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Human-nature connection and soundscape perception: Insights from Tierra del Fuego, Argentina

Dante Francomano [a,b,*,1], Mayra I. Rodríguez González [b,2], Alejandro E.J. Valenzuela [c,d,3], Zhao Ma [b], Andrea N. Raya Rey [c,e,f,3], Christopher B. Anderson [c,e], Bryan C. Pijanowski [a,b,3]

[a] Center for Global Soundscapes, Purdue University, 195 Marsteller Street, West Lafayette, IN 47907, USA
[b] Department of Forestry and Natural Resources, Purdue University, 195 Marsteller Street, West Lafayette, IN 47907, USA
[c] Instituto de Ciencias Polares, Ambiente y Recursos Naturales (ICPA), Universidad Nacional de Tierra del Fuego (UNTDF), Fuegia Basket 250, CP 9410, Ushuaia, Tierra del Fuego, Argentina
[d] Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Fuegia Basket 250, CP 9410, Ushuaia, Tierra del Fuego, Argentina
[e] Centro Austral de Investigaciones Científicas (CADIC), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Houssay 200, CP 9410, Ushuaia, Tierra del Fuego, Argentina
[f] Wildlife Conservation Society, Representación Argentina, Amenabar 1595, piso 2 of. 9, CABA, Argentina

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ABSTRACT

Human disconnection from nature is thought to have contributed to the environmental crises we currently face, and increasing connection with nature has been proposed as one way of promoting pro-environmental behavior, nature conservation, and social-ecological sustainability. Some efforts to increase connection with nature ("nature relatedness") have centered on exploring the social-ecological importance of soundscapes, but there is a paucity of empirical evidence supporting the theoretical linkage between soundscape perception and nature relatedness. Using prerecorded and *in situ* soundscape prompts, we conducted a street intercept survey in Ushuaia, Tierra del Fuego, Argentina to assess: 1) the relative importance of senses in experiences of nature, 2) the relationship between nature relatedness and soundscape perception, 3) differences in soundscape perception between various soundscapes, and 4) possible sociodemographic influences on sense importance, nature relatedness, and soundscape perception. Participants reported that hearing was of secondary importance to vision in experiences of nature. We also found that nature relatedness was positively correlated with the valuation of soundscapes—particularly more natural ones—but not with the discernment of soundscapes or identification of where soundscapes were recorded. Valuation of more natural soundscapes was higher than valuation of more technophonically dominated soundscapes, while soundscape discernment and location identification were higher for soundscapes that were likely more familiar to listeners. Sociodemographic influences on these variables were minor, but women reported higher sense importance, and having a nature-based occupation was associated with higher nature relatedness and valuation of a soundscape from a penguin colony. Our study highlighted a number of potential research areas concerning soundscape perception, including differences between prerecorded and *in situ* soundscape prompts, defining various aspects of soundscape perception, and the relative influences of sound sources and quantitative acoustic parameters on soundscape perception. Further research is certainly needed to account for global diversity in cultures and soundscapes, but we found some promising empirical support for the use of natural-soundscape-focused educational programs in efforts to promote nature relatedness.

* Corresponding author.
E-mail addresses: dfrancomano@alumni.purdue.edu (D. Francomano), Mayra.Rodriguez-Gonzalez@uvm.edu (M.I. Rodríguez González), avalenzuela@untdf.edu.ar (A.E.J. Valenzuela), zhaoma@purdue.edu (Z. Ma), arayarey@cadic-conicet.gob.ar (A.N. Raya Rey), canderson@alumni.unc.edu (C.B. Anderson), bpijanow@purdue.edu (B.C. Pijanowski).
[1] Present address: University Honors College, Portland State University, 1632 SW 12th Ave, Portland, OR 97201, USA.
[2] Present address: Gund Institute for Environment, University of Vermont; Spatial Analysis Laboratory, Rubenstein School of Environment and Natural Resources, University of Vermont, 210 Colchester Avenue, Burlington, VT 05405, USA.
[3] Alejandro E. J. Valenzuela, Andrea N. Raya Rey, and Bryan C. Pijanowski should be considered joint senior authors.

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1. Introduction

Our planet is facing anthropogenic crises—including biodiversity loss, climate change, and pollution—and resolutions to these problems will require massive societal restructuring (IPCC, 2014; Kates et al., 2001; Rockström et al., 2009; Sala et al., 2000). Governmental responsibilities cannot be ignored (Caldwell, 1970; Nihlén Fahlquist, 2009), but individuals can still assume important bottom-up roles in catalyzing and implementing change (Folke, 2019; Folke et al., 2005; John et al., 2006). In part, governmental inaction and ineffectiveness are products of insufficient popular pressure (Howlett & Kemmerling, 2017), and various factors likely influence this shortage of grassroots activism. It is commonly hypothesized, however, that many individuals lack recognition of and concern for environmental issues because they have become physically and psychologically disconnected from the natural world, particularly during childhood, and not least due to increasing urbanization and technological advancement in certain cultural contexts (Ives et al., 2018; Miller, 2005). This disconnected condition, popularized by Louv (2008) as Nature Deficit Disorder, is thought to cause a lack of familiarity with natural systems, a lack of awareness of human impacts on those systems, and a limited appreciation for human reliance on ecosystem services (*sensu* Millennium Ecosystem Assessment, 2003). Increasing human connection with nature might represent a step toward alleviating the global environmental crises bred by unsustainable societal practices (Whitburn et al., 2020).

To test the above hypothesis, one must operationalize the concepts of "nature" and (dis)connection from it. Ives et al. (2017) have provided a useful review of attempts at the latter, while noting that these efforts have often left "nature" undefined. Largely following Ives et al.'s generalized conception of "nature" as derived from the studies they reviewed, we here consider "nature" and "natural" to refer to a) non-human organisms, species, and communities and b) places, environments, and ecosystems with low human presence or influence, relative to other such entities.

A theoretical framework around the measurement and implications of "connection with nature" has developed at the intersection of environmental psychology, environmental planning and management, and sustainability science (Ives et al., 2017; Restall & Conrad, 2015). Numerous attempts to operationalize the construct of "connection with nature" have primarily come from environmental psychology (Tam, 2013; but see Ives et al., 2017; Restall & Conrad, 2015). A review by Tam found nine measures of connection with nature to be "markers of the same underlying construct", while exhibiting "subtle" divergence (Tam, 2013, p. 74). This divergence and the explicit multidimensionality of two of the considered metrics—"environmental identity" (Clayton, 2003) and "nature relatedness" (Nisbet & Zelenski, 2013; Nisbet et al., 2009)—led Tam to conclude that, "it may be useful to consider connection to nature to be multi-dimensional" (p. 67). A review by Restall and Conrad (2015) echoed these findings, and both Tam (2013) and Restall and Conrad (2015) highlighted positive correlations between this construct and pro-environmental behavior. Supporting the idea of a multidimensional, yet coherent, construct in a broader review, Ives et al. (2017) clustered 475 publications into three groups that considered "human-nature connection" as "mind", "experience", and "place", respectively. They also manually differentiated five classes of human-nature connection: "material", "experiential", "cognitive", "emotional", and "philosophical". Later work further emphasized these five classes and discussed their relative importance in terms of affecting change for social-ecological sustainability (Ives et al., 2018). Ives et al. (2018) asserted that the classes as listed above range from "external" to "internal" and increase in their "leverage" to induce system change. They also highlighted some overlap and the likelihood of positive interactions between the classes. Collectively, these studies suggest that an individual's connection with nature is measurable and meaningful (Ives et al., 2017; Tam, 2013) and that augmenting connection with nature at internal emotional and philosophical levels would be most effective at promoting social-ecological sustainability (Ives et al., 2018).

There are certainly many plausible approaches to increase connection with nature and pro-environmental behavior as prescribed by the theoretical framework described above (Jacobson et al., 2015). One such paradigm focuses on our auditory senses and the concept of a "soundscape", defined as the entire collection of sounds occurring in a given place over a given timeframe, which may include geophysical, biological, and technological sounds (Fig. 1; Gasc et al., 2017; Pijanowski et al., 2011a,b; Schafer, 1993; Southworth, 1969). We posit here that humans connect with ecosystems and nature through soundscapes and may do so at material, experiential, cognitive, emotional, and philosophical levels (Dumyahn & Pijanowski, 2011; Feld, 2012; Francis et al., 2017; Rodaway, 2002).

The manners in which humans have connected with nature through soundscapes have evolved over time. Experiential and cognitive connections have existed since the dawn of our species, as we have inhabited myriad ecosystems replete with biophony (sounds from organisms) and geophony (sounds from geophysical processes), and we have cognitively processed those sounds as cues that provide us with information about our surroundings (e.g., Filippi et al., 2017). Our emotional and philosophical connections with nature through soundscapes may have come later, but they were at least present by ancient times; for example, both positive and negative reactions to bird sounds and interpretations of those sounds' meanings appear in numerous ancient writings (Mynott, 2018). More recently, urbanization and industrialization have reduced our opportunities for experiential connection with nature through sound (Francis et al., 2017). This reduced exposure might yield divergent results: on one hand, a lack of exposure to natural soundscapes can impair the development of emotional and philosophical connections with nature through soundscapes (Francis et al., 2017); alternatively, the scarcity of natural soundscapes could lead to their increased valuation by some individuals, motivating them to experience nature while seeking out natural soundscapes (Marin et al., 2011).

The advent of acoustic recording and reproduction technologies has also led to material connections with nature through soundscapes, as natural recordings have been commodified. This same technology has played a role in promoting novel cognitive connections with nature through audio recordings. Recording and playback of sounds has greatly facilitated the study of animal sounds (i.e., bioacoustics; Penar et al., 2020) and, more recently, analysis of biodiversity trends and the ecological implications of soundscapes (i.e., soundscape ecology and/or ecoacoustics; Pijanowski et al., 2011a,b; Riede, 1993; Sueur & Farina, 2015). Much of this work has captured the public imagination outside of academia and has fostered emotional and philosophical connections with nature as well (Ghadiri Khanaposhtani et al., 2018a; Krause, 2012; Rothenberg, 2008). Awareness of the troublesome ecological implications of reduced biophony and acoustic masking caused by non-biological human sounds (technophony) will often generate feelings of loss, sadness, frustration, or anger (Carson, 2002; Krause, 2012). It may also cause one to question the justice of global human domination that comes at the expense of non-human animal communication and survival (Pepper, 2017).

The aforementioned manners of connection with nature through soundscapes seem intuitively valid, and they have inspired an array of efforts to promote such connections through the soundscape paradigm. These efforts range from soundwalks—dedicated excursions to observe the spatially varying sounds of certain areas (Behrendt, 2018; Westerkamp, 2007; Williams, 2017)—to more expansive soundscape-based curricula and human-nature connection initiatives (Barclay, 2014; Ghadiri Khanaposhtani et al., 2018a,b; US National Park Service, 2018a, 2018b). Unfortunately, despite the intuitive appeal of such efforts, there is a paucity of empirical evidence supporting the hypothetical underpinnings of connection with nature through soundscapes.

To investigate this theoretical linkage between connection with nature and the soundscape paradigm, we sought to quantify and compare

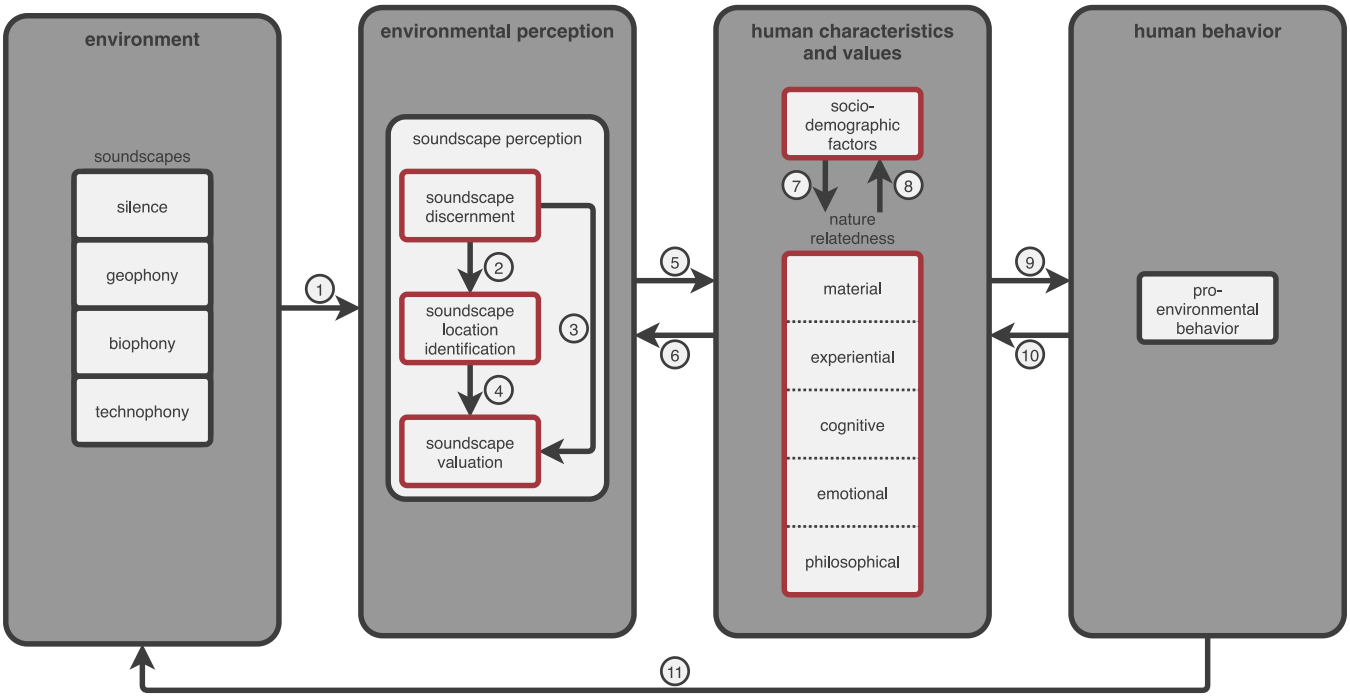

Fig. 1. Theoretical relationships between soundscapes, soundscape perception, nature relatedness, and pro-environmental behavior. Grey boxes indicate broad concepts concerning human-environment interactions, while white boxes indicate concepts pertinent to this study that are specific aspects or manifestations of the broader concepts. Dotted lines separate potentially overlapping concepts, and boxes with red borders indicate concepts that were assessed in this study. Text above a set of abutting boxes serves as the higher-level concept label for that set of boxes. Arrows indicate the following processes: 1) The environment (including soundscapes) forms the basis of our environmental perceptions. 2) Recognition and identification of sounds helps determine where those sounds are occurring. 3) Recognition and identification of sounds contributes to valuation of a soundscape. 4) Being able to identify where a soundscape occurs increases its meaningfulness, and associations with the location can alter perception of the soundscape's value. 5) Perceptions of environments are experiences that shape personal values. 6) Personal values serve as a lens through which environments are perceived. 7) Sociodemographic factors are associated with certain life experiences that influence the ways in which one connects with nature. 8) The ways in which one connects with nature influence life choices that result in membership in certain sociodemographic groups. 9) Human characteristics and values guide behavioral choices. 10) Behavioral choices reinforce or challenge characteristics and values. 11) Human behavior alters the environment. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

individual connection with nature, importance of senses in experiences of nature, and perceptions of various soundscapes. For the purposes of this study, we considered soundscape perception to be composed of three aspects: a) soundscape discernment (the accuracy and precision with which one can remember recently heard soundscapes and list and describe their component sounds), b) soundscape valuation (appreciation of the personal, social, and ecological significance of a soundscape), and c) soundscape location identification (the accuracy and precision with which one can identify the location in which a soundscape was recorded). We designed and conducted a survey to address several broad hypotheses concerning the above concepts, while also exploring potential sociodemographic influences on them. Our general hypotheses and predictions were as follows:

1. Hearing will be rated as the second most important sense for experiences of nature because a) vision has primacy in nature-based media, b) vision is exceptionally useful in navigating through natural environments, and c) natural soundscapes are popularly conceptualized as beautiful and relaxing, while touch, smell, and taste are generally neglected in descriptions of natural places and phenomena. While there is evidence supporting intercultural variability in sensory importance (Hutmacher, 2019; Majid et al., 2018), in a modern Western cultural context, linguistic and survey-based evidence supports the primacy of vision and the secondary role of hearing outside of any specific situation (Roque et al., 2015; Schifferstein, 2006).
2. Connection with nature or "nature relatedness" will be positively correlated with soundscape discernment, valuation, and location identification. These relationships were predicted because individuals that are highly nature related tend to spend more time outdoors (Mayer & Frantz, 2004; Nisbet et al., 2009) and are likely to: a) be very aware of their environments and capable of accurately recalling and describing soundscapes in detail, b) understand the ecological importance of soundscapes and actively consider the sounds around them, and c) have a greater awareness of places' characteristic soundscapes.
3. Soundscape discernment, valuation, and location identification will be positively correlated for a given soundscape, but not necessarily across different soundscapes. Better recognition of what one is hearing (discernment) would lead to more authoritative assessments of a soundscape's personal, social, and ecological importance and more accurate and precise recognition of a soundscape's location.
4. Soundscape discernment and location identification will be higher for soundscapes that are more familiar to listeners due to previous experiences with similar soundscapes. Axelsson et al. (2010) found familiarity to be an important dimension of soundscape perception, and it is easier to name and describe sounds that one has heard before, as opposed to novel sounds. Increasing familiarity should increase descriptive ability. Recognition of a more numerous set of sounds should then enhance one's ability to accurately and precisely identify the location where a recording was made.

2. Methods

2.1. Study area

We conducted our study in the city of Ushuaia, located on the northern coast of the Beagle Channel in Tierra del Fuego, Argentina

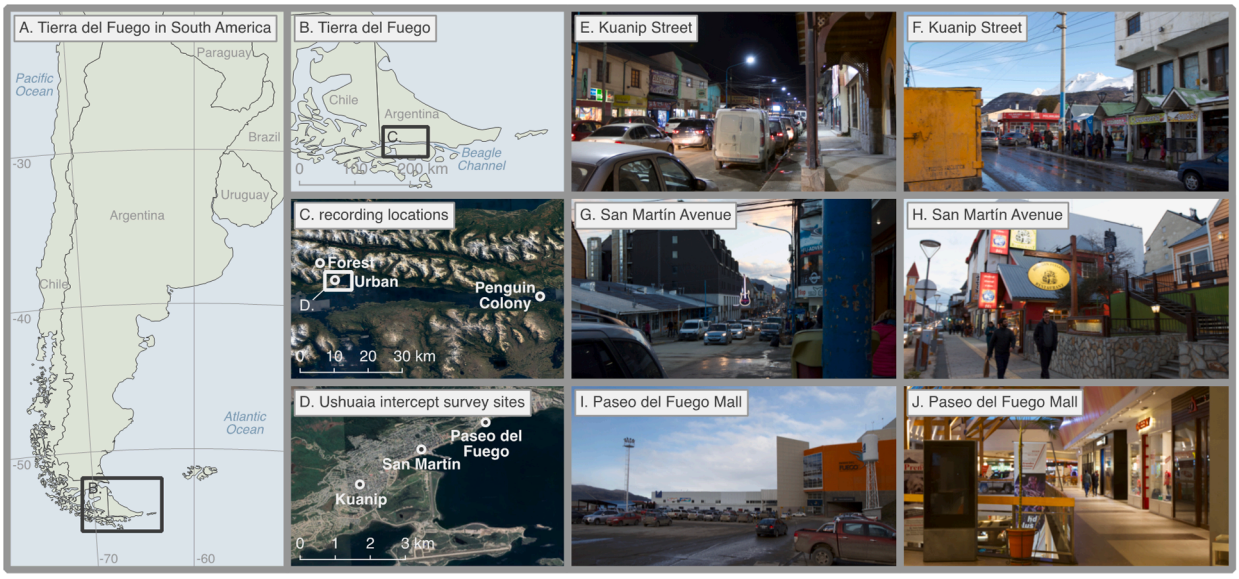

Fig. 2. Maps and photographs showing Tierra del Fuego in southern South America (A and B), the soundscape prompt recording locations (C), and the survey administration sites (D through J). Maps were produced in QGIS (QGIS.org, 2020) using satellite imagery from Google Maps.

(Fig. 2). Soundscapes differ vastly between the sharply defined urban core of Ushuaia, its forested surroundings, and the congregations of seabirds and marine mammals that occur in the Beagle Channel (Raya Rey et al., 2017). In addition to its diverse soundscapes, the social dynamics of this city make it an interesting place to explore the potential sociodemographic influences on nature relatedness and soundscape perception. Around 400,000 tourists visit Ushuaia annually, and many of Ushuaia's 70,000 residents are employed directly or indirectly by tourism (Instituto Fueguino de Turismo, 2017; Secretaria de Turismo de Ushuaia, Departamento Estadísticas y Econometría, 2011). Spurred on by both growing tourism and Argentine efforts to reinforce national sovereignty, the urban population of the Province of Tierra del Fuego, Antarctica, and South Atlantic Islands increased by 419% between 1980 and 2010 compared to a national urban increase of 57% (Herbert, 2014; Instituto Nacional de Estadistica y Censos, 2017). Social tensions over resources and the wilderness- and nature-based identity of the city have resulted from these rapid changes and have led to the identification of three distinctive social groups by Herbert (2014): long-term residents, amenity or lifestyle migrants, and economic migrants. The potential to observe differences between these groups in terms of their nature relatedness and soundscape perception was an additional factor that motivated our choice of this study site.

2.2. Survey design

To test the above hypotheses, we designed a street intercept survey. Intercept surveys originated in consumer research (Blair et al., 2013; Rookey et al., 2012) and have been adopted as a common data collection method in leisure and recreation research (Campbell, 2013; Loomis, 2007; Rickard et al., 2011). These surveys allow the gathering of *in situ* feedback to assess locally salient topics, measure sense of place, and reach out to people who might be hard to contact otherwise (Flint et al., 2016; McKenzie & Mistiaen, 2007; Troped et al., 2009). Our survey contained questions about participant: a) sociodemographics, b) nature relatedness, c) use of senses in experiences of nature, and d) perception of Fuegian soundscapes. The full texts of English and Spanish versions of the survey are presented in Appendix A. All variables employed in analyses that were generated directly or indirectly from survey responses are described in Table 1.

The nature relatedness survey section was closely modeled on the NR-6 scale of Nisbet and Zelenski (2013), in which participants rate their agreement with six statements about their relationship with the natural world on 5-point scales. We slightly modified the phrasing of several original NR-6 statements to adapt to the cultural context and to increase participant understanding (see Appendix A).

In the section about sensory experiences of nature, participants rated the importance of each of their five senses (vision, hearing, touch, smell, and taste) in their experiences of nature using a 4-point scale.

For the section on soundscape discernment, valuation, and location identification, participants responded to the same instructions for each of a sequence of the following four randomly ordered prompts: a) the sounds they had heard in approximately the 30 s preceding the survey (sounds generally included those of vehicles, people walking, and people talking; hereafter, "*In Situ*"), b) a 20-s recording from a Fuegian forest near a North American beaver (*Castor canadensis*) pond in Andorra Valley, just outside of Ushuaia, featuring sounds of wind, passerine vocalizations, and a beaver entering the pond (hereafter, "Forest"), c) a 20-s recording from a Magellanic penguin (*Spheniscus magellanicus*) colony on Martillo Island featuring sounds of wind, waves, and vocalizations from Magellanic penguin chicks and adults (hereafter, "Penguin Colony"), and d) a 20-s recording from the city of Ushuaia featuring sounds of passing cars, a stationary motor, a ship horn, and passerine calls (hereafter, "Urban"). Recording locations are shown in Fig. 2C, and the three sound files are provided as Appendices B through D. Audio files were played to participants from a tablet at maximum volume through Audio-Technica QuietPoint 50 active noise-cancelling headphones (Audio-Technica, 2019). This method of obtaining responses to audio prompts is similar to that employed by Marin et al. (2011).

To quantify soundscape discernment, participants were first asked to list and describe the sounds they heard in the prompt. The survey administrator wrote down the reported sounds and noted whether or not participant descriptions of each sound contained each of the following characteristics: amplitude, frequency, timbre, imitation, spatial reference, timing, and comparison (see Appendix E for definitions and examples). The survey administrator coded each listed sound for its accuracy and precision (see Appendix F for details).

We considered soundscape valuation to be a participant's appreciation of the personal, social, and ecological significance of a given soundscape. To measure this variable, we developed the soundscape valuation scale—a five-item agreement-based scale containing the following items:

Table 1
Analysis-form variables employed in this study.

Organizational category	Name	Type	Levels or observed and theoretical ranges	Description/derivation
nature relatedness	nature relatedness	interval	observed: 2.5–5; theoretical: 1–5	the mean of the six nature relatedness scale items (averaged due to unidimensionality; see Appendix E)
sense importance	sense	categorical	vision, hearing, touch, smell, taste	the names of the five senses
	sense importance	ordinal	of no importance, of little importance, of moderate importance, of high importance	the self-reported importance of each sense
	mean sensory importance	interval	observed: 1.8–4; theoretical: 1–4	the average of the five sense importance values
	relative hearing importance	ratio	observed: −2–1.4; theoretical: −2.4–2.4	the sense importance for hearing minus the mean sensory importance
soundscape prompt	soundscape prompt	categorical	Forest, *In Situ*, Penguin Colony, Urban	the names of the four soundscape prompts
soundscape discernment	soundscape discernment	interval	observed: 0–0.75; theoretical: 0–1	the weighted average of the scaled accuracy (weight = 0.5), precision (weight = 0.25), and description detail (weight = 0.25) scores for each soundscape description (see Appendices E and G for details)
	Forest soundscape discernment	interval	observed: 0.08–0.75; theoretical: 0–1	the weighted average of the scaled accuracy (weight = 0.5), precision (weight = 0.25), and description detail (weight = 0.25) scores for the description of the Forest soundscape (see Appendices E and G for details)
	In Situ soundscape discernment	interval	observed: 0–0.73; theoretical: 0–1	the weighted average of the scaled accuracy (weight = 0.5), precision (weight = 0.25), and description detail (weight = 0.25) scores for the description of the *In Situ* soundscapes (see Appendices E and G for details)
	Penguin Colony soundscape discernment	interval	observed: 0–0.61; theoretical: 0–1	the weighted average of the scaled accuracy (weight = 0.5), precision (weight = 0.25), and description detail (weight = 0.25) scores for the description of the Penguin Colony soundscape (see Appendices E and G for details)
	Urban soundscape discernment	interval	observed: 0.13–0.73; theoretical: 0–1	the weighted average of the scaled accuracy (weight = 0.5), precision (weight = 0.25), and description (weight = 0.25) scores for the description of the Urban soundscape (see Appendices E and G for details)
soundscape valuation	soundscape valuation	interval	observed: 1–5; theoretical: 1–5	the mean of the five soundscape valuation scale items for each soundscape prompt (averaged due to moderate unidimensionality; see Appendix E)
	Forest soundscape valuation	interval	observed: 2–5; theoretical: 1–5	the mean of the five soundscape valuation scale items for the Forest soundscape (averaged due to moderate unidimensionality; see Appendix E)
	In Situ soundscape valuation	interval	observed: 1–5; theoretical: 1–5	the mean of the five soundscape valuation scale items for the *In Situ* soundscapes (averaged due to moderate unidimensionality; see Appendix E)
	Penguin Colony soundscape valuation	interval	observed: 2–5; theoretical: 1–5	the mean of the five soundscape valuation scale items for the Penguin Colony soundscape (averaged due to moderate unidimensionality; see Appendix E)
	Urban soundscape valuation	interval	observed: 1–5; theoretical: 1–5	the mean of the five soundscape valuation scale items for the Urban soundscape (averaged due to moderate unidimensionality; see Appendix E)
soundscape location identification	soundscape location identification	interval	observed: 0–1; theoretical: 0–1	the mean of the scaled accuracy and precision scores for each soundscape location identification
	Forest location identification	interval	observed: 0–1; theoretical: 0–1	the mean of the scaled accuracy and precision scores for the Forest soundscape location identification
	Penguin Colony location identification	interval	observed: 0–1; theoretical: 0–1	the mean of the scaled accuracy and precision scores for the Penguin Colony soundscape location identification
	Urban location identification	interval	observed: 0–1; theoretical: 0–1	the mean of the scaled accuracy and precision scores for the Urban soundscape location identification
sociodemographics	occupation	binary	related, unrelated	whether or not the participant's primary occupation is related to nature or nature-based tourism (self-reported)
	education	ordinal	elementary, secondary, some post-secondary, bachelor's degree, graduate degree	the participant's highest level of education (self-reported)
	gender	binary	male, female	the surveyor's perception of the participant's gender
	age	ratio	observed: 18–69; theoretical: 18–122	the participant's age (self-reported)
	country	binary	Argentina, other	the participant's country of current residence with all but Argentina grouped as "other" (self-reported)
	years of residence	ratio	observed: 0–69; theoretical: 0–122	the participant's number of years lived in Tierra del Fuego (self-reported)
	reason for residence	categorical	visitor, original resident, economic reasons, lifestyle reasons, family reasons	the coded free responses as to why the participant had moved to Tierra del Fuego (if they had indeed moved there; self-reported)
	survey number	interval	observed: 0–233	the number referring to the order in which the surveys were completed

(*continued on next page*)

Table 1 (*continued*)

Organizational category	Name	Type	Levels or observed and theoretical ranges	Description/derivation
potentially confounding covariates	day of surveying	interval	observed: 0–21	the day of the survey period, not counting days on which no surveys were conducted
	minute of surveying	interval	observed: 4.6–524.9; theoretical: 0–545.6	the minute of the day at which the survey began, relative to the first overall time at which a potential participant was asked
	survey duration	ratio	observed: 469–1701 (07:49–28:21)	the duration of the survey in seconds
	survey site	categorical	Kuanip, San Martín, Paseo del Fuego	the site of the survey

1. I liked the sounds I heard.
2. The sounds I heard triggered memories.
3. The sounds I heard provided me with information about the place in which they occurred.
4. The sounds I heard have an effect (either positive or negative) on the animals living where the sounds occurred.
5. The sounds I heard made me feel emotions.

These statements were chosen to allow a participant to express their view of a soundscape's importance from several different personal and ecological perspectives and were inspired in part by the "soundscape values" proposed by Dumyahn and Pijanowski (2011).

Finally, for location identification of the three recordings, participants were asked where they thought the recording was made, and the survey administrator scored each response for its accuracy and precision (on 3- and 4-point scales, respectively). In addition, the surveyor wrote down any qualitative observations about the participants' actions or responses that could not have been otherwise captured in the survey data.

2.3. Data collection

Street intercept surveys were administered on 21 separate days between 16 July 2019 and 15 August 2019 between 11:30 and 21:00. Surveys were conducted at three sites within the city of Ushuaia: Kuanip Street (one of the city's principal commercial streets with minimal tourist traffic), San Martín Avenue (the city's main street with much tourist traffic), and Paseo del Fuego Shopping Mall (a mall featuring a gym, movie theater, and supermarket; Fig. 2D through 2J). We chose these three sites because they are Ushuaia's three principal public commercial centers, are geographically distributed across the city, and are frequented by different social groups. Surveying alternated daily between the two outdoor sites (12 total days split evenly between Kuanip and San Martín) except for days with inclement weather, when surveying was conducted in the entrance of Paseo del Fuego (9 days). Survey administration and sampling techniques were similar to those described by Flint et al. (2016) and Buschmann (2019), and they are presented in further detail in Appendix E. Additional information on survey dates, times, and sites is also available in Fig. E.2 through E.5.

2.4. Analysis

2.4.1. Preparatory data transformation and evaluation

Incomplete survey responses were discarded, and raw data were transformed into analysis-form variables (listed in Table 1) as indicated in Appendix G. All analyses were conducted in R 4.0.2 (R Core Team, 2020) with packages "car", "corrplot", "dendextend", "dplyr", "emmeans", "Hmisc", "lmerTest", "MASS", "multilevel", "openxlsx", "ordinal", "reshape", and "vegan" (Fox & Weisberg, 2019; Galili, 2015; Kuznetsova et al., 2017; Venables & Ripley, 2002; Wickham, 2007; Bliese, 2016; Christensen, 2019; Harrell, 2018; Lenth, 2019; Oksanen et al., 2018; Walker, 2018b; Wei & Simko, 2017; Wickham et al., 2019). Code is available at https://github.itap.purdue.edu/PijanowskiGroup/Francomano_et_al_2022_Soundscape_Perception_in_TDF. To evaluate the dimensionality of the composite scales employed in this study (nature relatedness and soundscape valuation for each of the four soundscape prompts), we calculated Cronbach's alpha and plotted the first two principal components of principal components analyses (PCAs; Bernard, 2011); results are provided in Appendix E (Fig. E.1).

2.4.2. Statistical tests

To evaluate the importance of hearing relative to other senses in experiences of nature, we performed a mixed-effects ordinal logistic regression with sense importance as the dependent variable, sense as a fixed independent variable, and survey number as a random independent variable. The proportional odds assumption was tested (Christensen, 2018; Harrell, 2015), and the significance of the model was evaluated through comparison against a null model. Our prediction that hearing is of secondary importance was tested using two *a priori* contrasts comparing vision against hearing and hearing against touch, smell, and taste.

We employed three linear mixed-effects models to examine the influence of the various soundscape prompts on soundscape discernment, valuation, and location identification. Each of the three soundscape perception variables was treated as the dependent variable in a distinct model with soundscape prompt as a fixed independent variable and survey number as a random independent variable. Assumptions of linearity, homogeneity of variance, and normality of error were graphically verified for each model. Pairwise contrasts were evaluated using a Tukey HSD test.

To explore the relationships between nature relatedness, mean sensory importance, the relative importance of hearing, and the discernment, valuation, and location identification of the four soundscape prompts (excluding location identification for the *In Situ* soundscape prompt), we applied nonparametric Spearman correlations (since Shapiro tests indicated that all but one variable failed to meet the assumption of normality, even following $\log_{10}$ transforms). Given the exploratory nature of this investigation and the relative inconsequentialness of committing Type I Error, we chose not to adjust p-values, as recommended by McDonald (2009).

The influence of sociodemographic factors on the importance of the five senses in experiences of nature was examined through a redundancy analysis that treated the five sense importance variables as dependent variables and all sociodemographic variables and covariates listed in Table 1 as independent variables (in the full possible model). Covariates were included in the model to account for any confounding effects they could have induced. We fit a full and null model, using the natural log transforms of age and survey duration to improve their distributional symmetry. We examined bivariate plots of all pairs of ordinal, interval, or ratio variables to ensure that none seemed particularly correlated, which led us to remove day of surveying in favor of survey number. We then performed forward and backward additions and subtractions of non-conditioning independent variables and chose the best fitting model based on permutational p-values and AIC (Borcard et al., 2011). The resultant model was checked for collinearity using variance inflation factors, and its explanatory power and significance were respectively evaluated considering the adjusted R^2 value and permutational p-value.

The redundancy analysis revealed that only gender and survey duration were significant predictors, so as a follow-up test, we performed a mixed-effects ordinal logistic regression with sense importance as the dependent variable, sense, gender, and their interaction as fixed independent variables, and survey number as a random independent

variable. The model was fitted and checked as described above, employing pairwise comparisons between genders for each sense.

To broadly assess the influence of sociodemographics on nature relatedness, mean sensory importance, relative importance of hearing, and discernment, valuation, and location identification (when applicable) of each of the four soundscape prompts, we conducted another redundancy analysis as described above. Age, survey duration, and Forest and Urban discernment were natural log transformed. As sociodemographic and covariate variables both remained after the model selection procedure, we conditioned the covariates in a partial redundancy analysis, that was evaluated as described above.

In addition to our general hypotheses and predictions described in the Introduction, we had several specific predictions and hypotheses related to the three identified social groups of Ushuaia (long-term residents, amenity or lifestyle migrants, and economic migrants; Herbert, 2014). Therefore, regardless of the redundancy analysis outcome, we tested them directly using general linear models. If models contained multiple independent variables, bidirectional, AIC-based model selection was performed. Assumptions of linearity, normality of error, and homogeneity of variance were then evaluated graphically, and if they were not met, the independent variable was square root transformed. Specific sociodemographic-related hypotheses, predictions, and model formulae are presented in Table E.1.

3. Results

We obtained 233 complete responses from 1,008 survey requests (23% response rate; Fig. E.2 through E.5). Six surveys were conducted in English (primarily with tourists), while the rest were conducted in Spanish. Participants were 48% male and 52% female (Fig. E.5). Maximum education levels were 9% primary school, 34% secondary school, 13% some post-secondary education, 42% bachelor's degree, and 2% graduate degree (Fig. E.6), and 24% reported having a nature-related occupation. Non-residents of Tierra del Fuego composed 19% of our participants, 6% of participants were from six countries other than Argentina, and 19% had lived in Tierra del Fuego for their whole lives (Fig. E.7). Our sample skewed more educated and slightly younger than the provincial population (Dirección General de Estadística y Censos, 2013). Mean, median, and mode nature relatedness were all around 4 on the 1-to-5 NR-6 scale, with higher values representing greater nature relatedness.

Self-reported importance of senses in experiences of nature differed between senses (likelihood ratio statistic = 223.15; d.f. = 4; $p < 0.001$; Fig. 3). In our *a priori* contrasts, vision was rated as more important than hearing (z-ratio = 6.34; $p < 0.001$), and hearing was rated as more important than the remaining three senses (z-ratio = 6.49; $p < 0.001$). Many individuals stated that all senses were of high importance, but others tended to follow the pattern indicated by the above tests (Fig. E.9).

Soundscape discernment differed between prompts ($F = 23.24$; d.f. = 3, 696; $p < 0.001$; Fig. 4A; see Table E.2 for all contrast statistics); it was highest for *In Situ*, followed by Forest, and then followed by approximately equal means for Penguin Colony and Urban. Soundscape valuation differed between all four prompts ($F = 142.14$; d.f. = 3, 696; $p < 0.001$; Fig. 4B) with that of Forest being highest, followed in descending order by Penguin Colony, Urban, and *In Situ*. Soundscape location identification differed as well ($F = 4.28$; d.f. = 2, 464; $p = 0.014$; Fig. 4C). Location identification was highest for Urban, but it did not differ substantially between Forest and Penguin Colony.

Correlations of interest are presented in Fig. 5. Nature relatedness and mean sensory importance were positively correlated, as were nature relatedness and soundscape valuation for all soundscapes except *In Situ*. Nature relatedness did not, however, exhibit correlations with soundscape discernment or location identification for any soundscape. Soundscape valuation was positively correlated with both soundscape discernment and location identification, but only for the two more natural soundscapes—Forest and Penguin Colony. Soundscape discernment and location identification of a given soundscape were positively correlated in all three cases.

Model selection yielded a redundancy analysis with a single sociodemographic variable—gender—and survey duration as meaningful predictors of sensory importance (adjusted $R^2 = 0.03$; pseudo-F = 4.25; d.f. = 2, 230; $p = 0.001$). The generalized ordinal logistic regression employed as a follow-up test produced an overall likelihood ratio statistic of 235.69 with 9 degrees of freedom and $p < 0.001$. The pairwise contrasts revealed that women reported higher importance than men within smell (z-ratio = 2.80; $p = 0.005$), touch (z-ratio = 2.60; $p = 0.009$), and hearing (z-ratio = 2.55; $p = 0.011$; Fig. 3). Results for taste and vision, respectively, were: z-ratio = 1.92, $p = 0.055$ and z-ratio = 0.41, $p = 0.682$.

The second redundancy analysis revealed that age, gender, and occupation are related to the suite of dependent variables employed: nature relatedness, mean sensory importance, relative importance of hearing, and discernment, valuation, and location identification (when

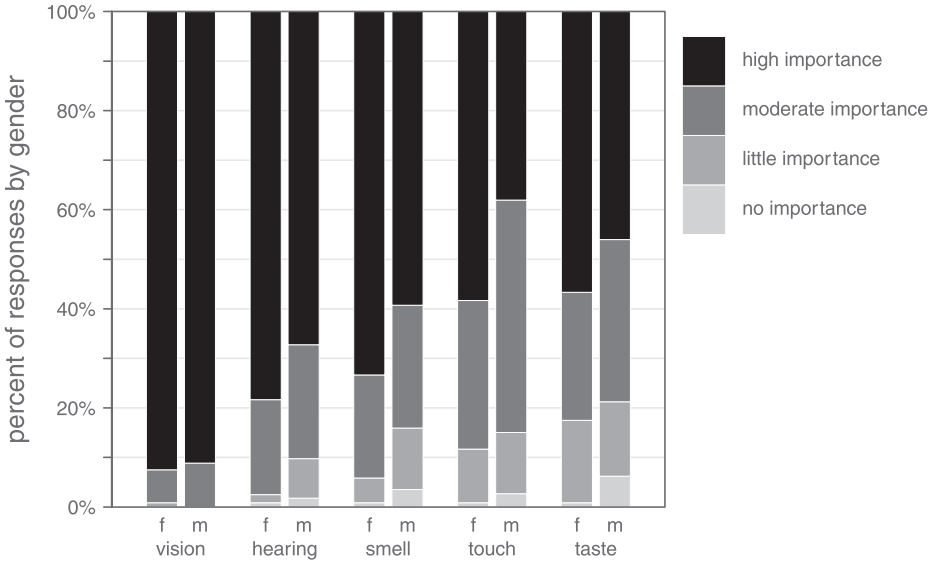

Fig. 3. Reported importance of the five senses in experiences of nature. Stacked bars represent the percent of participants of each gender who rated each sense with the degree of importance specified by the scale on the right (f = female; m = male).

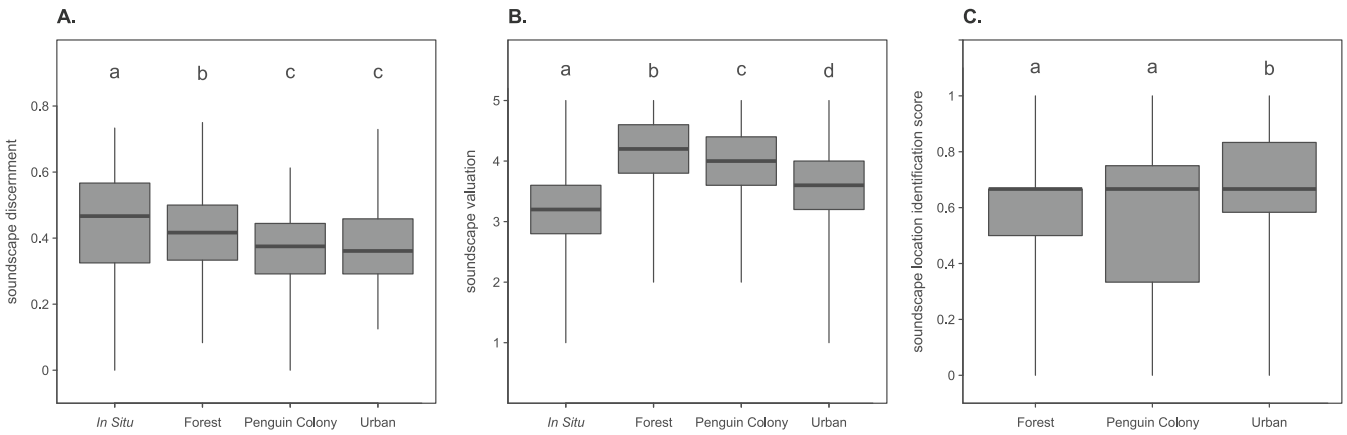

Fig. 4. Differences in soundscape A) discernment, B) valuation, and C) location identification by soundscape prompt. Horizontal lines in boxes represent medians, and boxes extend from the first to third quartile. Whiskers extend to minima and maxima. Differing letters between prompts signify contrasts with $p \leq 0.05$.

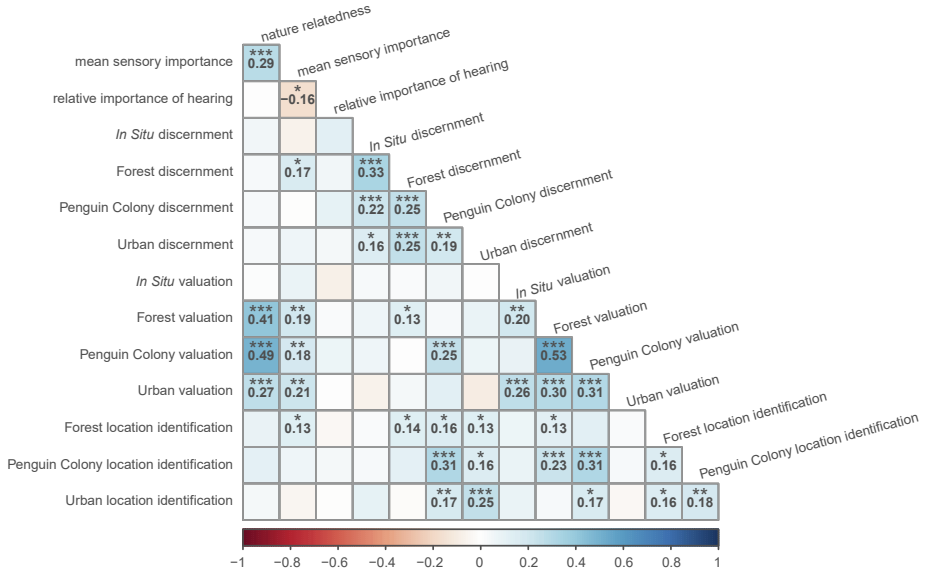

Fig. 5. Spearman correlations between dependent variables considered in this study. Correlation coefficients are indicated by the colors presented in the scale at the bottom of the figure, and coefficients with p-values ≤ 0.05 are printed in their corresponding boxes. P-values are indicated as follows: * signifies $0.05 \geq p > 0.01$, ** signifies $0.01 \geq p > 0.001$, and *** signifies $p \leq 0.001$.

applicable) of each of the four soundscape prompts (adjusted $R^2 = 0.02$; pseudo-F = 2.95; d.f. = 3, 226; p = 0.001). The correlation triplot (Fig. 6) indicates that having a nature-based occupation and being older appear positively linked to nature relatedness and soundscape valuation while negatively linked to soundscape discernment and location identification for most prompts other than Penguin Colony. Being female appears to relate to higher mean sensory importance and perception of the Forest soundscape, while being male appears linked to *In Situ* valuation, Penguin Colony discernment and location identification, and Urban location identification.

Attempts to test the specific sociodemographic-related hypotheses outlined in Table E.1 generally yielded insignificant ($p > 0.05$) or null (due to AIC-based elimination of all independent variables) models, with two exceptions: having a nature-based occupation was related to higher nature relatedness (F = 5.59; d.f. = 1, 231; p = 0.019) and Penguin Colony soundscape valuation (F = 7.03; d.f. = 1, 231; p = 0.008).

4. Discussion

While much work remains to develop and test soundscape-based efforts to promote nature relatedness, our findings offer some support for their theoretical basis and highlight several important directions for future research on this topic. Here, we delve into the implications and potential drivers of the secondary importance of hearing, the positive relationship between nature relatedness and soundscape valuation, the importance of soundscape "naturalness", the possible roles of soundscape familiarity and distinctiveness, and our limited findings concerning sociodemographic influences. We also highlight some of this study's limitations and outline the rationale behind potential directions for future research.

The appeal of using the soundscape paradigm to promote nature relatedness partially rests on the idea that hearing can convey a great deal of information and is generally a familiar sense, but is often an afterthought (Dumyahn & Pijanowski, 2011)—a "passive" sense in the terms of Yang and Kang (2005). Indeed, participants in our survey reported that hearing was of secondary importance to vision in their experiences of nature (Fig. 3), echoing findings from Roque et al. (2015) and Schifferstein (2006). It is important to note that sensory importance may vary across cultures (Hutmacher 2019; Majid et al. 2018), and it may depend on situational context (e.g., Schifferstein, 2006). In experiences of nature, the relative importance of senses could vary based on habitat, time of day, or season. For example, vision is not very useful at

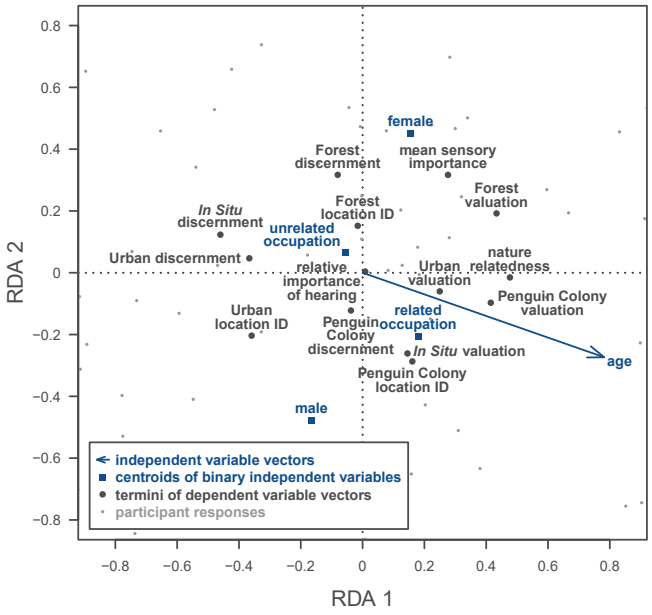

Fig. 6. Correlation triplot showing the influence of sociodemographic variables on nature relatedness, mean sensory importance, the relative importance of hearing, and soundscape discernment, valuation, and location identification (when applicable) for each soundscape prompt.

night in the rainforest, while hearing and smell might be hyper-stimulated in a raucous, stinky penguin colony. Overall, however, in the cultural and situational contexts we considered, hearing was of secondary importance in experiences of nature.

We found partial support for the hypothesized relationship between nature relatedness and the three aspects of soundscape perception that we considered. Nature relatedness was positively correlated with Forest, Penguin Colony, and Urban soundscape valuation, but not with soundscape discernment or location identification (Fig. 5). This limited relationship suggests that soundscape perception may be linked to nature relatedness primarily at emotional and philosophical levels, as opposed to experiential and cognitive levels (*sensu* Ives et al., 2018). Soundscape valuation may represent a deeper, more internal human-soundscape relationship than soundscape discernment and location identification, which could be considered more superficial. As the emotional and philosophical levels of nature relatedness provide greater leverage for affecting positive change in social-ecological systems (Ives et al., 2018), this partial support for our hypothesis still offers a favorable outlook on the use of the soundscape paradigm to promote positive social-ecological change. More generally, this finding also hints at how affective, as opposed to cognitive, dimensions of experiences of nature may be more meaningful in terms of promoting nature relatedness (Ives et al., 2018).

Some distinctions can be drawn between our findings for the two more natural soundscapes (Forest and Penguin Colony) and those for the two soundscapes that were more technophonically dominated (*In Situ* and Urban). Correlation coefficients between nature relatedness and soundscape valuation were highest for the two more natural soundscapes, indicating that valuation of natural soundscapes may be more strongly linked to nature relatedness. Ample evidence suggests a human preference for more natural, as opposed to technophonically dominated, soundscapes (Arras et al., 2003; Axelsson et al., 2010; Benfield et al., 2018; Carles et al., 1999; Hall et al., 2013; Payne, 2013; Pilcher et al., 2009; Yang & Kang, 2005). Most of the above studies, however, considered preference or pleasantness, as opposed to our more complex construct of valuation. Our soundscape valuation scale considered pleasure ("I liked the sounds I heard", was the first item), but it also sought to measure one's appreciation for the personal, social, and ecological importance of a given soundscape. By our measure, one could still highly value a soundscape, even if they did not like it.

Another finding related to soundscape "naturalness" concerned the predicted positive correlations between the three aspects of soundscape perception within each soundscape prompt (e.g., between Forest discernment, Forest valuation, and Forest location identification). This prediction was fully validated for just the two more natural soundscapes. Considered together, this finding and the high correlations between natural soundscape valuation and nature relatedness provide some limited evidence suggesting that it might be possible to promote nature relatedness through the three aspects of soundscape perception, though several caveats must be mentioned: 1) Our study was non-interventional—we found evidence of cross-sectional correlations, not change over time. 2) Emphasizing soundscape valuation would likely be a more direct approach to foster nature relatedness than emphasizing soundscape discernment and/or location identification. A focus on the latter two concepts might be reliant on a chain reaction (i.e., soundscape discernment and/or location identification promoting soundscape valuation, which in turn promotes nature relatedness). 3) These relationships might only be applicable to natural soundscapes.

Given the inclusion of the raucous but natural Penguin Colony soundscape in our study, these results suggest that qualitative descriptors of sound sources (e.g., natural or technological) may influence soundscape perception more than quantitative psychoacoustic parameters. Axelson et al. (2010) previously found an effect of sound sources on soundscape pleasantness, even after controlling for loudness. Much work remains to ascertain the relative extent to which sound source identity or classification and a full suite of psychoacoustic parameters influence soundscape perception. This topic merits future study in field and laboratory conditions for a greater diversity of soundscapes and a wider array of cultural contexts.

Our familiarity-based hypothesis concerning soundscape discernment found weak support. We expected a descending ranking from *In Situ* to Urban, Forest, and then Penguin Colony. The *In Situ* soundscape had just been heard in its environmental context, and given the survey sites in Ushuaia, the Urban soundscape from the city would likely be familiar as well. For the other two prompts, it is much more likely that one would have experienced a forest with passerine song than a penguin colony, so Penguin Colony was expected to follow Forest. *In Situ* did rank highest, but it was followed by Forest and then Urban and Penguin Colony, which were statistically similar. The flipping of Forest and Urban from our expected order may be due to the distinctiveness, as

opposed to the familiarity, of the soundscapes: the sounds in the Forest soundscape were slightly less ambiguous and potentially less misleading than those in the Urban soundscape. Especially if study participants had previously heard the Penguin Colony soundscape and interpreted it as "marine" to some extent, the ship horn at the beginning of the Urban soundscape seems to have misled some participants who subsequently thought that the passing cars were waves and the motor sound (from an idling truck or generator) was a boat engine. The difference in discernment between the Urban and *In Situ* prompts (which generally represented the two most qualitatively similar prompts) raises the question of whether similar, or even identical, soundscapes will always be discerned better *in situ* (relative to a recording) due to better audio quality, enhanced spatial awareness of audio sources, and additional sensory inputs (especially vision). In limited studies comparing perception of *in situ* and prerecorded soundscapes, playback methods and perceptual measures have largely differed from those we employed, precluding useful comparisons (Guastavino et al., 2005; Sudarsono et al., 2016). Nonetheless, this potential difference has important implications for the design of educational programs based on the soundscape paradigm. The implementation and results of such programs may differ vastly if structured around experiences of *in situ* or prerecorded soundscapes.

We expected to find differences in nature relatedness and soundscape perception between the social groups in Ushuaia that were distinguished by Herbert (2014). Generally, we had predicted that lifetime or long-term Fuegian residents, lifestyle migrants, and individuals with occupations related to nature or nature-based tourism would score higher on nature relatedness and most soundscape perception variables (see Table E.1 for specific sociodemographic-related hypotheses and predictions). However, we found only minor differences that were primarily limited to general variables like gender and age—not years of residence or reason for residence.

One important exception is that those with nature-related occupations exhibited higher nature relatedness and valuation of the Penguin Colony soundscape. The former finding likely represents a positive feedback loop (i.e., someone who is highly nature related could seek out a nature-related occupation, which further increases their nature relatedness and encourages them to stay in that field of work; Rosa & Collado, 2019; Zavestoski, 2003). Higher valuation of the Penguin Colony soundscape among those with nature-related occupations may reflect the higher probability that they had previously visited the colony where the recording was made and developed an experiential connection with the place and its sounds; positive environmental attitudes have been broadly linked with experiences of nature (Rosa & Collado, 2019). More generally, our findings suggest that social divisions in Ushuaia around nature relatedness may be defined more by occupation than by years of residence or reason for residence. In this context, any local soundscape-based educational programs to promote nature relatedness and social-ecological sustainability might be most appropriately targeted to those without nature-related occupations. To facilitate these programs, the robust system of nature-based tourism in Ushuaia (Raya Rey et al., 2017) could be leveraged to serve the local population through targeted community outreach. One source of tension highlighted by Herbert (2014) is that tourism benefits are not equitably shared amongst Ushuaians. Many of the nature-based touristic activities in Ushuaia are expensive, so reduced-cost natural excursions offered to locals could improve the public image of the tourism industry while simultaneously promoting public nature relatedness by allowing locals to experience the natural places and soundscapes that lie just outside their city.

Our results concerning the influence of gender on sensory importance, soundscape perception, and nature relatedness exhibited limited similarities with previous research. Our finding of women reporting higher sense importance corresponds with Schifferstein's (2006) finding that women reported slightly higher importance of senses in product evaluations. Yang and Kang (2005) noted that women responded more favorably toward several sounds including the sound of water, but the low R^2-value of our redundancy analysis and lack of clear general relationships between gender and soundscape perception in Fig. 6 preclude any conclusions. More broadly, work by Clayton (2003), Eisler et al. (2003), Kollmuss and Agyeman (2002), and Zelezny et al. (2000) has suggested that women tend to exhibit slightly more pro-environmental attitudes and behaviors, perhaps due to social promotion (in certain cultural contexts) of greater empathy and social responsibility in women (Zelezny et al., 2000). We did not explicitly test for the direct influence of gender on nature relatedness, but a clear relationship was not evident in Fig. 6. This disparate previous research suggests that women may connect with nature through soundscape valuation more easily or strongly than men, though our findings did not provide strong support for this hypothesis. Potential gender differences remain an important consideration in determining how to best leverage the soundscape paradigm to promote nature relatedness and social-ecological sustainability.

Our findings related to the influence of age on soundscape perception and nature relatedness are generally coherent with previous research. The negative relationships between age and soundscape discernment and location identification might be a product of the fact that human hearing often deteriorates with increasing age (Bowl & Dawson, 2019). Regarding soundscape valuation, Yang and Kang (2005) found that preference for natural sounds was higher for older individuals, while preference for technophonic sounds was higher for younger individuals. In our results, age was positively related to valuation of all soundscape prompts. This discrepancy between our findings for technophonic sounds and those of Yang and Kang (2005) might be related to our differing definitions of preference and valuation. As for nature relatedness, Colléony et al. (2017) also found older individuals to exhibit higher nature relatedness, but in their study and ours, it is unclear if this finding is due to a generational or aging-related effect. With a non-longitudinal study, it is impossible to tell if presently young people will become more nature related as they age or if presently old people were already more nature related when they were younger. Soundscape-based educational programs have largely been targeted at youth (Ghadiri Khanaposhtani et al., 2018a,b; US National Park Service, 2018b; but see Barclay, 2014); longitudinal investigation of nature relatedness and soundscape perception would help to determine the relative value of such programs at various ages and the longevity of their efficacy.

Beyond our contribution to the understanding of soundscape perception and nature relatedness, the soundscape valuation scale we developed may also be applicable in other contexts. Due to the nature of street-intercept surveys, we had to be judicious with the length of our survey questions and the number of questions included in the survey. We think the internal consistency and comprehensiveness of our soundscape valuation scale might be further improved by adding additional scale items. Particularly, recognition of the ecological importance of soundscapes could be probed further and may emerge as a clearly defined dimension of soundscape valuation. In addition, we used headphone-administered soundscape prompts in public spaces, which represented a compromise between representative sampling and good acoustic quality with little noise interference. Future large-scale studies seeking generalizability may wish to use an acoustically insulated booth in a public space to provide a more controlled acoustic and visual environment, while still allowing for random sampling of passersby (e.g., Marin et al., 2011).

We also recommend the testing of a more geographically and acoustically diverse set of audio prompts, more direct comparison of *in situ* versus prerecorded prompts, and deeper investigation of the role of "naturalness" in soundscape perception. For example, the *in situ* versus prerecorded distinction could be probed by replicating this study at the other recording locations we used outside of Ushuaia. Audio-based surveys are unfortunately time consuming—our average survey duration was over 12 min (Fig. E.8), and participants in a study by Hall et al. (2013) took about 5 hr to respond to 219 audio prompts. Despite this logistical hurdle, the diversity of global soundscapes necessitates testing

of diverse audio prompts with explicit consideration of sound source composition and a comprehensive analysis of acoustic parameters. Moreover, given the potential cultural variability in the relative importance of hearing (Hutmacher, 2019; Majid et al., 2018), nature relatedness (Colléony et al., 2017; Eisler et al., 2003), and soundscape perception (Yang & Kang, 2005), it is important to include more socio-demographically diverse participants.

5. Conclusions

This study provided important empirical evidence supporting the notion that nature relatedness might be promoted through a soundscape paradigm, as we identified positive correlations between nature relatedness and the valuation of soundscapes—particularly natural ones. The lack of correlations between nature relatedness and soundscape discernment or location identification indicates that the soundscape paradigm may promote nature relatedness more successfully at emotional and philosophical levels. These deep, affective human-nature connections are well suited to meaningfully impact social-ecological systems (Ives et al., 2018). For a given soundscape prompt, positive correlations between aspects of soundscape perception were generally only found for natural soundscapes as well. The "naturalness" of soundscapes thus appears to be an important factor in individual development of linkages between a) extracting information from a soundscape, b) valuing that soundscape, and c) feeling a connection with the natural world represented by that soundscape. Longer-term, interventional studies are needed to see if the soundscape paradigm can be strategically applied in formal and informal educational settings to promote nature relatedness, pro-environmental behavior, and social-ecological sustainability. We are hopeful that experiences intentionally designed to foster emotional and philosophical connections with natural soundscapes would support these outcomes. We hope future work will elucidate the relationship between nature relatedness and natural soundscape valuation in greater detail with an emphasis on global social and acoustic diversity, further exploration of soundscape valuation, and consideration of the relative importance of soundscape sources, informational content, and acoustic parameters.

CRediT authorship contribution statement

Dante Francomano: Conceptualization, Methodology, Software, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Funding acquisition. **Mayra I. Rodríguez González:** Conceptualization, Methodology, Writing – review & editing. **Alejandro E.J. Valenzuela:** Conceptualization, Methodology, Resources, Writing – review & editing, Supervision, Project administration. **Zhao Ma:** Conceptualization, Methodology, Writing – review & editing, Supervision. **Andrea N. Raya Rey:** Conceptualization, Methodology, Resources, Writing – review & editing, Supervision, Project administration. **Christopher B. Anderson:** Conceptualization, Methodology, Writing – review & editing, Supervision. **Bryan C. Pijanowski:** Conceptualization, Methodology, Resources, Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jnc.2021.126110.

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