 8

Proportion of categorical responses from primary nighttime noise annoyance sources that interferes with sleep (survey question 11)

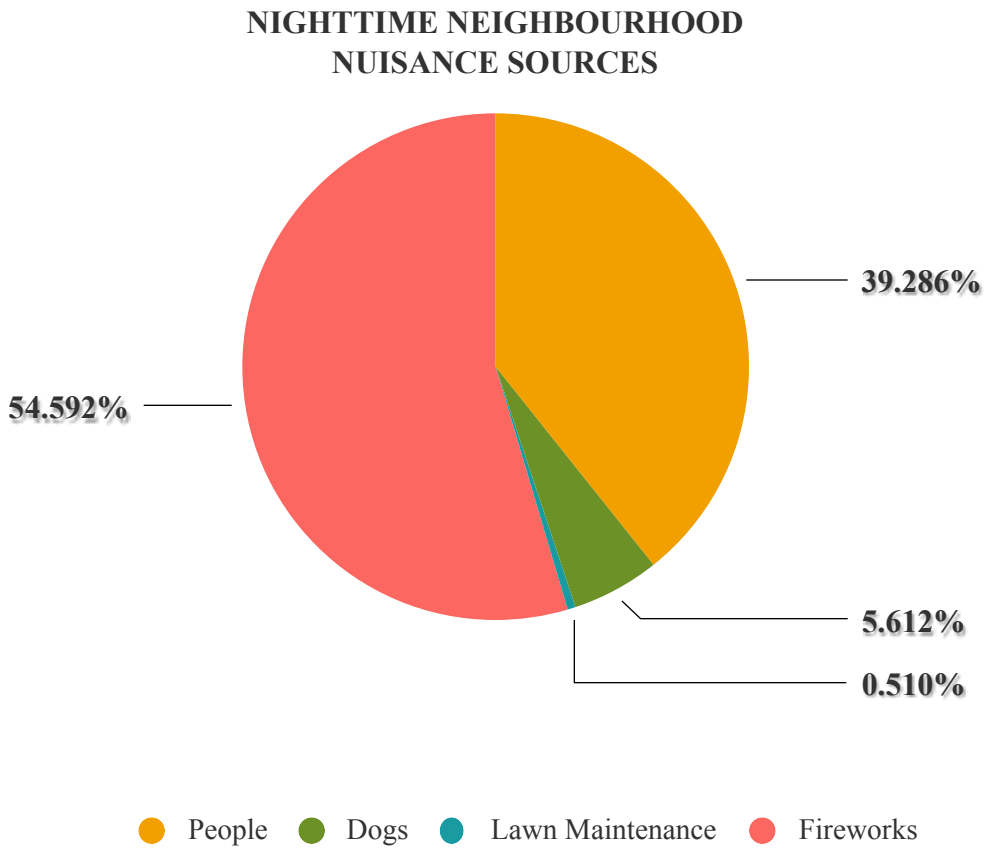


Note. Proportion of responses towards primary noise annoyance sources show neighbourhood nuisance as the dominant category followed by traffic.

As shown in Figure 8 above, there are remarkably similar noise annoyance sources chosen from study participants from question (9) carried through to question (11). Below in Figure 9, subcategories of neighbourhood nuisance noise sources are identified from question (11) analyzing more specifically the nighttime disturbance.

Figure 9

Proportion of sub categorical responses from primary nighttime noise annoyance sources that involve neighbourhood nuisance (survey question 11)



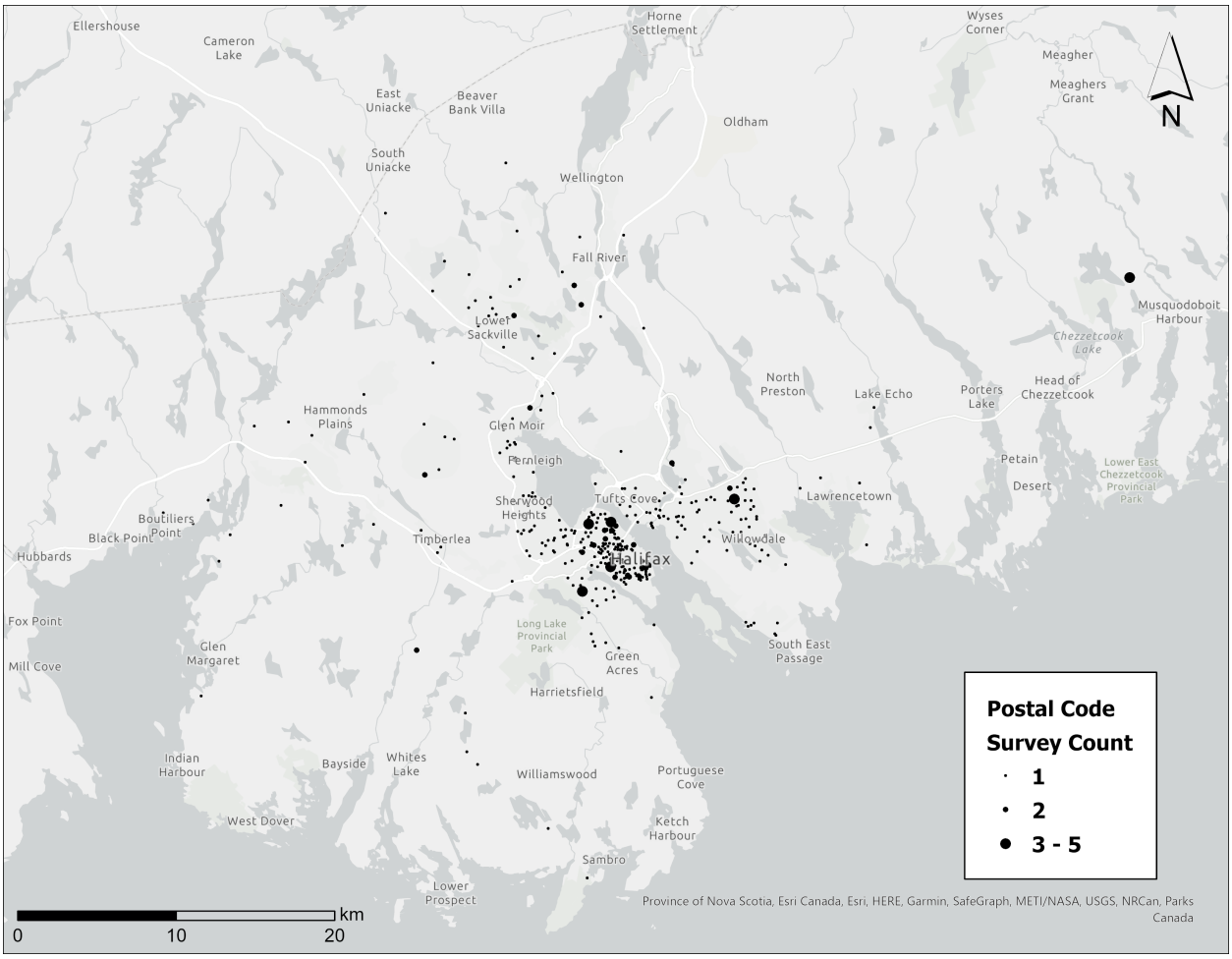
Note: Proportion of responses towards primary night time noise annoyance sources involving neighbourhood nuisance show fireworks (55%) as the dominant category followed by people (39%).

4.3 Spatial Representation of Survey Respondents

To investigate where highly annoyed residents were relatively distributed, the data was geocoded according to resident's postal code, and the centroid of the postal code polygon was found in ArcGIS Pro (Esri Inc., 2020). The centroid of the postal code polygon was then symbolized and mapped according to the frequency of surveys completed in each postal code. It can be seen in Figure 10 below that many residents from across the HRM participated in the survey, with the greatest frequency of respondents seemingly within downtown Halifax.

Figure 10

Frequency of Survey Respondents within Halifax Regional Municipality (HRM)



Note: Spatial Reference: NAD 1983 UTM Zone 20N

Postal Code Data: DMTI Postal Code Suite v2021.3

Mapped By: Kayla S. Rekowski, March 25, 2022

CHAPTER 5: DISCUSSION

The purpose of this research study is to investigate what level of annoyance residents of Halifax associate with noise outside their home or in their neighbourhood and what the most significant sources of noise annoyance are for residents. The research objectives are important to investigate due to the negative physical and mental health impacts noise can bring such as traffic noise being a significant source of stress, leading to sleep disruption, and hypertension (Bjork et al., 2006; Münzel et al., 2020). Previous research has also shown a link between reduced species diversity and reduced ability to communicate within high noise annoyance environments (Proppe et al., 2013; Rosa & Koper, 2018). Noise that is characterized as sudden and high amplitude is known to trigger anxiety and pain in some (Landon et al., 2016), and cause issues with memory recognition in children (Stansfield et al., 2005).

The results of this research reveal that Halifax residents are moderately to highly annoyed by noise in their home and neighbourhood. Ages 40-59 were found to be extremely or highly annoyed by noise than other age categories. Female respondents (76% of all respondents) were more annoyed with the level of noise in their neighbourhood. Respondents with the same comparable income as their neighbours were found to be highly to extremely annoyed by noise in their neighbourhood compared to those with an income which was lower or higher than that of their neighbours. In terms of coping with noise annoyance, the largest count of residents indicated that they were open to moving to another location given their level of annoyance with outdoor or neighbourhood noise. Noise was also identified as sometimes and often interfering with residents' ability to sleep.

Road traffic has been shown to be a common annoyance at any time and at nighttime. Neighbourhood nuisances tend to also be a significant noise annoyance source for the same time periods with fireworks identified as the main source of evening and overnight noise interfering with respondents' sleep. More than half of the responses within the neighbourhood nuisance category for nighttime and all the time were identified as fireworks. This is a relatively new finding for noise annoyance study within Canada, with the prevailing research identifying road traffic as the most common noise annoyance source (Michaud et al., 2005; Perron et al., 2016). Perron and colleagues research findings (2016), were derived from telephone surveys which had participants scale how annoyed they were with (8) pre-defined categories of noise sources (Ragettli et al., 2016). Although neighbourhood sources were a category within the Montréal survey for noise annoyance sources, the survey responses were not open-ended as in this research. The Canada-wide noise annoyance survey from Michaud and colleagues (2005), however, did ask participants what type of noise source was most annoying as an open-ended query, but this survey did take place over fifteen years ago and had a larger target population. The aim of this study was to represent resident noise annoyance levels for Halifax in the present day. Another factor that should be considered is the variability of noise by-laws in cities across Canada. For instance, in Montréal, fireworks are deemed illegal to use unless you have a permit from the fire department, and there are now increased fines for citizens of Montréal-Nord who do not abide by this law due to an increase in firework noise complaints stemming from the summer of 2020 (Mignacca, 2020). This is in direct contrast to the city of Halifax. Although HRM's Respecting Noise By-Law does restrict when fireworks can be used, they do not have a fireworks

specific by-law, or enforcement of fines for use of fireworks outside of the current legislation (Halifax Regional Municipality, 2022).

5.1 Limitations of Research

There are, however, limitations to this study. As noted earlier in the statistical analysis (section 3.5.1), the noise annoyance scale for survey question (7) in Appendix C had been reduced from the prescribed eleven-point scale (Fields et al., 2001) to a ten-point scale in the process of survey design due to limitations encountered on the Opinio survey platform. This reduces the absolute comparability of the study's results to other community noise annoyance surveys. Going forward, it may be wise to choose an alternative online survey platform, or another survey method that is able to display the full eleven-point noise annoyance scale to the study participant.

Both recruitment and participation into the research survey were based upon access to reliable internet through a personal device or a computer. In this way, the research may have unintentionally excluded lower-income individuals from participating who were unable to easily access the internet. It has been shown that income can have a direct and indirect effect on noise annoyance, with better-off individuals having the advantage of 'buying their way out' of the issue (Preisendörfer et al., 2022). In the future, designing the study to capture the study population more equitably across all income levels may then garner a wider variety of responses from residents who may have valuable insight into noise annoyance levels due to their inability of 'buying their way out' of the issue.

Lastly, the research sought to identify resident postal codes, but not civic addresses. This limits the research in understanding where significant noise annoyance sources such as traffic are most predominant. A future study into community noise annoyance levels in Halifax should aim to understand this. This would allow a better understanding into where specific buffers or other noise abatement solutions could be considered.

5.2 Recommendations

With traffic being one of the predominant sources of annoyance, the addition of green buffer zones may help reduce the amplitude of noise as earlier identified in the literature (Dzhambov & Dimitrova, 2014). The secondary source of noise annoyance, fireworks, has potential to be reduced dramatically if reduction measures, such as a fireworks specific by-law and subsequent fines, were considered in the city of Halifax to limit the sale and use of backyard fireworks. As fireworks are a nuisance to not only humans, but the natural environment as well (Halifax Regional Municipality, 2022; Lai & Brimblecombe, 2020), Halifax could have a positive impact forward towards overall sustainability by heavily limiting this noise annoyance source.

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APPENDICES

Appendix A: Research Ethics Board Approval

DALHOUSIE UNIVERSITY
Research Services

Social Sciences & Humanities Research Ethics Board
Letter of Approval

January 20, 2022
Kayla Rekowski
College of Sustainability\College of Sustainability

Dear Kayla,

REB #: 2022-5962
Project Title: Halifax Noise Study

Effective Date: January 20, 2022
Expiry Date: January 20, 2023

The Social Sciences & Humanities Research Ethics Board has reviewed your application for research involving humans and found the proposed research to be in accordance with the Tri-Council Policy Statement on *Ethical Conduct for Research Involving Humans*. This approval will be in effect for 12 months as indicated above. This approval is subject to the conditions listed below which constitute your on-going responsibilities with respect to the ethical conduct of this research.

Effective March 16, 2020: Notwithstanding this approval, any research conducted during the COVID-19 public health emergency must comply with federal and provincial public health advice as well as directives from Dalhousie University (and/or other facilities or jurisdictions where the research will occur) regarding preventing the spread of COVID-19.

Sincerely,

Dr. Karen Foster, Chair

Appendix B: Consent Form

The purpose of this study is to investigate your perception of noise levels in Halifax.

The study is being conducted by Kayla Rekowski and Daniel Rainham from the College of Sustainability and the Faculty of Health at Dalhousie University.

Should you choose to participate in the study you will be asked to complete a short online survey approximately 8-10 minutes in length. Your responses will be anonymous, and the information collected will have no way to identify you personally. You may choose to opt-out of the study at any time. Data collected by the survey are held on a secure server at Dalhousie University and are only accessible to the research team. Data will be kept available to the Research Ethics Board, if required for auditing purposes. These data will be kept for two years. After the two-year period, data will be deposited into Dataverse, a publicly accessible data repository platform, and a request for permission to access the data will be required from the supervisor (Rainham). A summary of the results from the study will be available online at: http://danielrainham.ca, and will be published as part of an undergraduate thesis research project and as a manuscript to be submitted to a peer-reviewed journal.

Benefits of the Study: Recent research indicates that excessive levels of noise can lead to an increase in stress, sleep interruptions and long-term health impacts. The results of this study will be extremely valuable for municipal planners, decision makers and public health researchers who require input on how best to create healthy and viable communities.

Potential Risks Involved: There is minimal risk involved in this study. Your involvement will consist of sharing your opinions about sources and levels of noise.

Consent: I agree to participate in the Halifax Noise Survey conducted by Kayla Rekowski and Daniel Rainham from Dalhousie University.

Should you have any questions regarding this research project, please contact Kayla Rekowski (k.rekowski@dal.ca) or Daniel Rainham (dr@dal.ca).

If you have any questions with regards to the ethical conduct of this study, you may contact the Research Ethics office at Dalhousie University by phone (902) 494-3423) or by email: ethics@dal.ca.

If you agree to complete the survey, please **click the link below to begin the survey.**

Continue to Survey

Appendix C: Participant Survey

INCLUSION CRITERIA:

You are required to be at least 18 years of age to complete this survey. Please confirm this below in order to continue

- Yes, I am at least 18 years of age

SECTION A: LOCATION

In order to compare your responses to data on noise levels and sound environment characteristics, we require information about your location. Note that this will not be used to identify you and that your information will be stored on a secure database at Dalhousie University.

1. What is your postal code?

   _____

SECTION B: NOISE PERCEPTION

2. How pleasant are the sounds you experience when you are **in your neighbourhood/ outside your dwelling**?

   1= very unpleasant, 9=very pleasant

   1 2 3 4 5 6 7 8 9

3. How calming, or stressing are the sounds you experience when you are **in your neighbourhood/outside your dwelling**?

   1= calm, 9=stressed

   1 2 3 4 5 6 7 8 9

4. How stressful does sound **in your neighbourhood/outside your dwelling** make you feel?

   1=not at all, 10=extremely

   1 2 3 4 5 6 7 8 9 10

5. Has **noise in your neighbourhood/outside** your dwelling ever made you feel that you should move to another location?

   1=never, 3=maybe, 5=all the time

   1 2 3 4 5

6. Thinking about the last 12 months or so, **when you are at home, how much does outdoor noise** bother, disturb or annoy you?

- ○ Not at all
- ○ Slightly
- ○ Moderately
- ○ Very
- ○ Extremely

7. Thinking about the last 12 months or so, **when you are at home**, what number from 1 to 10 best shows how much you are bothered, disturbed or **annoyed by outdoor noise**?

   1= not at all annoyed; 10= extremely annoyed

   1 2 3 4 5 6 7 8 9 10

8. Thinking about the last 12 months or so, **when you are outside in your neighbourhood**, how much does **outdoor noise** bother, disturb or annoy you?

- ○ Not at all

- Slightly
- Moderately
- Very
- Extremely

9. When you are **at home** what are the most annoying sources of noise from outside your home in order from most annoying to least annoying?

_____

_____

_____

_____

_____

10. Over the past 12 months or so, **while you were at home**, did **outdoor noise** never, seldom, sometimes, often or always interfere with your ability to sleep?

- Never
- Seldom
- Sometimes
- Often
- Always
- Don't know/Prefer not to answer

11. What is the primary source of noise from outside your home that interferes with sleeping?

_____

12. If you are employed outside of your home, are you currently exposed to loud noise(s) while at work?

- Yes
- No

- Don’t know/Prefer not to answer
- I work from home

13. Do you have noise-induced hearing loss?

- Yes
- No
- Don’t know/Prefer not to answer

14. Do you have any other hearing problems, including but not limited to tinnitus (ear ringing) or age-related hearing loss?

- Yes
- No
- Don’t know/Prefer not to answer

15. Would you say you are sensitive to noise?

- Not at all
- Slightly
- Moderately
- Very
- Extremely

16. Thinking about the last 12 months or so, how would you say that noise **in your neighbourhood** has impacted your quality of life?

-5 -3 0 3 5
-5: very negatively; -3: negatively; 0: neutral; 3: positively; 5: very positively

C: DEMOGRAPHIC INFORMATION

17. What is the year of your birth (e.g., 1973)?

_____

18. What was your sex at birth?

- Female
- Male
- Prefer not to say

19. What is your gender? (please select any that apply)

- Female (cisgender or transgender)
- Male (cisgender or transgender)
- Nonbinary
- Fluid
- Prefer not to say

20. What type of housing do you reside in?

- Detached
- Semi-detached
- Townhouse
- Low-rise apartment building (less than 5 floors)
- High-rise apartment building
- Other (Please specify):_____

21. Is your household income about the same, lower, or higher than other households in your neighbourhood?

- Same
- Lower
- Higher

Thank you for your participation in this study. If you would like to be entered into the draw for a pair of LOOP earplugs, then please click the link below. You will be redirected to a separate survey where you can provide us with your preferred method of contact. If you do not provide a method of contact, we cannot enter you into a prize draw.

- Mailing address
- Email
- Telephone Number

Appendix D: Recruitment Posting

Figure 11

Online Recruitment Posting Graphic

Residents of Halifax:

We invite you to participate in our study of noise levels in Halifax. Complete the short online survey (https://bit.ly/noisehfx) and you could win a set of Loop earplugs!

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