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JASA ARTICLE

A comparison of self-reported health status and perceptual responses toward environmental noise in rural, suburban, and urban regions in Canada

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ABSTRACT:

Health Canada, in collaboration with Advanis, conducted the *Canadian Perspectives on Environmental Noise Survey* (CPENS) to investigate expectations and attitudes toward environmental noise in rural and non-rural Canada. The CPENS, a 26-item questionnaire, was completed online by 6647 randomly selected Canadians, age 18 y and older between April and May 2021. The prevalence of reporting their area as often or always calm, quiet, and relaxing was 76.8%, 64%, and 48.4% in rural/remote, suburban, and urban, respectively. A high expectation of quiet was less prevalent yet followed the same pattern: rural/remote (58.2%), suburban (37.4%), and urban (21.8%). Self-reported health status and noise sensitivity were unrelated to geographic region. A high magnitude of non-specific sleep disturbance over the previous 12 months was reported by 7.8% overall; highest among urban dwellers (9.8%), followed by suburban (7.2%) and rural/remote (5.5%) dwellers ($p < 0.01$). High annoyance toward road traffic noise was 8.5% overall, and significantly higher in urban (10.5%), relative to suburban (7.9%) and rural/remote (6.6%) areas ($p < 0.0001$). Annoyance toward noise from rail, aircraft, mining, industry, marine activity, construction, wind turbines, and landscaping equipment is reported. The analysis also explores potential differences between Indigenous Peoples of Canada and non-Indigenous Canadians in their attitudes and expectations toward environmental noise. https://doi.org/10.1121/10.0009749

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I. INTRODUCTION

Environmental noise comprises unwanted or harmful sound originating from sources located outside buildings. Because of its ubiquity, the focus is often on human activity related to transportation, construction, and industry. As exposures are often below the levels known to cause hearing impairment, interference with communication, relaxation, leisure activities, and sleep receive the most attention in the provision of advice related to environmental noise (Health Canada, 2017). To a large degree, these responses to noise are subsumed in one's reported magnitude of annoyance on social surveys. Annoyance, in particular high annoyance with noise, remains one of the most studied reactions in socio-acoustic surveys with widespread agreement that the prevalence of high annoyance increases with increasing noise levels. The emphasis currently placed on high annoyance (International Standards Organization, 2021) can be traced to the analysis by Schultz (1978) and the U. S. Federal Interagency Committee on Noise (1992). Schultz collated the empirical evidence to plot the first comprehensive exposure response relationship between the proportion of a community highly annoyed by a noise and the average day–night sound level. Schultz defined "highly annoyed" as a response to a social survey question on noise annoyance with a response in the top 27%–29% on an anchored numerical scale, or in the top two categories on a 5-point adjectival scale. An emphasis was placed on the proportion of those highly annoyed by noise over lower magnitudes of annoyance because these weaker expressions were more likely to be influenced by non-acoustic variables at lower noise exposures, and therefore, more challenging to mitigate through noise legislation. Efforts to quantify the change in the prevalence of high annoyance have since dominated the vast majority of noise annoyance studies. Indeed, the World Health Organization (WHO) has estimated the burden of disease due to long-term (i.e., 1 y) high noise annoyance (World Health Organization, 2011), which is consistent with the emphasis on this measure in

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their most recent environmental noise guidelines (World Health Organization, 2018).

The Canadian federal department of health provides, upon request, advice on noise and health for impact assessments (IAs) under the Canadian *Impact Assessment Act* (Impact Assessment Act, 2019). In IAs, noise is considered one of several valued environmental components (like air, water quality, and country foods) and its potential impact on human health is evaluated. Outcomes that are of particular relevance include project-related changes in noise-induced community annoyance and sleep disturbance (Health Canada, 2017). Of these, a change in the calculated prevalence of a high magnitude of annoyance by noise greater than 6.5% triggers a recommendation for noise mitigation (Michaud *et al.*, 2008a; Health Canada, 2017). Formulated from a global science base derived from social and socio-acoustic surveys conducted in developed urban/suburban areas, the advice may not reflect current attitudes and expectations toward noise in rural or remote communities across Canada. This is a knowledge gap insofar as Health Canada's guidelines on noise (Health Canada, 2017) include a +10 dB adjustment in the derivation of a rating level for calculating the change in the prevalence of high annoyance in so-called quiet rural areas where there exists an implicit high expectation for and value placed upon peace and quiet (ISO 1996–1:2016; ANSI, 2021). Indeed, many of the communities impacted by project-related changes in environmental noise would qualify as rural/remote. Any additional insights the department may glean through social surveillance in rural and remote areas would support the provision of advice on noise under the *IAA*, especially with respect to noise annoyance. Furthermore, to our knowledge, no data that are specific to Indigenous Peoples of Canada [i.e., First Nations, Métis, Inuk (Inuit)] have been collected that would permit an assessment of potential differences between Indigenous and non-Indigenous Canadians in their attitudes, expectations, and response toward environmental noise.

Previous national surveys on noise annoyance in Canada provide some data on the prevalence of high noise annoyance among Canadians (Michaud *et al.*, 2005, 2008b). However, these surveys lacked an evaluation of expectations of quiet and did not include the range of noise sources evaluated in the current survey, and no information was collected to permit an assessment of the response to noise among Indigenous Canadians.

The inaugural *Canadian Perspectives on Environmental Noise Survey* (CPENS) was conducted to inform Health Canada's advice on noise under the *IAA*. The survey provides new data on the prevalence of noise annoyance toward multiple sources in rural/remote, suburban, and urban areas from all 10 provinces. The potential adverse impact that a project's construction and/or operational noise may have on sleep is usually a consideration in IA. Current advice is based largely on the World Health Organization's Guidelines for Community Noise (World Health Organization, 1999) and Night Noise Guidelines for Europe (World Health Organization, 2009). This has proven to be a challenge insofar as the WHO guidelines are often exceeded under baseline (i.e., pre-project) conditions. Therefore, in addition to evaluating attitudes and expectations toward environmental noise, the CPENS also assessed the prevalence of sleep disturbance and the sources respondents attributed to their disturbed sleep. This provides important context when evaluating project-related noise impacts on sleep.

II. METHODS

A. Sample design

1. Target population, sample size, and response rate

The target audience for the CPENS was Canadians age 18 y or older, aiming for 5000 completed questionnaires in total. In addition, there were target goals of 500 Indigenous respondents in rural areas, and 1000 Indigenous Peoples from all geographic areas. The survey aimed to recruit 30% of Canadians living in rural areas. To collect the data, Health Canada contracted Advanis (Montréal, Waterloo and Edmonton, Canada), a bilingual, research-based full-service consulting firm that has successfully executed social research and market research in the public and private sector across several industries and government departments. For the current study, Advanis used its general population probability-based random sample (GPRS) in all provinces to recruit respondents via telephone to the online survey. The GPRS is a proprietary representative sample source recruited via probability sampling. This random digit dialing sampling method allows full statistical testing, while avoiding the challenges commonly associated with non-probability (e.g., panel) samples, in particular coverage bias and satisficing. The sample includes around 500 000 Canadians who were contacted by either phone, or interactive voice response from a random sample of cell phone and landline numbers. These individuals agreed to be contacted again for studies of public interest. For this study, the sample was created using two approaches. A random digit dialing approach (i.e., GPRS) for the general population part across the country where the sample was pulled randomly by province proportionally to their size nationally and by postal codes of the First Nation and remote area in order to oversample those specific groups.

The probability-based study was conducted using a two-step approach where potential respondents were initially recruited as mentioned above (i.e., by phone or interactive voice response) as follows: *Hello, this is [recruiter's name] calling from Tell City Hall. We are conducting an online study about community noise on behalf of Health Canada. The online survey will take about 10 min to complete. Can I send you (SMS or email based on their preference) to complete when you have time?* If agreeable, an email or short message service (based on their preference) instructed them to complete the online survey. After the initial invitation, respondents who did not complete the survey were sent a reminder message 3 and 6 days after the initial recruitment. Of the respondents who completed the screener, 93% were recruited via SMS, and 7% were recruited by email.

As shown in Table I, 24 133 phone numbers were called between April 12, 2021 and May 19, 2021. Of the 22 892

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TABLE I. Response rate calculation.[a]

	Telephone calls n(%)
Generated (N = 24 133)	
Used	24 133 (100)
No service	1027 (4.3)
Not residential/business	60 (0.2)
Line problems	82 (0.3)
Fax	60 (0.2)
Wrong number	12 (0.0)
Invalid[b]	1241 (5.1)
Potentially eligible	22 892 (94.9)
No answer	1692 (7.4)
Busy	22 (0.1)
Answering machine/voicemail	5318 (23.2)
Unresolved[c]	7032 (29.1)
Language barrier	14 (0.1)
Illness/incapacity	22 (0.1)
Household refusals	13 (0.1)
Respondent refusal	4171 (18.2)
Appointments	48 (0.2)
In-Scope non-responding[d]	4268 (17.7)
Ineligible	100 (0.4)
Quota blocked	0 (0.0)
Completed	11 492 (50.2)
Responding units[e]	11 592 (50.6)
Completed web surveys	6647 (57.8)
Refusal (%)[f]	(18.3)
Completed (%)[g]	(50.2)
Cooperation rate (%)[h]	(73.1)
Response rate on recruitment (%)[i]	(50.6)
Overall response rate (%)[j]	(29.0)

[a]Phone numbers were called between April 12, 2021 and May 19, 2021.
[b]No possible contact at this number.
[c]Cases where it cannot be established whether a call was made to eligible or ineligible respondent.
[d]Includes refusals, break-offs, and other eligible non-respondents.
[e]Includes cases who would have participated but were disqualified, completes, and partial completes.
[f]Household + respondent refusal/potentially eligible sample.
[g]Completed/potentially eligible sample.
[h]Responding units/(potentially eligible–unresolved).
[i]Responding units/(unresolved + in-scope non-responding + responding units).
[j]Completed web surveys/potentially eligible respondents.

potentially eligible respondents, 11 492 were recruited to the survey, for a rate on the recruitment of 50.6%. Of the 11 492 recruited participants, 6647 completed the online survey, for an overall response rate among eligible respondents of 29.0%.

The study aimed at having a representative sample of rural, urban, and suburban areas. To this end, weights were used to ensure the data were aligned with the most recent Statistics Canada census data. As well, this corrected for over and under sampled groups in certain geographic locations. The weights used did not show extreme values that would have been indicative of a bias i.e., an issue common in unrepresentative data. The margin of error for the study was ±1.2%, at a 95% confidence interval (i.e., 19 times out of 20).

B. Determining geographic sampling regions

The sampling frame was originally set to target respondents from remote/rural, suburban, and urban areas in all 10 Canadian provinces using the forward sortation area (FSA) postal code information (Canada Post Corporation, 2021). Respondents indicated the geographic region that best corresponded to the area in which they lived based on population size. The geographic region in the statistical analysis was based on the self-reported geographic region.

C. Data collection

1. Questionnaire development, pre-testing, and quality control

The questionnaire for the CPENS was designed by Health Canada and pre-tested in either English or French by Advanis.

For the pre-testing, 299 people were recruited by phone (212 in English and 87 in French). This led to 72 completed online surveys (61 English and 11 French). Minor changes made to the survey after pre-testing did not affect that pre-test data, and therefore, results collected during the pre-test were included in the final analysis.[1] (See supplementary material for the English version of the survey and the French version is available upon request).[2]

The survey included content to evaluate noise perception, annoyance, and expectations of quiet, health-related, and socio-demographic variables. The survey data related to the reported impact that COVID-19 had on health, stress, well-being, and annoyance toward outdoor and indoor noise will be presented by the authors as a separate publication. It should be noted that self-reported physical health, mental health, and overall well-being data were collected using content developed for the current survey and not through validated questionnaires, which would have added significant time to the survey. The average length of time to complete the online survey was just under 10 min.

All Advanis online surveys are hosted internally by Advanis, and employ a rigorous and stringent set of data collection control mechanisms to ensure the highest quality for the data collected, including:

- Respondents have a unique access code to ensure that only that participant can complete the online survey.
- Extensive internal logic checks are programmed directly into the survey to ensure logical responses.
- Web surveys are implemented using Advanis' proprietary software (which is designed to handle complicated survey formats).
- Advanis administered a detailed internal test and an external pre-test to ensure that the survey instrument was working as planned.
- The questionnaire was tested in multiple browsers and provided to Health Canada to conduct internal testing.

2. Defining "highly annoyed"

Annoyance toward various sources of noise was assessed (individually) using an 11-point numeric scale, where 0 represented "not at all annoyed" and 10 represented "extremely annoyed". As specified originally by Schultz (1978) and the most recent recommendations in ISO/TS 15666 (2021), "high annoyance" was defined as a response on the annoyance question of 8, 9, or 10. Annoyance toward road traffic noise was evaluated in a question that preceded a separate question that evaluated road traffic noise noticeability (i.e., assumed to reflect audibility in the current analysis). However, using separate questions for all sources evaluated in the survey was not practical and would have significantly lengthened the time required to complete the questionnaire. Therefore, the response category for sources other than road traffic included a "do not hear" option. A similar approach was taken for defining "highly sleep disturbed" (see Sec. II D).

D. Statistical methodology

Weighted frequencies and cross-tabulations were used to explore the characteristics and perceptions of participants in the different geographic regions (rural/remote, suburban, urban) and were compared using a chi square test of independence. Where length of time living in one's home was used as an adjusting factor, the Cochran-Mantel-Haenszel (CMH) chi square test of independence was applied. The weighting of the final data was based on four variables: age, gender, Indigenous status, and geographic location. There were 28 people who did not indicate their age, for whom Advanis used their pre-profiled age category for weighting. The population sizes are based on the latest Statistics Canada census results published in the 2016 Census. Since the value for the 18–19 age category was not available, in the segments required for the current study (only the 15–19 age was provided), we reduced the 15–19 y category by $3/5$ of the size to reflect the best estimate of the number of 18–19 y olds. Weighting was used to ensure that the results match the marginal population proportions for age, gender, Indigenous status, and geographic location. Survey respondents were asked to indicate the extent to which they were annoyed, sensitive, or sleep disturbed by certain environmental noises. The various factors were rated on a scale of 0–10, where 0 indicated that their annoyance, sensitivity, or sleep disturbance was not at all annoyed, sensitive or sleep disturbed, and 10 indicated that they were extremely annoyed, sensitive or sleep disturbed. The highly annoyed, sensitive or sleep disturbed denotes values of 8, 9, or 10; not highly annoyed, sensitive, or sleep disturbed denotes values of 0–7. Statistical analysis was performed using SAS Enterprise Guide 7.15 (SAS Institute, 2017). A 0.05 statistical significance level was implemented throughout unless otherwise stated. Tables represent overall p-values, when significant. In addition, Bonferroni corrections were made to account for all pairwise comparisons to ensure that the overall type I (false positive) error rate was less than 0.05. Pairwise comparisons are discussed in the text. Estimates with a coefficient of variation (CV) between 16.6% and 33.3% were designated "E" and are to be interpreted with caution due to the high sampling variability associated with it; CV estimates that exceeded 33.3% were designated "F", indicating that these data could not be released due to questionable validity. No results were reported for cell frequencies less than 10. In cases where participants "Preferred not to answer", the number of unweighted non-respondents is reported and not included in further analysis. This study was approved by the Health Canada and Public Health Agency of Canada Review Ethics Board (Protocol no. REB 2020-038H).

III. RESULTS

A total of 6647 respondents aged 18 y and older were collected from the survey, with the majority of responses coming from Ontario (40.3%), followed by Quebec (18.6%), British Columbia (14.4%), and Alberta (12.1%). Combined, 5% of the respondents were from Manitoba and Saskatchewan and 9% represented the four Atlantic provinces (New Brunswick, Prince Edward Island, Nova Scotia, and Newfoundland and Labrador). Distribution of participants from the different geographic regions in the provinces was not equal (see Table II) ($p < 0.0001$). This was expected

TABLE II. Sample distribution by province and geographic region.[a]

		Geographic region			
Province N[c]	Overall 6647	Rural/remote 1819	Suburban 1898	Urban 2930	p-value[b]
British Columbia (BC)	14.4 (13.6–15.3)	14.6 (12.7–16.8)	15.6 (14.4–16.9)	12.5 (11.2–14)	<0.0001
Alberta (AB)	12.1 (11.4–12.9)	12.1 (10.3–14.1)	10.4 (9.4–11.4)	14.8 (13.4–16.3)	
Manitoba (MB)/ Saskatchewan (SK)	5 (4.5–5.5)	5.7 (4.5–7.2)	3.3 (2.8–4)	7.1 (6.1–8.2)	
Ontario (ON)	40.3 (39.1–41.5)	33.3 (30.7–36.1)	41.6 (39.9–43.3)	42 (40–44.1)	
Quebec (QC)	18.6 (17.7–19.6)	20.3 (18–22.7)	19.7 (18.3–21)	16.2 (14.7–17.8)	
Atlantic provinces[d]	9.6 (8.9–10.3)	14 (12.1–16.1)	9.5 (8.6–10.6)	7.4 (6.4–8.6)	
Prefer not to answer	18				

[a]Territories were not included in the study.
[b]p-value is based on the chi square test of independence.
[c]N is the unweighted frequency in each geographic region.
[d]Atlantic provinces include New Brunswick, Prince Edward Island, Nova Scotia, and Newfoundland and Labrador.

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since weighting was used to ensure that the results match the marginal population proportions for age, gender, Indigenous status, and geographic location, based on the latest Statistics Canada census results published in the 2016 Census (Statistics Canada, 2016).

Table III presents characteristics of the population in the study by geographic region. Some notable observations were that working or attending school outside the home was highest in rural/remote locations (43.3%) compared to both suburban (34.9%) and urban (34.8%) areas ($p < 0.0001$, in both cases). In contrast, working or attending school inside the home was highest in suburban (37.8%) and urban (36.4%) areas compared to rural/remote (24.7%) locations ($p < 0.0001$, in both cases). Other types of employment status (retired, unemployed, paid leave, and other) as listed in Table II were equally distributed in the three geographic areas. A higher proportion of those living in rural/remote locations reported having a certificate/diploma as their highest level of education (45.5%) compared to those living in suburban (35.8%) and urban (35.2%) areas. In comparison, a higher proportion of those living in suburban (45.8%) and urban (48.1%) areas reported having bachelor or post graduate degrees compared to rural/remote areas (31.0%) ($p < 0.0001$, in both cases). Higher household income homes

TABLE III. Demographic characteristics by geographic region.[a]

Variable	Overall	Geographic region			
N	6647	Rural/remote 1819	Suburban 1898	Urban 2930	p-value[b]
Self-identified as Indigenous					
First Nation, Métis, Inuk (Inuit)	4.8 (4.3–5.3)	6.2 (4.9–7.7)	4.2 (3.6–4.9)	4.9 (4.1–5.9)	<0.05
Non-Indigenous	95.2 (94.7–95.7)	93.8 (92.3–95.1)	95.8 (95.1–96.4)	95.1 (94.1–95.9)	
Gender					
Female	51 (49.8–52.2)	51.1 (48.1–54)	52.3 (50.6–54)	49 (46.9–51.1)	
Male	48.4 (47.2–49.6)	48.3 (45.4–51.2)	47.1 (45.4–48.8)	50.3 (48.2–52.4)	
Other	0.6 (0.5–0.9)	X	0.6 (0.4–0.9) E	0.7 (0.5–1.2) E	
Prefer not to answer	51				
Age[c]					
18–34	27.3 (26.2–28.4)	23.8 (21.4–26.4)	27.5 (26.1–29.1)	28.7 (26.8–30.6)	
35–54	34.1 (33–35.3)	36.3 (33.6–39.2)	33.9 (32.3–35.5)	33.3 (31.3–35.3)	
55+	38.6 (37.4–39.8)	39.8 (37–42.7)	38.6 (36.9–40.2)	38 (36–40.1)	
Employment status					
Working or attending school outside home	36.3 (35.2–37.5)	43.3 (40.4–46.2)	34.9 (33.3–36.6)	34.8 (32.8–36.8)	<0.0001
Working or attending school inside home	35.1 (33.9–36.2)	24.7 (22.3–27.3)	37.8 (36.1–39.4)	36.4 (34.4–38.4)	<0.0001
Retired	22.6 (21.6–23.6)	23.5 (21.1–26)	22.8 (21.4–24.3)	21.8 (20.1–23.5)	
Unemployed	8.1 (7.5–8.8)	9.5 (7.9–11.4)	7.6 (6.8–8.6)	8 (7–9.3)	
Paid leave	2.7 (2.3–3.1)	2.9 (2–4) E	2.8 (2.3–3.4)	2.5 (1.9–3.2)	
Other	3.3 (2.9–3.8)	4.5 (3.4–5.9)	3 (2.5–3.7)	3.2 (2.5–4)	
Education					
High school[d]	18.7 (17.8–19.7)	23.5 (21.1–26.1)	18.4 (17.1–19.8)	16.7 (15.2–18.4)	<0.0001
Certificate or Diploma[e]	37.3 (36.1–38.4)	45.5 (42.5–48.4)	35.8 (34.2–37.5)	35.2 (33.2–37.2)	
Bachelor or post graduate degree	44 (42.8–45.2)	31 (28.4–33.8)	45.8 (44.1–47.5)	48.1 (46–50.2)	
Prefer not to Answer	147				
Household income					
<$40 000	18.4 (17.4–19.4)	20.4 (18–23)	16.3 (15–17.7)	20.3 (18.6–22.2)	<0.0001
$40 000-$79 999	28 (26.8–29.1)	30.5 (27.7–33.4)	26.4 (24.8–28.1)	28.9 (27–31)	
$80 000 to $149 999	35.9 (34.7–37.1)	33.9 (31.1–36.9)	38.5 (36.7–40.3)	33.1 (31–35.2)	
$150 000+	17.8 (16.8–18.8)	15.2 (13.1–17.5)	18.8 (17.4–20.2)	17.6 (16–19.4)	
Prefer not to Answer	756				
Duration of residency in current home					
Less than 1 y	10.9 (10.2–11.7)	10.6 (9–12.6)	10.1 (9.1–11.1)	12.3 (11–13.8)	<0.0001
1 y to less than 5 y	28.6 (27.6–29.7)	28.3 (25.8–31)	27 (25.5–28.5)	31.2 (29.3–33.2)	
5 y to less than 10 y	19.8 (18.9–20.8)	20 (17.8–22.4)	20 (18.6–21.4)	19.5 (17.9–21.2)	
10 y or more	40.6 (39.5–41.8)	41 (38.2–43.9)	43 (41.3–44.7)	36.9 (34.9–38.9)	

[a]The unweighted frequency (N) is represented in each geographic region.
[b]p-value based on the chi square test of independence. The null hypothesis (H_o): there is no association between the variable and geographic location versus the alternative hypothesis (H_a). At least one geographic location has a statistically different prevalence rate. Where significances are present ($p < 0.05$), pairwise tests are discussed in Sec. III.
[c]Age: there were 28 missing observations; Advanis imputed them based on the information in their proprietary database.
[d]Up to high school diploma or equivalent.
[e]Certificate or diploma from a registered apprenticeship or other trade, college, CEGEP or other non-university, or university below bachelor's level.

($80,000 to $149,999) were mostly represented in suburban areas (38.5%) compared to rural/remote (33.9%) and urban (33.1%) areas ($p < 0.0001$, in both cases). Whereas the lower income households (<$40,000 and $40,000 to $79,999) were equally distributed between rural/remote and urban areas. Duration of residency less than one year was more prevalent in urban areas, whereas longer residency (10 or more years) was more prevalent in rural/remote and suburban areas ($p < 0.0001$, in both cases).

Table IV considered physical and mental well-being of participants in the three geographical locations rated as "excellent/very good", "good", and "fair/poor". Participants rated their physical and mental health similarly in the three geographic regions. Table IV also presents other health indicators (heart disease including high blood pressure, anxiety/depression, sleep disorder, and hearing loss) and their distribution by geographic area. There was no indication of an association between these health indicators and gegraphical area.

Community noise–related variables are presented in Table V. High noise sensitivity was observed in 13.4% of the population and was equally distributed across the three geographic regions (Table V). Survey respondents were asked how outdoor noise has changed since they lived in their home as well as their expectation of quiet in their area. These responses may be dependent on length of time living in one's home; therefore, the analysis was adjusted for this using the CMH chi square test of independence. One in three Canadians perceived that the overall outdoor daytime noise around their home was louder with a significantly higher proportion being among those in urban areas (36.6%) compared to suburban (33.1%) and rural (27.4%) areas ($p < 0.0001$, in both cases), regardless of the length of time living in one's home. The data showed that 58.1% perceived there to be "no change" in the overall outdoor daytime noise with the highest proportion being represented in rural/remote locations (64.1%). Similar results were observed when participants were asked about their perception of overall outdoor nighttime noise. Particularly, those in urban areas found it to be louder (24.5%) compared to rural/remote (15.7%) and suburban (20.2%) areas; and a higher proportion of those living in rural/remote areas (73.5%) reported there was no perceived change to the outdoor nighttime noise compared to those living in suburban (68.2%) and urban (63.8%) areas. Differences were considered to be significant between urban and rural/remote geographic areas ($p < 0.01$) in the above comparisons, regardless of length of time living in one's home.

TABLE IV. Health-related characteristics by geographic region.[a]

Variable	Overall	Geographic region			
		Rural/remote	Suburban	Urban	
N	6647	1819	1898	2930	p-value[b]
Physical health					
Excellent/very good	50.2 (49–51.4)	49.9 (47–52.8)	49.5 (47.8–51.2)	51.3 (49.2–53.4)	
Good	33.4 (32.3–34.6)	33.3 (30.6–36.1)	34 (32.4–35.6)	32.7 (30.7–34.7)	
Fair/Poor	16.4 (15.5–17.3)	16.8 (14.7–19.1)	16.5 (15.3–17.8)	16 (14.5–17.6)	
Mental health					
Excellent/Very good	48.3 (47.1–49.5)	49.8 (46.9–52.7)	48.3 (46.6–50)	47.6 (45.5–49.7)	
Good	30.6 (29.5–31.8)	29.4 (26.8–32.1)	30.9 (29.3–32.5)	31 (29–32.9)	
Fair/Poor	21.1 (20.1–22)	20.8 (18.5–23.2)	20.9 (19.5–22.3)	21.5 (19.8–23.2)	
Heart disease including high blood pressure					
Diagnosed	19 (18.1–20)	19.4 (17.2–21.8)	19.7 (18.4–21.1)	17.8 (16.3–19.5)	
Not diagnosed but suffer from	3.2 (2.8–3.7)	4.1 (3.1–5.4)	3.1 (2.5–3.7)	3 (2.3–3.8)	
Does not apply	77.7 (76.7–78.7)	76.5 (74–78.9)	77.2 (75.8–78.6)	79.2 (77.4–80.8)	
Anxiety or depression					
Diagnosed	20.4 (19.5–21.4)	19.8 (17.5–22.2)	19.9 (18.6–21.3)	21.5 (19.8–23.3)	
Not diagnosed but suffer from	20.4 (19.4–21.4)	19.9 (17.7–22.3)	21.1 (19.8–22.5)	19.5 (17.9–21.2)	
Does not apply	59.2 (58–60.4)	60.3 (57.5–63.1)	59 (57.3–60.6)	59 (56.9–61)	
Sleep disorder					
Diagnosed	11.5 (10.8–12.3)	10.5 (8.9–12.5)	12.4 (11.3–13.6)	10.7 (9.5–12.1)	
Not diagnosed but suffer from	17.6 (16.7–18.6)	17.9 (15.8–20.2)	17 (15.7–18.3)	18.5 (16.9–20.2)	
Does not apply	70.9 (69.7–71.9)	71.5 (68.9–74.1)	70.6 (69.1–72.2)	70.8 (68.9–72.7)	
Hearing loss					
Diagnosed	9.1 (8.4–9.8)	10 (8.4–11.9)	8.8 (7.9–9.8)	9 (7.9–10.3)	
Not diagnosed but suffer from	10.6 (9.9–11.3)	11.8 (10–13.8)	10.2 (9.2–11.3)	10.5 (9.3–11.9)	
Does not apply	80.3 (79.4–81.3)	78.2 (75.7–80.5)	81 (79.6–82.3)	80.5 (78.7–82.1)	

[a]The unweighted frequency (N) is represented in each geographic region.
[b]p-value based on the chi square test of independence. The null hypothesis (H_o): there is no association between the variable and geographic location, versus the alternative hypothesis (H_a). At least one geographic location has a statistically different prevalence rate. Where significances are present ($p < 0.05$), pairwise tests are discussed in Sec. III.

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TABLE V. Community noise-related sample characteristics by geographic region.[a]

Variable	Overall	Geographic region			
		Rural/remote	Suburban	Urban	
N	6647	1819	1898	2930	p-value[b]
Noise sensitivity					
Highly sensitive	13.4 (12.6–14.3)	12 (10.3–14.1)	13.9 (12.7–15.1)	13.5 (12.1–15)	
Not highly sensitive	86.6 (85.7–87.4)	88 (85.9–89.7)	86.1 (84.9–87.3)	86.5 (85–87.9)	
Perception of change in overall outdoor daytime noise around home (7AM–10PM)					
Louder	33.3 (32.2–34.4)	27.4 (24.9–30.1)	33.1 (31.5–34.7)	36.6 (34.6–38.6)	<0.0001
Less loud	8.6 (8–9.3)	8.5 (7–10.2)	8.7 (7.8–9.7)	8.5 (7.4–9.8)	
No change	58.1 (56.9–59.3)	64.1 (61.3–66.9)	58.2 (56.5–59.8)	54.9 (52.8–56.9)	
Perception of change in overall outdoor nighttime noise around home (10PM to 7AM)					
Louder	20.9 (19.9–21.9)	15.7 (13.7–17.9)	20.2 (18.9–21.6)	24.5 (22.8–26.4)	<0.0001
Less loud	11.5 (10.7–12.3)	10.8 (9.1–12.7)	11.6 (10.5–12.7)	11.7 (10.4–13.1)	
No change	67.7 (66.5–68.8)	73.5 (70.9–76)	68.2 (66.6–69.8)	63.8 (61.7–65.8)	
Live in an area where you have a high expectation of tranquility, peace, and quiet					
Definitely	35.8 (34.7–37)	58.2 (55.3–61)	37.4 (35.8–39)	21.8 (20.1–23.6)	<0.0001
Somewhat	49.1 (47.9–50.3)	36 (33.3–38.8)	52.5 (50.8–54.2)	50.8 (48.7–52.9)	
No	15.1 (14.3–16)	5.8 (4.6–7.3)	10.2 (9.2–11.2)	27.4 (25.6–29.3)	
Outdoor noise levels are very quiet, calm, and relaxing					
Always/Often	61.1 (59.9–62.2)	76.8 (74.2–79.1)	64 (62.4–65.6)	48.4 (46.3–50.5)	<0.0001
Sometimes	33.8 (32.6–34.9)	20.3 (18.1–22.8)	32.1 (30.5–33.7)	43.2 (41.2–45.3)	
Never	5.2 (4.7–5.7)	2.9 (2.1–4) E	3.9 (3.3–4.6)	8.3 (7.2–9.6)	

[a]N is the unweighted frequency in each geographic region.
[b]p-value to compare the prevalence of noise sensitivity in each geographic location is based on the chi square test of independence. For all other tests, the p-value is based on the Cochran-Mantel-Haenszel chi square adjusting for length of time living in one's home. The null hypothesis (H_o): there is no association between the variable and geographic location after adjusting for length of time living in your home versus the alternative hypothesis (H_a). At least one geographic location has a statistically different prevalence rate, after adjusting for length of time living in one's home. Where significances are present ($p < 0.05$), pairwise tests are discussed in Sec. III.
E denotes coefficient of variation was between 16.6% and 33.3%; interpret with caution due to the high sampling variability.

When asked about their expectation of tranquility peace and quiet, 35.8% overall responded that they definitely had a high expectation, with the highest prevalence for this response coming from those living in rural/remote areas (58.2%) compared to only 21.8% in urban ($p < 0.0001$) and 37.4% in suburban areas ($p < 0.0001$) (Table V). Participants were asked if outdoor noise levels were quiet, calm, and relaxing; 61.1% responded with "Always/often" with the majority being rural/remote dwellers (76.8%), followed by suburban (64.0%) and urban (48.4%) dwellers ($p < 0.0001$, for all pairwise comparisons). In contrast, urban dwellers were more likely to respond "Sometimes" and "Never" to outdoor noise levels being very quiet, calm, and relaxing. One of the survey objectives was to assess if one's expectation of quiet "matched" one's perception that their environment was, in fact, quiet, or not. As expected, perception and expectation of quiet were positively associated with each other, both overall ($p < 0.0001$) and in each geographic region ($p < 0.0001$). However, reporting an area as one that is often or always quiet exceeded the prevalence of reporting a high expectation of quiet across all three geographic regions. The relationship remained unchanged even after adjusting for length of time living in one's home.

Figure 1 presents the proportion of participants who reported to be highly annoyed by road traffic noise in the previous 12 months and how often road traffic noise is

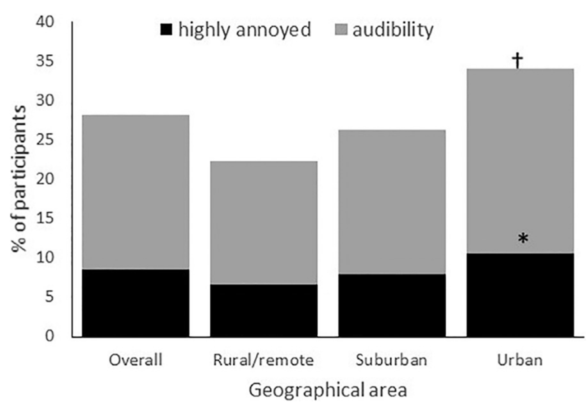

FIG. 1. Proportion of participants as a function of geographic area. The figure plots the proportion of participants that reported to be highly annoyed by road traffic noise over the previous 12 months while inside or outside their home. Highly annoyed is defined as reporting a magnitude of annoyance as 8, 9, or 10 on the 11-point response scale, where 0 indicates "not at all annoyed" and 10 indicates "extremely annoyed". The figure also shows the prevalence of reporting that road traffic noise was always or often noticeable (audible) while inside or outside their home. *$p < 0.01$, annoyance in urban area significantly different from rural/remote and suburban areas, no significant difference in annoyance between rural/remote and suburban areas; †$p < 0.01$, audibility of road traffic noise in urban area significantly different from rural/remote and suburban areas, no significant difference in audibility between rural/remote and suburban areas.

noticeable either inside or outside the respondents' homes. Overall, 8.5% of the population was highly annoyed by road traffic noise. Urban dwellers were significantly more prone to reporting high annoyance toward road traffic noise (10.5%) compared to both suburban (7.9%) and rural/remote (6.6%) dwellers ($p < 0.0001$, in both cases). Similarly, 28.1% responded that road traffic noise was audible "always/often", with the highest proportion being reported by those in urban areas (34%), significantly higher than those in rural/remote (22.3%) and suburban (26.3%) areas ($p < 0.0001$, in both cases).

The proportion of Indigenous respondents who reported to be highly annoyed by road traffic noise was 11.1% (95% CI: 8.1, 15) compared to non-Indigenous respondents 8.4% (95% CI: 7.8, 9.1), although this difference was not significant ($p > 0.05$). There was no significant difference in the prevalence of high annoyance toward road traffic noise between Indigenous and non-Indigenous respondents even after adjusting for geographic location (data not shown).

Table VI reports participants' annoyance toward various noise sources over the previous 12 months. Unlike the road traffic noise question, respondents could select a "do not hear" option for each of these sources. This was necessary to avoid including a separate audibility question for each source. Annoyance to rail was equally distributed across all three geographic regions. High annoyance toward aircraft noise ($p < 0.01$), other industry unrelated to mining ($p < 0.0001$), and construction activity including backup

TABLE VI. Reported annoyance toward community noise sources by geographic region.[a]

		Geographic region			
Variable N	Overall 6647	Rural/remote 1819	Suburban 1898	Urban 2930	p-value[b]
Rail					
Highly annoyed	3.5 (3.1–4)	3.3 (2.4–4.5)	3.3 (2.8–4)	4 (3.3–4.9)	
Not highly annoyed	52.4 (51.2–53.6)	50.8 (47.9–53.7)	52.2 (50.5–53.9)	53.7 (51.6–55.8)	
Do not hear	44 (42.8–45.2)	45.9 (43–48.8)	44.5 (42.8–46.2)	42.3 (40.3–44.4)	
Aircraft including helicopters					
Highly annoyed	3.9 (3.5–4.4)	2.1 (1.4–3.1) E	4 (3.4–4.7)	4.7 (3.9–5.7)	<0.01
Not highly annoyed	80.5 (79.5–81.4)	80.4 (78–82.6)	80.9 (79.6–82.2)	79.8 (78.1–81.4)	
Do not hear	15.6 (14.8–16.5)	17.6 (15.5–19.9)	15.1 (13.9–16.3)	15.5 (14–17)	
Wind turbines					
Highly annoyed	0.7 (0.5–0.9)	0.9 (0.5–1.7) E	0.4 (0.3–0.7) E	0.8 (0.5–1.3) E	<0.05
Not highly annoyed	24.4 (23.4–25.5)	26.8 (24.3–29.5)	23.5 (22.1–25)	24.5 (22.7–26.3)	
Do not hear	74.9 (73.9–76)	72.2 (69.5–74.7)	76 (74.6–77.5)	74.7 (72.8–76.4)	
Mining activities					
Highly annoyed	1.1 (0.8–1.3)	1.3 (0.8–2.2) E	1 (0.7–1.4) E	1 (0.7–1.6) E	<0.01
Not highly annoyed	24.3 (23.3–25.4)	28.1 (25.5–30.8)	22.7 (21.3–24.2)	24.8 (23.1–26.7)	
Do not hear	74.6 (73.5–75.6)	70.6 (67.9–73.2)	76.3 (74.8–77.7)	74.1 (72.3–75.9)	
Other industry unrelated to mining					
Highly annoyed	2.2 (1.9–2.6)	2.3 (1.6–3.4) E	2 (1.6–2.6)	2.5 (1.9–3.2)	<0.0001
Not highly annoyed	31.3 (30.2–32.4)	36.7 (33.9–39.5)	28.9 (27.4–30.5)	32 (30.1–34)	
Do not hear	66.5 (65.4–67.6)	61 (58.1–63.8)	69 (67.5–70.6)	65.5 (63.5–67.5)	
Marine activity (e.g., ships, boats, watercraft)					
Highly annoyed	0.8 (0.6–1.1)	1.3 (0.8–2.1) E	0.7 (0.5–1.1) E	0.8 (0.5–1.3) E	<0.0001
Not highly annoyed	30.2 (29.2–31.4)	35.8 (33–38.6)	28.2 (26.7–29.7)	30.5 (28.7–32.5)	
Do not hear	68.9 (67.8–70)	63 (60.1–65.7)	71.1 (69.6–72.6)	68.6 (66.7–70.5)	
Construction activity including backup warning alarms					
Highly annoyed	7.6 (7–8.2)	3.9 (2.9–5.2)	6.2 (5.4–7.1)	11.5 (10.3–13)	<0.0001
Not highly annoyed	70 (68.8–71)	67.9 (65.1–70.5)	70.1 (68.5–71.6)	70.9 (68.9–72.7)	
Do not hear	22.5 (21.5–23.5)	28.2 (25.7–30.9)	23.7 (22.3–25.2)	17.6 (16–19.2)	
Lawnmowers, hedge trimmers, leaf blowers, chain saws					
Highly annoyed	6.3 (5.8–6.9)	3 (2.2–4.2) E	7.1 (6.3–8)	6.9 (5.9–8.1)	<0.0001
Not highly annoyed	88.6 (87.9–89.4)	89.7 (87.8–91.4)	89.5 (88.4–90.5)	86.7 (85.2–88.1)	
Do not hear	5 (4.5–5.6)	7.2 (5.9–8.9)	3.4 (2.8–4.1)	6.4 (5.4–7.5)	
Noise sensitivity					
Highly sensitive	13.4 (12.6–14.3)	12 (10.3–14.1)	13.9 (12.7–15.1)	13.5 (12.1–15)	
Not highly sensitive	86.6 (85.7–87.4)	88 (85.9–89.7)	86.1 (84.9–87.3)	86.5 (85–87.9)	

[a]The unweighted frequency (N) is represented in each geographic region.
[b]p-value based on the chi square test of independence. The null hypothesis (H_o): there is no association between the variable and geographic location versus the alternative hypothesis (H_a). At least one geographic location has a statistically different prevalence rate. Where significances are present ($p < 0.05$), pairwise tests are discussed in Sec. III.

warning alarms ($p < 0.0001$) were more prevalent in urban areas compared to rural/remote areas. However, high annoyance toward wind turbines ($p < 0.05$), mining activities ($p < 0.01$), and marine activity ($p < 0.0001$) were more prevalent in rural/remote areas compared to urban and suburban areas. High annoyance toward noise from lawnmowers, hedge trimmers, leaf blowers, and chain saws was more prevalent in suburban areas compared to rural/remote areas ($p < 0.0001$).

Participants reported how disturbed their sleep was for any reason while at home during the last 12 months or so (Fig. 2). Overall, 7.8% of participants reported to be highly sleep disturbed for any reason. The highest prevalence was reported among those living in urban areas (9.8%), which was significantly higher than both suburban (7.2%) and rural/remote (5.5%) locations ($p < 0.0001$, in both cases).

Table VII presents the magnitude of sleep disturbance that respondents attributed to different sources by geographic region. Survey respondents were far more likely to attribute their sleep disturbance to stress, anxiety, or worrying with an overall prevalence of 12.8%, which was more prevalent in urban dwellers (13.6%) than rural dwellers (11.2%) ($p < 0.05$). Noise from neighbors, indoor sources, and road traffic were identified by 6.1%, 3.0%, and 5.2% of respondents, respectively.

Results regarding differences between Indigenous and non-Indigenous Canadians showed that the proportion of Indigenous Canadians living in rural/remote areas (6.2%) was statistically similar to the number of Indigenous Canadians living in urban areas (4.9%) but was statistically higher than the proportion of Indigenous Canadians living in suburban areas (4.2%) ($p < 0.01$). While no differences in perceived changes in outdoor daytime noise were observed, Indigenous respondents were more likely to report louder outdoor nighttime noise over time (26.8%, 95% CI:22.2%–31.9%) compared to non-Indigenous Canadians (20.6%, 95% CI:19.6%–21.6%) ($p < 0.05$). When asked to

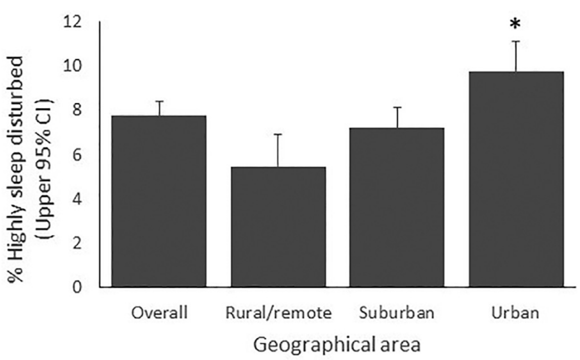

FIG. 2. Proportion of participants as a function of geographic area. The figure plots the proportion of participants that reported to be highly sleep disturbed for any reason while at home over the previous 12 months. Highly sleep disturbed is defined as reporting a magnitude of sleep disturbance as 8, 9, or 10 on the 11-point response scale, where 0 indicates "not at all sleep disturbed" and 10 indicates "extremely sleep disturbed". *$p < 0.01$, sleep disturbance in urban area significantly different from rural/remote and suburban areas, no significant difference in sleep disturbance between rural/remote and suburban areas.

report if they lived in an area where they had a high *expectation* for tranquility, peace and quiet, the prevalence of reporting, "Yes, definitely" was lower among Indigenous Canadians (28.2%, 95% CI:23.6%–33.4%) compared to non-Indigenous (36.2%, 95% CI:35.0%–37.4%) ($p < 0.01$). Consequently, the prevalence of Indigenous Canadians reporting to live in an area they considered quiet, calm and relaxing was significantly lower (52.8%, 95% CI:47.3%–58.2%) compared to non-Indigenous Canadians (61.5%, 95% CI:60.3%–62.7%) ($p < 0.01$).

The data indicated that 13.5%, 95% CI:10.2%–17.7% of Indigenous respondents reported to be highly noise sensitive, which was similar to non-Indigenous Canadians (13.4%, 95% CI:12.6%–14.3%). Despite a similar sensitivity to noise, the prevalence of high annoyance toward road traffic noise was higher among Indigenous Canadians (11.1%, 95% CI:8.1%–15.0%) compared to non-Indigenous Canadians (8.4%, 95% CI:7.8%–9.1%), though this difference was not statistically significant. Similar patterns were observed for rail, aircraft noise, other industry unrelated to mining and construction activity including backup alarms, where again, Indigenous Canadians reported higher prevalence of high annoyance, but the difference was not statistically different from non-Indigenous Canadians (data not shown).

IV. DISCUSSION

Nearly 20 years have passed since the first national survey was conducted in Canada to evaluate the prevalence of noise annoyance. In 2002, the national prevalence of high annoyance toward road traffic noise was 5.0% among Canadians age 15 y and older (Michaud *et al.*, 2005). In a follow-up survey conducted in 2005, the prevalence was 7.6%[3] (Michaud *et al.*, 2008). In these early surveys, annoyance was evaluated using two questions as recommended in ISO/TS 15666 (2021); one question had an 11-point numeric scale and a second incorporated a 5-point adjectival scale. It is notable that on the 5-point response scale, where highly annoyed was defined as "very" or "extremely", the prevalence of high annoyance was 6.7% in both surveys. To minimize questionnaire length and reduce response fatigue, the current survey only included the 11-point numeric scale. The overall prevalence of high annoyance toward road traffic noise was 8.5% (95% CI: 7.9%–9.2%), ranging from 6.6% (95% CI: 5.3%–8.2%) in rural/remote areas, to 7.9% (95% CI: 7.0%–8.9%) in suburban areas and 10.5% (95% CI: 9.3%–11.9%) in urban areas. Although there are slight differences in their design, the collective surveillance data to date suggest an increase in the prevalence of high annoyance toward road traffic noise among Canadians over the past two decades. Despite being a country with approximately half the population, the overall prevalence of high annoyance toward road traffic noise is nearly identical to that reported in the UK National Noise Attitude Survey conducted in 2000 and again in 2012; in both, surveys the prevalence of reporting to be very or extremely annoyed was

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TABLE VII. Extent of sleep disturbance attributed to various factors by geographic region.[a]

Variable	Overall	Geographic region			p-value[b]
		Rural/remote	Suburban	Urban	
N	6647	1819	1898	2930	
Wind turbines					
Highly sleep disturbed	0.4 (0.3–0.6) E	X	X	0.6 (0.4–1.1) E	
Not highly sleep disturbed	22.8 (21.9–23.9)	25.6 (23.2–28.2)	22.2 (20.8–23.6)	22.4 (20.7–24.2)	
Does not apply	76.8 (75.7–77.8)	74 (71.4–76.5)	77.6 (76.1–78.9)	77 (75.2–78.7)	
Noisy neighbors					
Highly sleep disturbed	6.1 (5.6–6.7)	3.8 (2.8–5)	5.9 (5.2–6.8)	7.7 (6.6–8.9)	<0.0001
Not highly sleep disturbed	78.3 (77.3–79.3)	72.9 (70.3–75.4)	79 (77.6–80.3)	80 (78.3–81.7)	
Does not apply	15.6 (14.7–16.5)	23.3 (20.9–25.9)	15.1 (13.9–16.4)	12.3 (11–13.7)	
Pain, illness, or sleep disorder					
Highly sleep disturbed	7.6 (7–8.3)	6.4 (5.1–7.9)	7.8 (7–8.8)	8 (6.9–9.2)	
Not highly sleep disturbed	68.6 (67.4–69.7)	70 (67.3–72.6)	68 (66.4–69.6)	68.6 (66.6–70.5)	
Does not apply	23.8 (22.8–24.9)	23.6 (21.2–26.1)	24.2 (22.7–25.6)	23.4 (21.7–25.3)	
Partner's sleep disturbance (e.g., using washroom, snoring, sleep disorder, illness, pain)					
Highly sleep disturbed	5.5 (4.9–6)	4.3 (3.3–5.6)	6.4 (5.6–7.2)	4.7 (3.9–5.7)	<0.01
Not highly sleep disturbed	69.1 (68–70.2)	72.8 (70.2–75.3)	68.4 (66.8–70)	68.2 (66.2–70.1)	
Does not apply	25.4 (24.4–26.5)	22.9 (20.5–25.4)	25.2 (23.8–26.7)	27.1 (25.3–29)	
Having to use the washroom					
Highly sleep disturbed	6.2 (5.6–6.8)	4.7 (3.7–6.1)	5.8 (5–6.6)	7.6 (6.5–8.7)	<0.01
Not highly sleep disturbed	81.7 (80.8–82.6)	82.1 (79.8–84.3)	82.4 (81.1–83.7)	80.5 (78.8–82.1)	
Does not apply	12.1 (11.3–12.9)	13.1 (11.3–15.2)	11.8 (10.8–13)	12 (10.7–13.4)	
Stress, anxiety or worrying					
Highly sleep disturbed	12.8 (12.1–13.7)	11.2 (9.5–13.1)	12.9 (11.8–14.1)	13.6 (12.2–15.1)	<0.05
Not highly sleep disturbed	77.1 (76.1–78.1)	77.2 (74.7–79.6)	76.7 (75.2–78.1)	77.6 (75.8–79.3)	
Does not apply	10.1 (9.4–10.8)	11.6 (9.9–13.6)	10.4 (9.4–11.5)	8.7 (7.6–10)	
Indoor noise from people, TV, radio, ventilation					
Highly sleep disturbed	3 (2.7–3.5)	2.2 (1.5–3.3) E	3 (2.5–3.6)	3.6 (2.9–4.4)	<0.01
Not highly sleep disturbed	78.6 (77.6–79.6)	75.5 (72.9–77.9)	79.6 (78.2–80.9)	78.9 (77.1–80.5)	
Does not apply	18.3 (17.4–19.3)	22.3 (20–24.8)	17.5 (16.2–18.8)	17.6 (16–19.2)	
Road traffic noise					
Highly sleep disturbed	5.2 (4.7–5.8)	4.3 (3.3–5.6)	4.6 (3.9–5.3)	6.7 (5.7–7.8)	<0.0001
Not highly sleep disturbed	81.7 (80.7–82.6)	77.5 (75–79.8)	81.5 (80.2–82.8)	84.1 (82.5–85.6)	
Does not apply	13.1 (12.3–13.9)	18.2 (16.1–20.6)	13.9 (12.8–15.1)	9.2 (8.1–10.5)	

[a]The unweighted frequency (N) is represented in each geographic region.
[b]p-value based on the chi square test of independence. The null hypothesis (H_o): there is no association between the variable and geographic location versus the alternative hypothesis (H_a). At least one geographic location has a statistically different prevalence rate. Where significances are present ($p < 0.05$), pair-wise tests are discussed in Sec. III.

8% (Department for Environment Food & Rural Affairs, 2014).

Although the majority of Canadians reported no change in outdoor daytime and nighttime sound levels over the time they have lived in their home, a sizeable proportion of the surveyed respondents perceived outdoor levels as louder, especially during the daytime. Only about 10% of the sample reported that outdoor noise was less loud than it had been in the past. As with most of the noise-related variables evaluated, the trends across geographic areas point toward increasing noise and noise-related reactions in urban areas. For instance, although it was generally low across all areas (i.e., <10%), the prevalence of high sleep disturbance was highest in urban areas, and lowest in rural areas. While this reflected sleep disturbance for *any* reason, citing a noise source as the cause (e.g., road traffic, noisy neighbors, indoor noise) was more prevalent in urban areas. Nevertheless, stress was more likely to be identified as causing one's sleep disturbance than any of the noise sources evaluated.

Consistent with the accumulated noise literature showing an independence between sound levels and noise sensitivity (van Kamp *et al.*, 2004; Job, 1988), the CPENS showed that reporting to be highly noise sensitive was unrelated to geographic region. Again, at an overall prevalence of around 13%, this was remarkably similar to that reported in the most recent UK survey where 12% reported to be "very sensitive" to noise (Department for Environmental Food and Rural Affairs, 2014). That the prevalence of high noise sensitivity was this similar is somewhat unexpected given that in the UK survey, "very sensitive" represented the most extreme response option available on the 7-point numeric scale. In the CPENS, "highly noise sensitive" was defined as selecting 8, 9, or 10 on an 11-point numeric scale. The most extreme response option (i.e., 10) was selected by only 5.1% of Canadians (data not shown). Our approach aligns highly noise sensitive with highly noise annoyed and highly sleep disturbed. It is uncertain how the two countries would compare using the same question.

The CPENS evaluated annoyance toward several other noise sources based on their relevance to IA. Construction noise can be very high and of a relatively long duration e.g., 1–2 y continuously, or intermittently present for several years. In these cases, it too, or alone, can be the focus of concern of residences in the vicinity of the project. Construction of tunnels, bridges, and port facilities can involve pile driving, a highly impulsive noise. Only where there is continuous construction for a significant fraction of a year is the proposed percentage highly annoyed criterion intended for use. In the current study, the overall prevalence of high annoyance toward construction noise over the previous 12 months fell just below road traffic at 7.6% (CI: 7.0%–8.2%). As alluded to above, the same geographic pattern was observed, i.e., construction noise annoyance was lowest in rural/remote areas (3.9%), followed by suburban (6.2%), and highest in urban areas (11.5%). Annoyance toward rail and aircraft noise was about half as prevalent when compared to road traffic or construction. Mining, other industrial activities, marine activities, and under some circumstances, wind turbines, can all be sources of concern to communities impacted by a new project. However, a very high prevalence of respondents in the CPENS reported these sources as inaudible. This is a study limitation insofar as the reported prevalence of noise annoyance toward these sources cannot be used to estimate how a community in a particular geographic area would respond if they were exposed. Future surveys that aim to estimate annoyance toward these sources would need to target populations that are close in proximity. Other limitations of the CPENS are inherent to the design itself. Data collected at a single point in time does not necessarily reflect a stable response to environmental noise as unique circumstances at the point of data collection have the potential to skew responses. In this regard, it should be considered that the results might reflect a transient change in a number of measures including, but not limited to annoyance, as data collection overlapped with a Canada-wide lockdown designed to combat the spread of COVID-19. Although such measures have been shown to reduce environmental noise (Aletta *et al.*, 2020; Asensio *et al.*, 2020; Bruitparif, 2020; Dümen and Şaher, 2020), one's tolerance to additional stressors may have likewise decreased during the global pandemic for a number of reasons, including but not limited to the challenges created by stay-at-home orders. In the CPENS, respondents reported on how the pandemic affected their annoyance toward environmental noise and indoor noise. Overall, 80.7% and 82.1% reported that their annoyance to environmental noise and indoor noise, respectively, was either unchanged or improved since the pandemic (Libraries and Archives Canada, 2021). Nevertheless, it is only through future cycles of the CPENS that the apparent impact of the pandemic (or lack thereof) on the community response to noise will become more certain. Furthermore, the apparent increase in the prevalence of annoyance might simply reflect the known variability in annoyance. It is noteworthy that in a compilation of 61 surveys on road traffic noise annoyance dating back to 1969, Gjestland (2020) found no evidence for an increase in the prevalence of high annoyance over time. An increase in Canada would therefore be at odds with the overall global database.

Another study limitation relates to evaluated health status, which was limited to content developed specifically for the current survey and not based on validated psychometric tools. While these questionnaires are readily available, their use in the CPENS would have added significant length to the questionnaire, potentially reducing response rates. Despite falling within the expected range for online surveys, the low response rate in the current survey is a study limitation.

One of the primary objectives for this survey was to acquire more Canadian-based data on the community response to environmental noise to support the provision of Health Canada's advice on IA. Currently, in estimating project impacts on a community, a project proponent will estimate the change in the prevalence of high annoyance using Eq. (1).

$$\%\text{highly annoyed} = 100/\left[1 + \exp(10.4 - 0.132 * \text{RL})\right] \quad (1)$$

In calculating the relationship between the rating level (RL) and percentage highly annoyed, where the RL in Eq. (1) is typically an adjusted day average nighttime sound level (DNL), adjustments that include +10dB for quiet rural areas are made. This adjustment is rooted in the implicit assumption that there exists a greater expectation for quiet in rural/remote areas relative to other geographic regions (Health Canada, 2017). Although the CPENS indicates that there is certainly no one to one relationship between reporting a living area as quiet and having an *expectation* of quiet, the current survey reaffirms the greater expectation for quiet in rural/remote areas, relative to suburban and urban areas.

Where modelled project noise results in an increase in calculated annoyance that is greater than 6.5%, Health Canada would recommend the implementation of technically and economically feasible noise mitigation measures. This means that the allowable increase in project noise is determined by the assumed prevalence of noise annoyance at baseline. Excluding natural sources of sound, Health Canada (2017) guidance estimates the DNL in rural areas to be at least 45 dB. Without any adjustment applied, using Eq. (1), the prevalence of high annoyance toward general noise at 45 dB DNL is 1.3% (Health Canada, 2017). Applying a +10 dB adjustment to the baseline for an expectation of quiet results in a baseline annoyance prevalence of 4.1%. The current survey suggests that annoyance toward road traffic noise alone in rural/remote areas is actually around 6.6% (CI: 5.3%–8.2%). This is consistent with a greater level of high annoyance in remote or quiet rural areas than what would be predicted based solely on sound level, although it would be necessary to quantify the level of traffic noise to make a more definitive conclusion.

To our knowledge, to date, there has been no information collected from Indigenous Peoples that could inform Health Canada's advice on environmental noise as part of the IA review process. In an effort to begin addressing this knowledge gap, the CPENS sought to investigate potential differences in the response to environmental noise between Indigenous and non-Indigenous Canadians. Some tentative observations were that Indigenous respondents were more likely to report louder outdoor nighttime noise over time; they had lower expectations of quiet and were less likely to report living in areas they considered quiet, calm, and relaxing. Despite a similar sensitivity to noise, the prevalence of high annoyance toward road traffic noise was just over three percentage points higher among Indigenous Canadians compared to non-Indigenous Canadians, although the difference did not reach statistical significance. Similar patterns were observed for rail and aircraft noise, other industries unrelated to mining, and construction activity including backup warning alarms. However, for the remaining sources evaluated, there were either no apparent differences or the variability in the data was too high to report. The authors acknowledge that the CPENS does not provide a comprehensive evaluation of the response among the Indigenous Peoples of Canada to environmental noise in rural and nonrural areas. It is a study limitation that the survey did not evaluate noise impacts on traditional land use, places of worship, and the historical soundscape. It is a further limitation that the survey did not extend to the Yukon, the Northwest Territories, or Nunavut due to their small population densities. Under the governance of Indigenous leaders across Canada, future research in this area could expand the scope of the CPENS to include these and other important issues.

As part of the CPENS, respondents provided home addresses to facilitate outdoor noise modelling in the future. Noise modelling would provide exposure response relationships and this information could inform the provision of advice on noise annoyance and sleep disturbance. As mentioned above, there is a wide scatter in the noise annoyance data such that predicting the prevalence of annoyance at any given sound level has a large uncertainty. This is because numerous non-acoustic factors influence community annoyance and collectively, they have at least as strong an impact on annoyance as an energy averaged long-term noise metric (Job, 1988). Similarly, predicting the sound level from a known prevalence of annoyance is equally uncertain. While there is obviously a value added to modelling noise levels, there is also much that can be learned by evaluating the response to noise across geographic areas.

V. CONCLUSION

In addition to other measures, the CPENS provides new data on the prevalence of noise annoyance, noise sensitivity, sleep disturbance, expectations of quiet in rural/remote, suburban, and urban areas across Canada. These national data serve as a reference to track trends in the response to noise over time and provide a valuable point of comparison with other jurisdictions. The data do reaffirm some conventional thinking regarding the expectation of quiet in rural/remote locations, yet they also suggest the need to revisit assumptions around the baseline prevalence of annoyance in these areas. While the CPENS did not reveal any striking disparities in the response to noise between Indigenous and non-Indigenous Canadians, this general observation should be interpreted with caution as this is the first study to consider the response to noise among Indigenous Peoples of Canada, and more research in this area is required. Finally, the value of the CPENS would be enhanced if supplemented with noise modelling for the purpose of developing exposure response relationships. If the uncertainty in the relationship between modelled noise level and response is reasonably low, this could inform the advice Health Canada and others provide in environmental impact assessments.

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[1]After the first English pre-test, it was determined that respondents were potentially selecting the "Not at all" options rather than the "Does not apply/Do not hear" options on the Q8 and Q10 rating questions. This was due to the placement of the response level at the bottom of the lists (i.e., below the 10 "Extremely" options). The response lists were reordered so the "Does not apply/Do not hear" options were displayed next to the "Not at all" options. In this layout, respondents were more likely to select the appropriate response if the questions did not apply to them. Once field-testing was completed, it was determined that the level of "Other, specify" responses given on Q18 was too high, and a review of the responses was conducted. After this, responses were coded back into existing survey levels, and a new response level of "On paid leave" was added to categorize those who indicated they were on sick, maternity/paternity, or disability leave. Additionally, variables were created for weighting purposes that combined the gender and sex at birth questions. Indigenous levels (First Nations, Métis, Inuk) were grouped to avoid having extreme weights and/or large coefficients of variation that would preclude the reporting for each Indigenous level. Age was imputed for respondents who did not provide this information ($n = 28$) based on pre-profiled age category for the respondent to ensure proper weighting.

[2]See supplementary material at https://www.scitation.org/doi/suppl/10.1121/10.0009749 for the English version of the survey questionnaire.

[3]The prevalence of high annoyance toward road traffic noise reported in Michaud *et al.* (2008) was 9.4%; however, this was based on an annoyance score of 7, 8, 9, or 10 on the 11-point numeric scale. Defining "highly annoyed" as ≥ 7 was found to correlate best with defining "highly annoyed" as "very or extremely" on the 5-point adjectival scale used in the same survey. The raw data from the survey were re-evaluated to determine the prevalence of reporting 8, 9, or 10 so that it could be compared to the current survey.

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