An Auditory Exploration of Environmental Awareness

_____

A Master of Arts Project

Presented to

Emergent Digital Practices

University of Denver

_____

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

_____

by

Ilona M. Kovacs

June 2023

Committee Chair: Timothy Weaver

Committee Members: Kate Hollenbach and Trace Reddell

Author: Ilona Kovacs
Title: An Auditory Exploration of Environmental Awareness
Advisor: Timothy Weaver
Degree Date: June 2023

Abstract

This research project examines how auditory indications triggered by speed, elevation, and time data recorded during alpine activity can promote the expansion of environmental awareness practices to encompass survival, protection, and appreciation. It extracts short audio clips from soundscapes recorded in Salida, Colorado, and uses them as notification sounds to provoke a deeper understanding of the human impact and relationship to nature. It demonstrates how data-driven short auditory cues can reflect changes within the environment as an introduction to enhanced awareness through adaptive and generative audio. It expands on biophilia, societal systems harmful to the environment, and the concept of indicator species, by using cybercartographic methods to tell a data story auditorily. The previously collected field data from various mountain resorts in Colorado has been transcoded through a Max8 Patch to influence the volume and playback speed of native bird song clips as audio notifications. Each Trek is a sound map and story of its respective field research journey as a SonEco model for how a real-time system could exist to indicate cues to enhance environmental awareness.

Table of Contents

INTRODUCTION & DESCRIPTION

The need for environmental awareness is becoming increasingly urgent, as the world faces unprecedented challenges such as climate change, pollution, and habitat destruction. An innovative approach to promoting environmental awareness is through the emerging field of ecoacoustics. This field explores the sounds of the natural world and provides a unique way to understand the relationships within an environment. As the population exploring alpine regions continues to grow, the systems for preserving the environment itself and how the population interacts with it can also improve.

We can aim to increase environmental awareness by providing a better understanding of the environment through sound, or ecoacoustics. This encourages the appreciation of natural sounds and an understanding of the complexity of the environment. By listening to the sounds of the environment, we gain a deeper appreciation for the nuances of the natural world and the importance of preserving it. To capitalize on its nuances and also consider Western culture's practice of hierarchical individualization, sound can be tied to direct user influence while maintaining elements from the existing environmental soundscape. This can help to bridge the gap between power constructs and the intricacies of the environment.

This research and SonEco project was completed over the course of the 2022-2023 academic year. It focuses on the data collection of speed, altitude, and time from one individual’s eight separate Treks during winter sport activity in the Colorado Rocky Mountain area. It additionally incorporates short clips from recordings of the natural soundscape of the alpine environment near Salida, Colorado. The SonEco project aims to

demonstrate data collection methods through field research opportunities, explore the potential of transcoding Trek data into auditory indication triggers, and contribute to the development of innovative approaches to address the urgent need for environmental awareness.

Discovering emerging tactics to promote the expansion of environmental awareness practices to encompass survival, protection, and appreciation allows for the opportunity to critically reflect. How can invisible and inaudible environmental factors be perceived? Are there any ways to more consciously notice our impact on the environment and our interactions with it? SonEco explores the approach of transcoding human-environmental interaction data into aural notifications of naturally occurring bird songs as a meaningful insight into how digital indication systems may be used to support environmental awareness. It provides sound map stories about how a user interacted with the environment by making hidden factors noticeable through audio feedback.

SonEco's approach reviews the Literature & Media Background research that further details how Biophilia & Thing-ification, Ecofeminism, Psycho-ecoacoustics, Adaptive & Generative Audio, and Sound Maps & Cybercartography approaches influenced the overall outcome in the first chapter. The second chapter covers the Scope & Timeline wherein the project was completed. Chapter three reviews the Materials & Methods used for Data Collection & Field Research, Hardware, and Software for both data Treks and audio Recordings. The Project Discussion & Conclusions details aspects of how the field research data collected was used to transcode a model of an environmental indication system that monitored its user in the fourth chapter. The final

chapter provides suggestions for additional research opportunities in the hopes that this project may inspire further innovations in the audio space to impact environmental awareness.

My recommendation is to open the SonEco Environmental Data Auditory Notification System Model Max8 Patch and follow the instructions for any one given Trek to allow you to select your own read-through speed and volume adjustment preferences if you are able. Each Trek is additionally provided as a video with audio at preset paces if access to Max8 is unavailable or you would like a quick look. More details about the system model and the prerecorded videos of the system are provided in the Trek Audio Transcoding section of the Project Discussion chapter.

LITERATURE & MEDIA BACKGROUND

Environmental awareness has been fundamental in supporting human evolution since our earliest migrations over 60,000 years ago. It once described the initial survival tactics utilized by the first tribes. These tactics included learning the patterns of predators and prey, testing flora and fauna's edibility, and even developing ways of communicating that knowledge. Awareness of the natural environment required the use of both learned behaviors and the body's senses for survival. The early humans were quick in their emergence of hunting tools, fire, and agricultural technologies to continuously increase their endurance to the environment during their migrations until they eventually felt the status of *control over nature*.[1] We can wonder: has Earth similarly been adapting for its own survival? Reconnecting with the planet as it exists could be a forefront solution in deepening our understanding of the human impact and the necessity for sustaining our habitat.

BIOPHILIA & THING-IFICATION

There is an instinctive love of life in humans, referred to as Biophilia, that has not historically been fostered to the degree required to cultivate full respect for all other organisms. Without understanding lives beyond those that are human, value becomes assigned based solely on usefulness even in moments of self-reflection.[2] This Western practice of *worth equals productivity* becomes harmful across all relationships and can be described as one of the root issues in systemic labor, wealth, and identity divisions.

---

[1] David C. Krakauer et al., *History, Big History, & Metahistory* (Santa Fe, NM: SFI Press, 2017).
[2] Edward O. Wilson, *Biophilia* (Cambridge, MA: Harvard University Press, 1984).

Working to dismantle the constructs of value placing can be best emphasized with the idea of thing-ification. To treat something or someone as if it lacks agency is to objectify. Instead, ideating the politics and cares of something or someone can increase its *thing* status, where it has value in the system in which it exists. To create and foster this relationship has the potential to create interest. For example, imagining what a plant may care or think about could help a human understand, empathize, and value the plant.[3] The relationships between humans and nonhumans making up the environment have space for positive, mutually beneficial growth.

Earth's biodiversity is one of the planet's most beneficial resources. Regrettably, the maximum potential of utilizing that diversity is far from met. This is particularly true for traditional agriculture where only a minuscule percentage of all available edible plants are used as common crops. Due to this human hyperfocus on limited specific uses of organisms, life forms are overused to the point of causing endangered species and full extinctions, whether it be directly from the hunt of the organism itself or indirectly through the destruction of ecological systems and habitats. 23 species were removed from the Endangered Species Act by the U.S. Fish and Wildlife Service in 2021 "because they've probably gone extinct, and you can't keep protecting what's already gone."[4] Beyond the results of species extinctions and habitat destruction, the environmental changes on the planet have been increasingly evident. Climate change can be as obvious as the critical wildfire zones and quickly receding glaciers, or even invisible factors such

---

[3] María Puig de la Bellacasa, *Matters of Care: Speculative Ethics in More than Human Worlds* (Minneapolis, MN: University of Minnesota Press, 2017).
[4] John R Platt, "The Lord God Bird and Dozens of Other Species Declared Extinct in 2021," The Revelator (Center for Biological Diversity, January 6, 2022).

as the exponential spread of diseases and harmful air quality. These obvious features have been accelerated during the Anthropocene Epoch. While frequently dismissed by discussion of previous mass extinctions in Earth's history, human impact has proven more harmful in an intensely short interval of time.[5]

In attempting to reverse the negative destruction that human society has caused to ecosystems in their desire to conquer nature, the focus remains overly centralized on one organism. Conservation efforts are meant to increase personal interest for an individual rather than the more classically pushed narrative where decisions are made based on the impacts that they will have on future generations. By leaning into the need for inwardness to foster biophilia, human beings will better understand the value of other organisms and themselves beyond a specific usefulness. The outcome of SonEco aims to foster the practice of environmental awareness on a broader scale, expanding from surviving the environment to protection and appreciation of the environment as well. Survival of the individual will be impractical if the Earth does not survive first.

ECOFEMINISM

In further exploring ways in which organisms are decent in accordance with their particular use and even controlled, the patriarchal system becomes another example. It emphasizes the negative effects of objectification where another's agency is infringed upon. Earth and its ecological biodiversity have been treated as lower-value objects due to power dynamics similar to those inflicted on females. This is because the Western patriarchal system has long been characterized by a hierarchical structure that puts

[5] Edward O. Wilson, *Biophilia* (Cambridge, MA: Harvard University Press, 1984).

primarily white men in positions of authority and power over those deemed weaker and inferior, such as women and the environment. The attitude of control is perpetuated in the behaviors in which the environment is regarded as something to be exploited, rather than something to be respected and preserved.[6]

Systemic patriarchal barriers also extend into reproductive rights in females of all species resulting in power over the population control practices and food production.[7] Beyond female fertility's vitality in increasing the production of animal meat and flowering plants as a food source is the traditional indigenous human female expertise in understanding agricultural biodiversity for medicinal herbs and sustainable edible crops. This expertise was an opportunity for females to connect intimately with the biosphere by encouraging a deeper understanding of it.[8] Then, in urban development it is still most often that male trees are favored in promoting community interaction with the environment leading to higher levels of pollen production and a lack of species diversity.[9]

By using an ecofeminist lens to understand environmental consciousness, it realigns the survival of self as a practice more similar to those previously discussed in early human migration. However, the environment is not always full of new wildlife experiences but rather a more frequently present predator now sustained by the

---

[6] María Puig de la Bellacasa, *Matters of Care: Speculative Ethics in More than Human Worlds* (Minneapolis, MN: University of Minnesota Press, 2017).
[7] Greta Gaard, "Ecofeminism and Climate Change," *Women's Studies International Forum* 49 (2015): pp. 20-33
[8] Douglas A. Vakoch, Nicole Anae, and Panchali Bhattacharya, "Indigenous Ecofeminism and Contemporary Northeast Indian Literature: Lessons in Eco-Swaraj," in *Indian Feminist Ecocriticism* (Lanham, MD: Lexington Books, 2022), pp. 79-92.
[9] Paloma Cariñanos and Manuel Casares-Porcel, "Urban Green Zones and Related Pollen Allergy: A Review. Some Guidelines for Designing Spaces with Low Allergy Impact," *Landscape and Urban Planning* 101, no. 3 (June 2011): pp. 205-214, https://doi.org/10.1016/j.landurbplan.2011.03.006.

patriarchal system. Historically, a debriefing of what happened throughout the day needed to be shared to ensure the safety of all, known as a Meadow Report. Now, consistently checking your surroundings for danger has become a skill and part of the instinct of being environmentally aware. This is especially true for those who are not in immediate systemic power. This environmental awareness skill is more commonly practiced in today's society while in urban environments to protect against other human intrusions than in a more remote habitat for large animals. An updated version of a Meadow Report would likely include judgments of character and recommendations for well-lit streets. “Nature is a shelter these women seek in their refuge from violence which is mostly perpetuated against them by decision-making patriarchy.”[10] Despite the appeal of the natural environment as this haven, the time and money barriers maintained unequally by many modern political systems often restrict the desired connection to nature to enhance personal well-being.[11]

Practiced dualisms are a root source for this discord: femininity to masculinity, nature to culture, and the more commonly understood body to mind. Bridging these dualities will not only interfere with the systemically supported but result in deeper self-understanding. By recognizing both the oppressions of the human species and of other organisms fueled by Westernized culture, the return to biophilia and sensorial

---

[10] Douglas A. Vakoch, Nicole Anae, and Nibedita Mukherjee, “Ecofeminism in Assamese Literature,” in *Indian Feminist Ecocriticism* (Lanham, MD: Lexington Books, 2022), pp. 51-64.
[11] Kay Fretwell and Alison Greig, “Towards a Better Understanding of the Relationship between Individual’s Self-Reported Connection to Nature, Personal Well-Being and Environmental Awareness,” *Sustainability* 11, no. 5 (June 2019): p. 1386.

connections through the thing-ification of nature would be intensified and help to regress society further from the persistent exploitative practices.[12]

PSYCHO-ECOACOUSTICS

The evolution of environmental soundscapes throughout the history of civilization is significant in examining the impacts that noise can have on human behaviors and emotions. Environmental psychology more broadly describes a person's perception of the physical world surrounding them with an emphasis on the five senses. It explores the differences between natural and built environments by studying their effects on human behavior, and especially how those behaviors affect the environment in return. The individual's connection to nature has become something measurable on a scale that relates "environmental values, behaviors, awareness, and time in nature."[13]

While visual engagement has taken predominancy to aural ways humans interact with environment, the auditory space has much to offer. Acoustic ecology has been explored as the study of relationship between sound of life and society primarily to point to unhealthy imbalances.[14] "The perception of sound and noise is inherently psychological."[15] Research is examining how natural soundscapes can have positive impacts on attention restoration and cognitive control by finding descriptive evidence that

---

[12] Rhonda Roland Shearer, "Ecofeminism by Maria Mies, Vandana Shiva; Ecofeminism and the Sacred by Carol J. Adams; Ecofeminism, Women, Animals, Nature by Greta Gaard; Women, the Environment and Sustainable Development: Towards a Theoretical Synthesis by Rosi Braidotti, Ewa Charkiewicz, Sabine Häusler, Saskia Wieringa," *Signs*, (1997): 496–501, pp. 496-501

[13] Julia Meis-Harris, Kim Borg, and Bradley S. Jorgensen, "The Construct Validity of the Multidimensional AIMES Connection to Nature Scale: Measuring Human Relationships with Nature," *Journal of Environmental Management* 280 (2021): p. 111695.

[14] 1. R. Murray Schafer, *The Soundscape: Our Sonic Environment and the Tuning of the World* (Rochester, VT: Destiny Books, 1994).

[15] Britton L Mace, pp. 189-194.

the playing of bird songs and wind audio clips from national parks is more beneficial than no sound at all.[16] In a more direct environmental awareness sense, bird song has been used as an indicator of unlivable chemical amounts in the air during early mining operations.

> Rachel Carson's Silent Spring identified the risks of bioaccumulation to egg-laying animals, especially raptors (1962); habitat destruction led to the near extinction of the snail darter (1977) and the Northern Spotted Owl (1980s); the fungal threat to the existence of the Cavendish banana (1992) brought attention to the Gros Michel banana crisis of the 1950s, both related to monocultural farming practices; a marked increase in malformed amphibians highlighted the issue of water pollution (1995); the decline of Monarch butterfly populations was linked to the rise of genetically modified crops (1999); and the global warming-induced extinction of polar bears, projected to occur within the next hundred years (2003), are all examples of canary-in-a-coal-mine scenarios.[17]

Noting how animal behavior gives additional evidence for the climate crisis provides opportunities for it to be more closely observed. The natural evolution of animal behavior shapes the environmental soundscape. The surprisingly high-frequency whistle calls of the Rocky Mountain Elk (Cervus canadensis nelsoni) are a response to other sound frequencies occurring in the environment, most directly, the rustling of the foliage on evergreen trees from the wind.

While there are many approaches to using AI to adapt audio, key systems to this research project include relating notification sounds with their environment. On the everyday usage scale, a cell phone application, *Warblr*, is already fine-tuning the AI

---

[16] Lauren C. Abbott et al., "The Influence of Natural Sounds on Attention Restoration," *Journal of Park and Recreation Administration* 34, no. 3 (2016): pp. 5-15.
[17] Katherine Coburn, "The Last Canary in the Coal Mine: Small, Yellow, and Ominously Silent," SCQ, *The Science Creative Quarterly*, (May 30, 2007).

needed to quickly and conveniently identify birds in the UK by their songs with crowdsourced data on an interface similar to Shazam.[18] This project determines relevant sound clips over long periods of time using spectral mapping to visually assist in choosing quality biodiversity content. By emphasizing notable pieces of sonic information like bird songs from alpine areas of Colorado with quantitative individual relevancy, the effects of psycho-ecoacoustics will more strongly correlate human behavior's relationship and hierarchal structure with nature and promote the conscious habit of listening to those environmental sounds.[19]

There is innovative power that comes with understanding ecosystem relationships beyond what is visible to the human eye. Recentering to a more acoustic experience, in a more present sense than ambient background noise to tune out, is contradictory to the current attitudes towards visual stimulation.[20] Sound is a sensorial perception obvious enough to most hearing-abled humans that can greatly influence how environmental awareness can be practiced.

ADAPTIVE & GENERATIVE AUDIO

By using the field information collected about movement, elevation, and time to influence signals with the SonEco system, the emergence of adaptive audio usage makes for a real-life environmental awareness that could be compared to those simulated in video games. "To date, the development of adaptive music systems (AMSs) for video

---

[18] Matthew Hutson, "Watch out, Birders: Artificial Intelligence Has Learned to Spot Birds from Their Songs," *Science*, (July 18, 2018).
[19] Almo Farina, "Ecoacoustics: A Quantitative Approach to Investigate the Ecological Role of Environmental Sounds," *Mathematics* 7, no. 1 (December 26, 2018): pp. 1-16.
[20] Bruce Davis, "FM Radio as Observational Access to Wilderness Environments," *Alternatives: Perspectives on Society, Technology and Environment* 4, no. 3 (1975): pp. 21-27.

games is limited both by the nature of algorithms used for real-time music generation and the limited modeling of player action, game-world context, and emotion in current games," making casual listenability of generative music almost absent, but in experimentation trials, outside of the gaming industry.[21]

A recent research project relating the gestures of humans to MIDI music yielded significant results from a user study about their immersive experience within the room environment.[22] The instinctual reaction of participants in the user study was described as moving away from obstacles to not distort the music being produced by their tracked location. By additionally relating the noise itself to the environment the user is in, SonEco was used to demonstrate how immersion in an outdoor experience with an aural mapping of a user's interaction over time would sound.

Auditory notification indicators of sudden changes to environmental elements such as temperature and elevation in alpine regions can assist in decision-making during real-time explorations. SonEco models how these cue indications would be triggered to an individual user with the data collected on short-term field expeditions during winter sports activity in high-altitude areas around Colorado. While additional cues could potentially be provided by adapting user-made playlists to speed promptings or to accommodate the rising interest in fringe sports from the general population, relating topographic changes with tempo adjustments as well as noise signifiers for things like

---

[21] Patrick Edward Hutchings and Jon McCormack, "Adaptive Music Composition For Games," *IEEE Transactions on Games* 12, no. 3 (September 2020): pp. 270-280.
[22] Bernardo Breve et al., "Enhancing Spatial Perception through Sound: Mapping Human Movements into Midi," *Multimedia Tools and Applications* 81, no. 1 (June 18, 2022): pp. 73-94.

temperature, air-quality index, wildlife encounters, and natural disaster zones, that are beyond the scope of this project.

With the popularity of headphones in modern society, human listening has been increasingly studied for commercialization and immersive listening emergence. More directly, one mainstream movement is finding ways to tackle the reproduction of the natural ambisonic experience in the convenience and portability of everyday Bluetooth headphones. Additional leaps in the headphone industry include head tracking, equalization, and sound scene decomposition to best render natural sounds for fully immersive listening.[23] Innovations are even further emerging with attempts to fully eliminate user interaction with devices altogether through sound-beaming technologies and in the syncing of ambient noise to moods, though currently being primarily researched for productivity increase purposes.[24]

Applications that are leading the movement into fully integrating biometric and psychometric data into generative AI music have been *Endel* and *Weav* which both adjust the tempos of songs to their incoming information such as weather, location, heart rate, and steps. *Endel* more specifically experiments with sound masking techniques to perfectly play off of the existing distracting sounds, or noise pollution, in one's environment to boost wellness by composing endless responsive soundscapes of music with artificial intelligence (AI). *Weav* works instead to sync a user's workout experience to music that already exists for the best possible experience by impacting motivation

---

[23] Kaushik Sunder et al., "Natural Sound Rendering for Headphones: Integration of Signal Processing Techniques," *IEEE Signal Processing Magazine* 32, no. 2 (March 2015): pp. 100-113.
[24] Ilona Kovacs, "Designed by IKO," *Designed by IKO*, blog, (March 15, 2022).

levels in things like running and skiing.[25] The ski coaching application, *Carv*, further advances these techniques in mainstream ways by using a device that can attach to a user's ski boot for monitoring pressure and motion to enhance the customization of the audio feedback for instruction purposes. These innovations are resulting in more adaptive options beyond auditory response, including integrating workout-motivating vibrations into sneakers, much like an Apple Watch will remind you to stand.

SOUND MAPS & CYBERCARTOGRAPHY

Emerging sound maps can be described as a technique encouraging humans to slow down and tune into their surroundings in both urban and natural landscapes. They are geographic maps that point to a certain aural experience given a specific location. By connecting sound maps to a specific story, individual user, set of quantitative information, and interest in society, the research intersects with innovative uses of cybercartography.

> Cybercartography is now defined as a complex, holistic, user-centered process which applies location-based technologies to the analysis of topics of interest to society, and the presentation of the results in innovative ways through cybercartographic atlases. A cybercartographic atlas is a metaphor for all kinds of qualitative and quantitative information linked by location and displayed in innovative, interactive, multi-modal and multisensory formats. Cybercartographic atlases permit user communities to tell their own stories. Both mapping and storytelling are basic human instincts and are a central part of the holistic nature of Cybercartography.[26]

---

[25] Beth McGroarty, "Wellness Music," 2020 Wellness Trends, from the Global Wellness Summit, *Global Wellness Summit*, (January 29, 2020).
[26] D.R. Fraser Taylor, "Cybercartography Revisited," in *Modern Cartography Series*, ed. Erik Anonby and Kumiko Murasugi, vol. 7 (Academic Press, 2019), pp. 3-23.

Relating an environment's story to the user interacting with it is a practice used frequently to enhance an experience, even just in themed walking tours of a city.

This intersection of sound mapping and cybercartographic approaches is framed by SonEco's use of information to interpret aurally back to a user in relation to their location and the promotion of environmental awareness. This is done to provide insight into the soundscape in which they interact and the potential to influence the soundscape through their actions. This cybercartographic atlas contains the stories, or Treks, of winter sport activity in the Colorado Rocky Mountain region and the songs of the birds who naturally inhabit the environment creating a deeper relationship between the user's interaction and the space.

The act of listening is inherently disruptive and cannot be forced, so it's helpful to have non-threatening guidance on how to do it and its importance for ecoacoustics.[27] Soundwalking has been explored as a method for understanding our ear-to-environment relationship without interference.[28] To expand on this method as well as the popularity of everyday headphone usage, the notification system model adapts a naturally occurring environmental sound.

The relationship between nature and listening habits can be enhanced through sound mapping. Explorations of soundscapes through musical style recordings can demonstrate deeper awareness practices, for example the pitches and rhythms of the

---

[27] Hildegard Westerkamp, "The Disruptive Nature of Listening: Today, Yesterday, Tomorrow," *Sound, Media, Ecology*, (July 3, 2019), pp. 45-63.
[28] Hildegard Westerkamp, "Soundwalking as Ecological Practice," *The West Meets the East in Acoustic Ecology*, (November 3, 2006).

Danube River.[29] The goal of the SonEco system is to emerge a new routine of how the unique story composition that the environment and its listeners create is presented, shared, and actively listened to.

[29] Annea Lockwood, "A Sound Map of the Danube," Annea Lockwood, (July 14, 2017).

SCOPE & TIMELINE

This research MA Project was completed over the course of the 2022-2023 academic year after its original proposal in the Autumn of 2022 as part of the completion of the Master of Arts at the University of Denver. After approval, the recording devices available through the Emergent Digital Practices Tech Check and Professor Timothy Weaver were explored and narrowed down to AudioMoth devices based on ease of use and flexibility with protective cases. The review of literature and media support continued throughout the school year but was prioritized while waiting for ski resorts around the Colorado Rocky Mountains to open to complete Treks. Additionally, learning methods of transcoding and experimenting with how Max8 can present data aurally was a continuous process in making the SonEco system.

While still determining the location for soundscape recording deployment, data recording Treks #1-3 were completed on November 22nd, December 20th, and December 21st respectively. During Trek #4 on December 22nd, I met friends who had moved near Salida post-graduation and worked to accommodate their schedules to visit again when the weather improved to deploy AudioMoths on their 14-acre property. Unfortunately, COVID and car break-ins postponed this date twice though it was finally able to be completed on March 30th. In the meantime, data for Trek #5 was tracked on January 6th, Trek #6 was recorded on January 13th, and Trek #7 was completed on January 25th. The final Trek #8 was finished on March 31st while AudioMoth devices captured soundscape recordings around 30 minutes away.

After the AudioMoths' recordings were recovered, the audio was reviewed and clipped into usable, interesting pieces that captured the local biodiversity. Various clips were trialed in transcoded readthroughs from the Max8 Patch, and 3 bird clips were selected for the final piece. This project presents an Environmental Data Auditory Notification System Model through Max8. It uses the data recorded from each Trek and audio clips from soundscapes recorded over the course of the academic year. This project was presented for oral defense to the Emergent Digital Practices project committee of Chair Prof. Timothy Weaver, Prof. Kate Hollenbach, and Prof. Trace Reddell on May 17th, 2023 with the date of June 9th, 2023 set for graduation.

MATERIALS & METHODS

By focusing this research on psycho-ecoacoustics, the exploration reviewed the connection between auditory experience in hearing-abled persons and environmental awareness in the practices of surviving, protecting, and appreciating the environment. To research, data was collected during outdoor excursions around the Rocky Mountains in Colorado. Additionally, environmental soundscapes were recorded and assessed for indications of biodiversity. SonEco demonstrates an example of how environmental awareness can be enhanced with individually centered indicators by transcoding movement data into audio notifications.

> And man-made noise, as we invade ever more natural spaces, is a wildlife and ecosystem killer. As Les Blomberg, founder of the Noise Pollution Clearinghouse, put it: "What we're doing to our soundscape is littering it. It's…acoustical litter—and, if you could see what you hear, it would look like piles of McDonald's wrappers, just thrown out the window as we go driving down the road."[30]

Much like the brain completes visual stimuli based on historically collected information, auditory experiences can have hallucinatory profiles due to signal processing from both the brain and the sensing organs. Visual and aural senses can become cluttered, however, unwanted noise can effectively be eliminated with audio balances.[31] An example of this practice is suppressing tinnitus symptoms with additional noise, such as environmental soundscapes and white noise. Alternatively, if humankind

---

[30] Beth McGroarty, "Wellness Music," 2020 Wellness Trends, from the Global Wellness Summit, *Global Wellness Summit*, (January 29, 2020).
[31] Steve Goodman et al., "The Auditory Hallucination," in *Audint Unsound: Undead* (Falmouth, United Kingdom: Urbanomic, 2019), pp. 109-112.

begins to use an auditory indication that occurs naturally as a commonplace signal about their surroundings, it should ideally become habitual to notice.

TREKS

The exploration of how human auditory experiences can better mimic environmental awareness stimuli was brought to fruition through a prototyped movement notification system, SonEco. To organize the structure of data notifications similar to one that would respond to a user's environment, eight separate expeditions were traveled and tracked with GPX waypoints. Each of these data collection sessions are referred to as Trek #1-8.

Data Collection & Field Research

Each Trek was tracked with waypoints through a GPX system on the *snoww* iOS application at the ski resorts Monarch, Copper, Eldora, Winter Park, and Arapahoe Basin in the Colorado Rocky Mountain region while engaging in ski activity. The data collected during each ski Trek includes time, latitude, longitude, distance, elevation, and speed. Each Trek was exported from *snoww* as a GPX file. The GPX file was then opened as a web map through the tool *Geo.JaVaWa.nl* and copied to a *Microsoft Excel* file for the overall organization.

The range of waypoints collected varies from Trek to Trek depending on the total time duration and amount of terrain explored. For example, Trek 1 was tracked at Copper Mountain for 2:26:31 and collected 3,106 waypoints while Trek 2 was tracked at Winter Park Resort for 3:35:11 and collected 5,460 waypoints.

Figure 1: Map view of GPX data recorded by snoww *app of Trek 1 displayed on* Geo.JaVaWa.nl

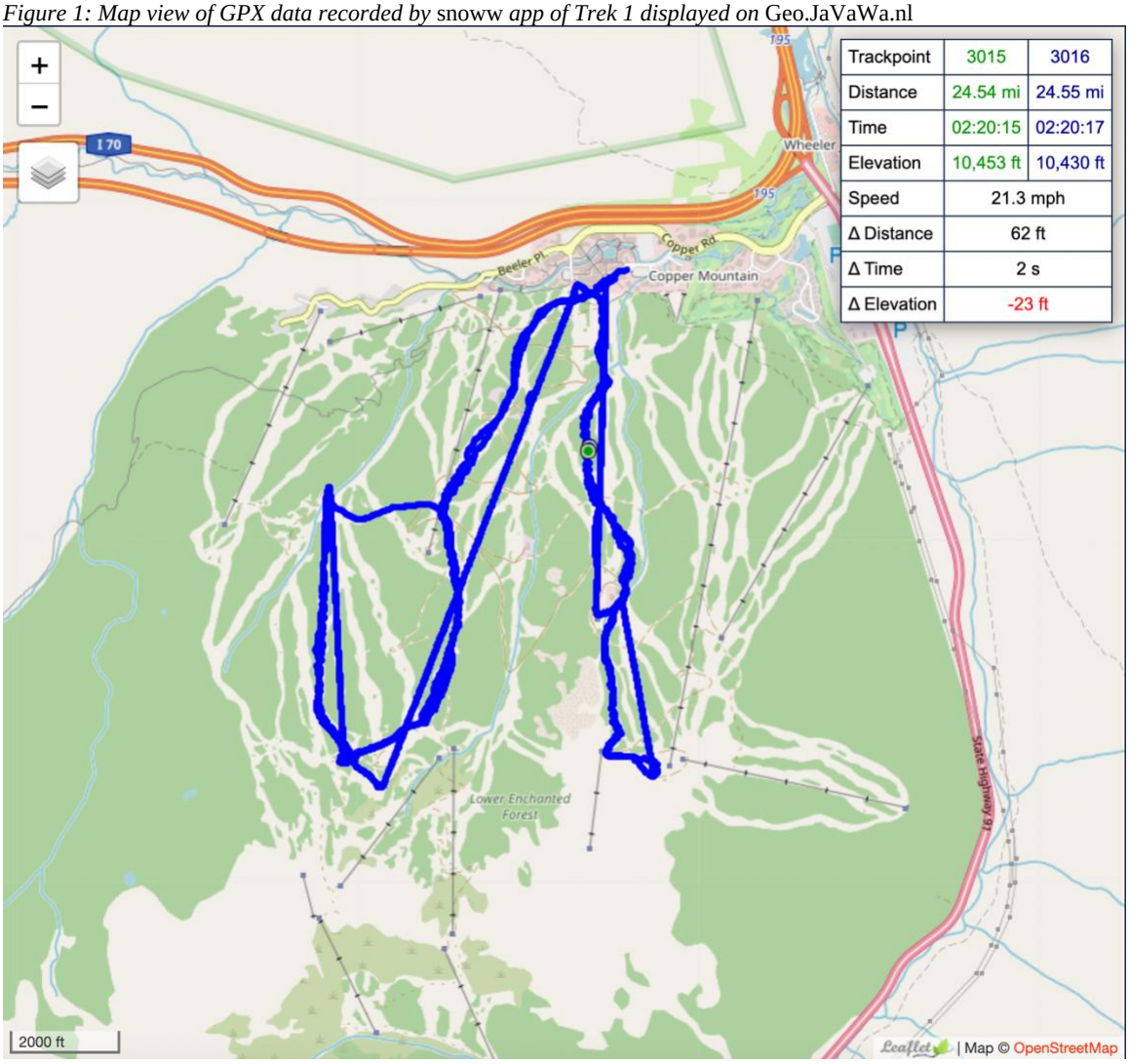


Table 1: Overview of all Trek data in Microsoft Excel

Trek	Total Waypoints	Location	Date	Start Time	End Time	Total Time	Downhill Hours	Total Distance (mi)	Downhill Distance (mi)	Avg Speed (mph)	Max Speed (mph)	Peak Altitude (ft)	Min Altitude (ft)
1	3106	Copper	11/22/22	9:55:08 AM	12:21:39 PM	02:26:31	0.92	25.288	13.6	15.90	42.8	12041	9744
2	5460	Winter Park	12/20/22	9:53:10 AM	1:28:53 PM	03:35:43	1.50	26.937	17.2	12.83	42.9	10741	9091
3	2560	Copper	12/21/22	10:07:50 AM	1:43:01 PM	03:35:11	2.20	21.003	13.2	14.20	41.1	12021	9570
4	3827	Monarch	12/22/22	9:17:48 AM	2:13:57 PM	04:56:09	2.18	17.112	10.4	10.32	33.3	11814	10764
5	3766	Copper	1/6/23	9:46:15 AM	12:57:14 PM	03:10:59	1.25	30.675	16.9	15.58	41.5	12061	9464
6	3588	Eldora	1/13/23	9:12:04 AM	11:36:36 AM	02:24:32	0.83	18.653	10.9	13.11	44.2	10604	9249
7	3435	Arapahoe Basin	3/28/23	9:11:02 AM	12:45:18 PM	03:34:16	2.63	18.328	10.8	13.82	45.6	12487	10787
8	3122	Monarch	3/31/23	9:48:44 AM	2:16:03 PM	04:27:19	2.77	14.216	8.5	9.81	34.3	11850	10679
Total / Average							14.28	172.21	101.5	13.2	45.6	12487	9091

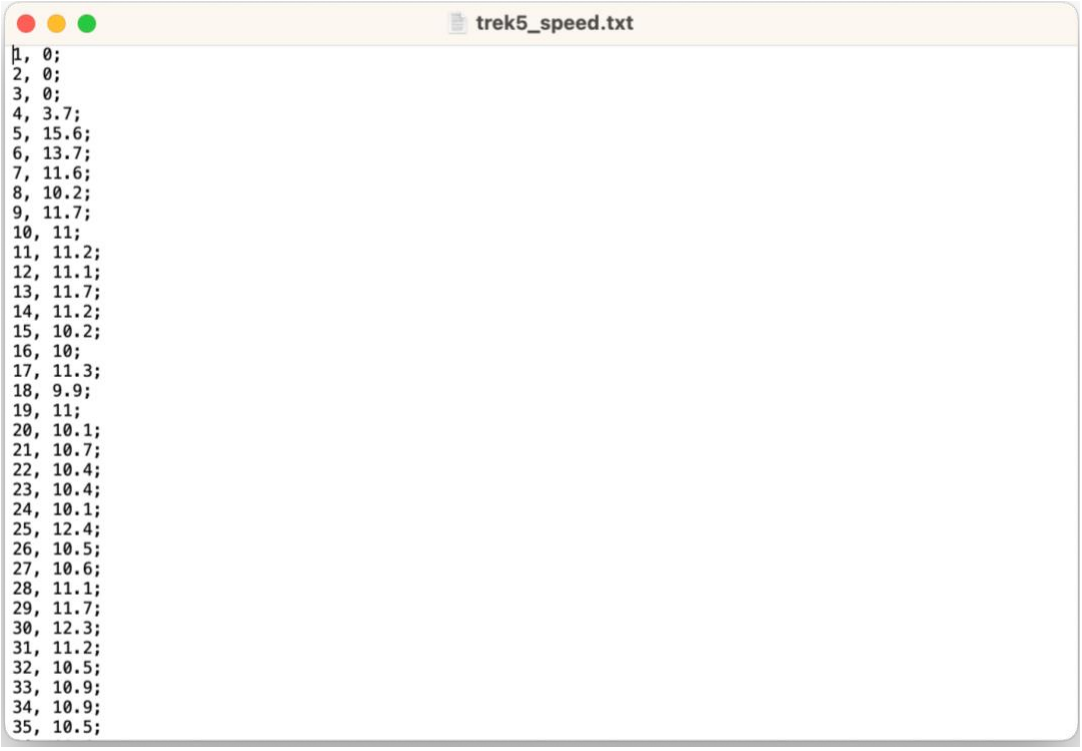
Table 2: The first 35 waypoints of Trek 5 in Microsoft Excel

Copper										
Trackpoint	Date/time	Lat. [°]	Lng. [°]	Distance [ft]	Time	Elevation [ft]	Speed [mph]	Δ Distance [ft]	Δ Time [s]	Δ Elevation [ft]
1	1/6/23 9:46	39.4994	-106.1464	0	0:00:00	9645.6	0	282	2	31
2	1/6/23 9:46	39.4994	-106.1454	282	0:00:02	9676.6	0	89	0	0.3
3	1/6/23 9:46	39.4993	-106.1451	371	0:00:02	9676.9	0	758	1	18.2
4	1/6/23 9:46	39.4976	-106.1466	1129	0:00:03	9695.1	3.7	5	1	54.6
5	1/6/23 9:46	39.4975	-106.1466	1134	0:00:04	9749.8	15.6	46	2	64.2
6	1/6/23 9:46	39.4974	-106.1466	1180	0:00:06	9814	13.7	40	2	42.2
7	1/6/23 9:46	39.4973	-106.1465	1220	0:00:08	9856.2	11.6	34	2	27
8	1/6/23 9:46	39.4972	-106.1465	1254	0:00:10	9883.2	10.2	45	3	16.3
9	1/6/23 9:46	39.4971	-106.1466	1299	0:00:13	9899.5	11.7	34	2	9.8
10	1/6/23 9:46	39.497	-106.1466	1333	0:00:15	9909.4	11	48	3	15
11	1/6/23 9:46	39.4969	-106.1466	1382	0:00:18	9924.4	11.2	33	2	9.6
12	1/6/23 9:46	39.4968	-106.1466	1414	0:00:20	9934	11.1	49	3	17.2
13	1/6/23 9:46	39.4967	-106.1467	1463	0:00:23	9951.1	11.7	34	2	23.7
14	1/6/23 9:46	39.4966	-106.1467	1498	0:00:25	9974.8	11.2	33	2	9.1
15	1/6/23 9:46	39.4965	-106.1467	1530	0:00:27	9983.9	10.2	45	3	19.2
16	1/6/23 9:46	39.4964	-106.1468	1575	0:00:30	10003.1	10	44	3	20.5
17	1/6/23 9:46	39.4962	-106.1468	1619	0:00:33	10023.6	11.3	33	2	11.1
18	1/6/23 9:46	39.4961	-106.1468	1652	0:00:35	10034.7	9.9	44	3	20.3
19	1/6/23 9:46	39.496	-106.1468	1696	0:00:38	10055.1	11	48	3	25.1
20	1/6/23 9:46	39.4959	-106.1469	1744	0:00:41	10080.2	10.1	44	3	23.4
21	1/6/23 9:46	39.4958	-106.1469	1789	0:00:44	10103.5	10.7	47	3	20
22	1/6/23 9:47	39.4957	-106.1469	1836	0:00:47	10123.6	10.4	46	3	21
23	1/6/23 9:47	39.4955	-106.147	1882	0:00:50	10144.6	10.4	46	3	19.8
24	1/6/23 9:47	39.4954	-106.147	1927	0:00:53	10164.4	10.1	45	3	21.6
25	1/6/23 9:47	39.4953	-106.147	1972	0:00:56	10186	12.4	36	2	8.2
26	1/6/23 9:47	39.4952	-106.147	2008	0:00:58	10194.2	10.5	46	3	16.8
27	1/6/23 9:47	39.4951	-106.1471	2054	0:01:01	10211	10.6	47	3	18.7
28	1/6/23 9:47	39.4949	-106.1471	2101	0:01:04	10229.7	11.1	49	3	14
29	1/6/23 9:47	39.4948	-106.1471	2150	0:01:07	10243.7	11.7	34	2	5.8
30	1/6/23 9:47	39.4947	-106.1472	2184	0:01:09	10249.5	12.3	36	2	8.4
31	1/6/23 9:47	39.4946	-106.1472	2220	0:01:11	10257.9	11.2	49	3	13.1
32	1/6/23 9:47	39.4945	-106.1472	2270	0:01:14	10271	10.5	46	3	15.4
33	1/6/23 9:47	39.4944	-106.1473	2316	0:01:17	10286.4	10.9	48	3	15.8
34	1/6/23 9:47	39.4942	-106.1473	2364	0:01:20	10302.2	10.9	48	3	16.3
35	1/6/23 9:47	39.4941	-106.1473	2412	0:01:23	10318.5	10.5	46	3	19.6

Software

To transcode the data collected into a meaningful auditory notification of movement, columns of information from Table 2 were isolated and exported as comma-separated values (CSV) files for each of the eight Treks. The isolated data was reformatted as a plain text (TXT) file with Cycling ‘74’s Max8 and MSP to be legible as a collection for further utilization within the software system.

Figure 2: The first 35 waypoints of the speed data column from Trek 5 isolated and reformatted as TXT file



After each data column for each Trek was saved in the TXT format, the information was scaled and transcoded to influence a sonic cue to reflect when certain indications are detected in the data. This was done through the creation of a Max8 patch that models receiving input from a moving user and emits a notifying sound to engage environmental awareness. The patch system uses the speed, elevation, elevation change, and time data recorded from Treks as key components of influence in being environmentally aware during an activity like skiing. For example, Trek 1 should repeat the process of separating and converting the columns for speed, time, elevation, and delta elevation to individual TXT files. Each TXT file is read by different indication system settings within the Max8 patch to emit different sounds.

SonEco's goal is to allow the auditory notifications to be informative to a listener about changes to the environment relevant to their movements. These sonic cues can

ultimately provide an expansion of human environmental awareness practices in promoting the sustainability of oneself and the planet. By making the unintelligible noise within alpine soundscapes audible to the average hearer with informed signifiers, the changes and adaptations of the planet's environment around one can become more notable, recognizable, meaningful, and valuable.

RECORDINGS

To utilize the surrounding Rocky Mountain environment in this research project, soundscape audio recordings were captured to guide a deeper understanding of awareness. The opportunity to deploy recording devices to passively record sonic information in the alpine regions of Colorado provided for exploration of how an environment sounds when the researcher is not present like in extreme weather and without invasions on ecological behaviors.

Data Collection & Field Research

Four AudioMoth recording devices were placed around a thirteen-acre property near Salida, Colorado to capture environmental soundscapes over a 24-hour period, including overnight. The height of each device's deployed location was variable to the environment but aimed to be eye-level at its very highest. The location selection also considered distances between the house where we would be residing on the property, nearby livestock, human or humanmade mechanism intrusion, and the microclimates which exist in mountainous regions.

AudioMoth 1 was placed on the ground and wedged beneath one of the few snow patches struggling to melt due to being shaded by the trees. AudioMoth 2 was secured to a wooden pallet on the ground outside of the chicken coop around windchimes and

antique farming equipment. AudioMoth 3 was attached to a low-hanging tree branch near a clearing. AudioMoth 4 was secured to a low-hanging tree branch as well, but in an area where a group of mule deer had just been resting. The location of each was noted photographically.

Figure 3: Map of private property near Salida, CO displaying AudioMoth drop locations

Figure 4: Location site of AudioMoth 4 indicated by a blue circle

The property elevation was estimated at around 7,750 feet indicating a higher altitude community of biodiversity. Animals best suited for the low temperatures and pressures of a mountain environment that have previously been spotted around or near the property include deer and elk, a large variety of birds, black bears, skunks, and mountain lions.

Hardware

AudioMoth devices were selected as the recording device because of their capabilities in the environmental and biodiversity audio capturing space. The device provides an acoustic spectrum of up to 384 kHz in a compact, AA battery-operated

shell.[32] Four total AudioMoth recorders were deployed and kept protected from the outdoor elements by makeshift plastic meal saver containers adapted with Gore-Tex and secured to trees with cable ties throughout the private property. Each AudioMoth was updated and flashed to the most recent operating system available using Open Acoustic Devices' AudioMoth – Flash, – Sync, and – Configuration. The devices were set to the 'DEFAULT' recording mode where one continuous WAV audio file was captured at 48 kHz and with medium gain, rather than setting filtering or triggering.[33] To combat the energy consumption of a continuous recording as well as to accommodate extreme alpine conditions, Lithium batteries were used.[34]

Software

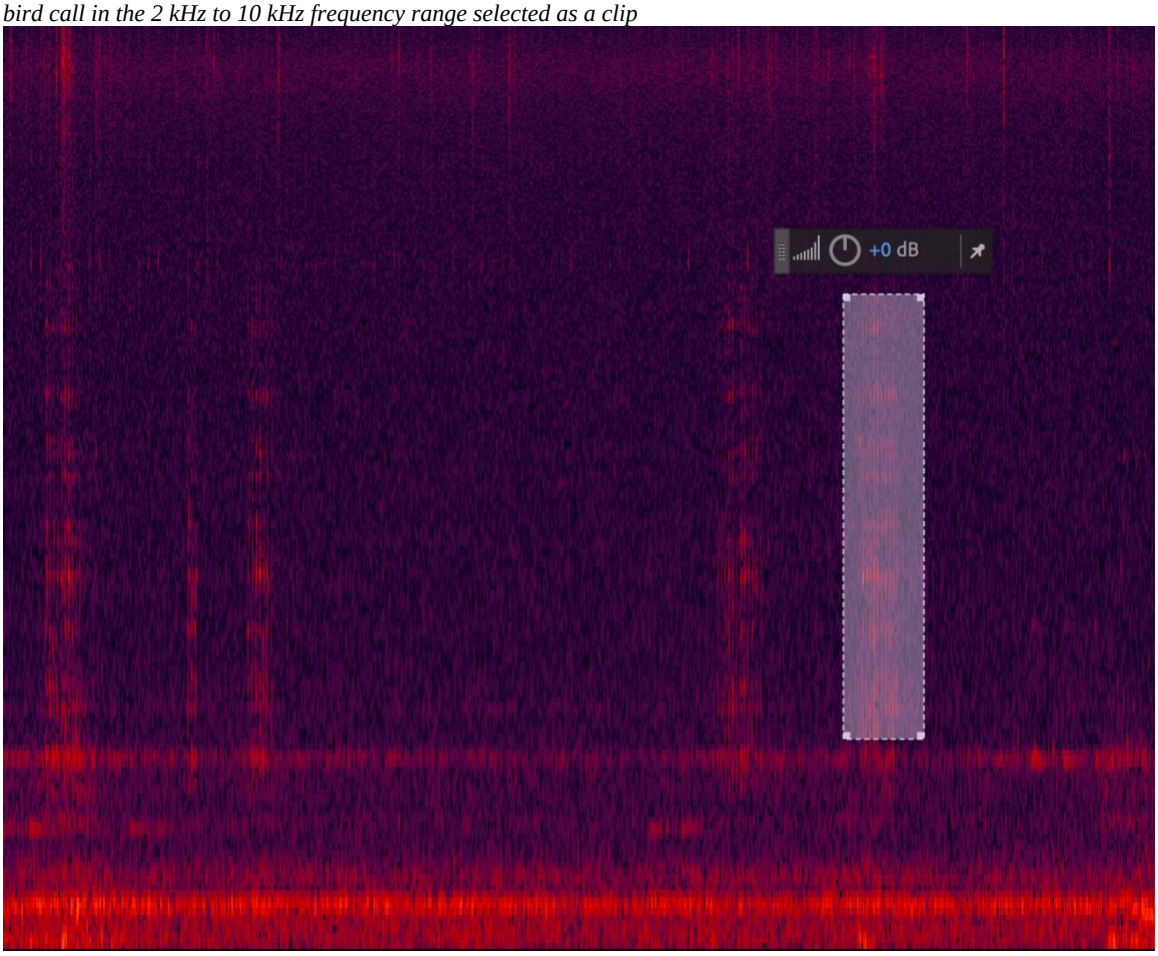
Adobe's Audition software for digital audio mixing allowed for visualization of the WAV files captured by the AudioMoth. The audio files were hand filtered to select the frequencies outlying in the 2 kHz to 10 kHz frequency range as they were inconsistent with the ambient environmental noise. Each outlying instance was selected and exported as an individual short audio clip. The exported audio clips were added to Max8 so they could be accessible throughout the creation of the sonic notification system prototype. Max8 automatically categorizes audio files by length, promoting the selection of appropriately timed clips for each notification. Audio clip 2.2.4 of 00:01 duration was assigned and modified for speed signals, 2.2.18 of 00:02 duration was assigned to signal

---

[32] Andrew P. Hill et al., "Audiomoth: Evaluation of a Smart Open Acoustic Device for Monitoring Biodiversity and the Environment," *Methods in Ecology and Evolution* 9, no. 5 (May 15, 2018): pp. 1199-1211.
[33] The Team Open Acoustic Devices, "Using Audiomoth with Filtering and Triggered Recordings," GitHub (Open Acoustic Devices, May 11, 2022).
[34] Peter Prince et al., "Deploying Acoustic Detection Algorithms on Low-Cost, Open-Source Acoustic Sensors for Environmental Monitoring," *Sensors* 19, no. 3 (January 29, 2019): p. 553.

when a 30-minute interval of time has passed, and 1.2.6 of 00:00:45 was assigned and modified to signal drastic elevation changes.

Figure 5: Adobe Audition spectral frequency display of a ten-minute portion of AudioMoth 4's recording showing a bird call in the 2 kHz to 10 kHz frequency range selected as a clip



PROJECT DISCUSSION & CONCLUSION

By focusing on notable pieces of sonic information, the effects of psycho-ecoacoustics will more strongly contribute to human behavior's ability in assigning value to nature.[35] In recent news, the combination of indices and machine learning has been used in recording marine acoustics to monitor coral reef health with sound[36] showing that even ecosystems that are seemingly impossible to hear with the average-abled, naked ear can be tuned correctly for human auditory stimulation and response. This project combines clips of the natural soundscape with data-transcoded auditory signifiers of cues to speed, elevation changes, and time to explore how environmental awareness could be sonically stimulated in the ways presented of survival, protection, and appreciation. Environmental awareness is increasingly vital in sustaining the lives of humankind as well as Earth and its ecosystems. Modern capitalistic approaches to sustainability will not matter if there is no longer a habitat for humankind.

The goal of collecting data over these eight Treks and transcoding them into sonic signifiers that would naturally occur in the environment is to increase awareness of the otherwise inaudible sounds. Listening to bird song signals dependent on an individual's own behavior should additionally enhance the experience of an auditory notification while in a natural environment. Habitually listening for sounds that would occur in the environment for individual gain makes it more likely to recognize those sounds when they do just happen in nature. The patterns in things like speed and altitude while

---

[35] Almo Farina, "Ecoacoustics: A Quantitative Approach to Investigate the Ecological Role of Environmental Sounds," *Mathematics* 7, no. 1 (December 26, 2018): pp. 1-16.
[36] Ben Williams et al., "Enhancing Automated Analysis of Marine Soundscapes Using Ecoacoustic Indices and Machine Learning," *Ecological Indicators* 140 (July 2022): p. 108986.

participating in snow sport activity can be observed and recognized in a new way to ultimately intensify keenness on preparation and survivability during an expedition. In an additional development, the use of data transcoding to sound can be transformative in the growth of adaptive and generative audio usage in everyday life.

RECORDING AUDIO & DATA

The four deployed AudioMoth recording devices were 50% successful in capturing the surrounding soundscape. The audio successfully recovered from the devices after the 24-hour session includes 43:53:35 of audio footage from two active AudioMoths of the heavy winds experienced in Salida throughout the recording period. The weather during the period of soundscape recording at the end of March of 2023 described a minimum temperature of 8 degrees Fahrenheit, a maximum temperature of 37 degrees Fahrenheit, and an average temperature of around 24 degrees Fahrenheit with a maximum wind speed of 21 miles per hour. A light dusting of snow occurred over the period, though no precipitation was recorded.[37]

The primary audio clips extracted from the AudioMoth recordings were various bird calls ranging in the 2 kHz to 10 kHz frequency range because of their visual indication on the spectral frequency display. While not discounting the weather and time of recording, the activity captured on the devices was generally low. Still, over 25 individual audio clips were pulled for notification sound usage and only 3 very short clips under 00:02 duration of different bird calls were used in the final iteration of the movement notification system.

---

[37] "March 2023 Weather History in Salida Colorado, United States," Salida March 2023 Historical Weather Data (Colorado, United States) - Weather Spark (Cedar Lake Ventures, Inc.)

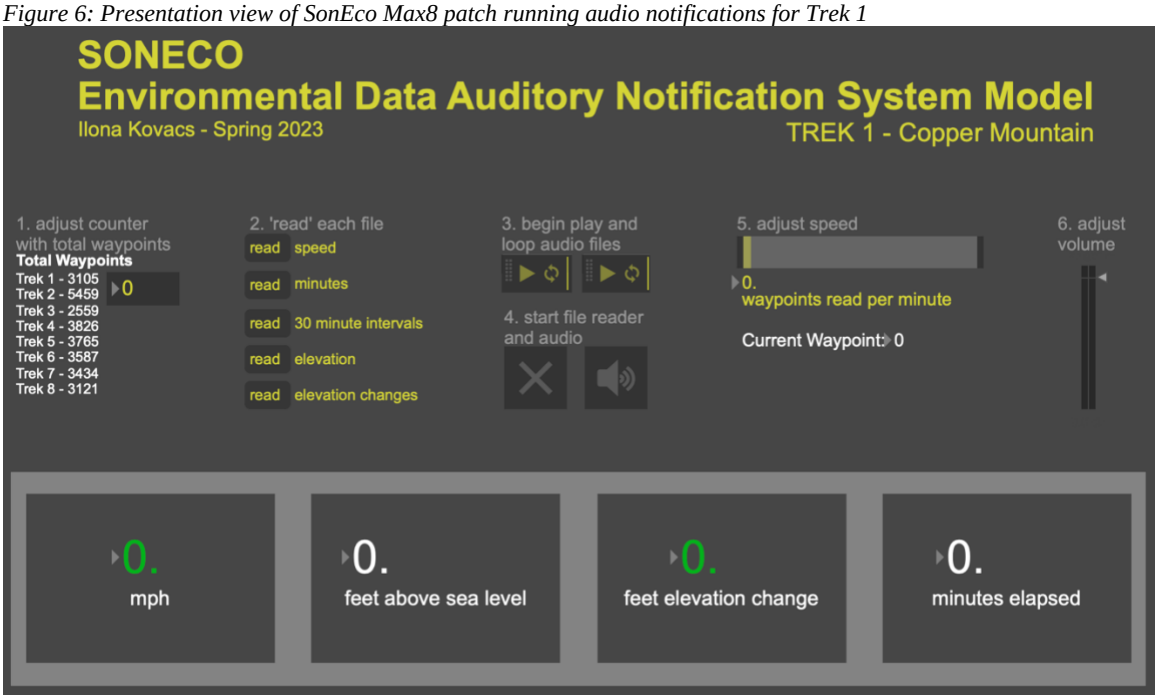
By using bird calls that naturally occur in the environment relevant to the user, SonEco creates an artificial flock that is less disruptive than traditional digital notification noises. While using ecoacoustics in this technological way can be directly contradictory to its environmental and naturalist goals, it leans into the reliance on digital interfaces present in today's Western culture. Additionally, despite its conflicts with overlaying the natural soundscape, SonEco is aimed to better practice a user with indicator species listening habits. It flips the canary in the coal mine concept, asking humans to listen to what biodiversity may be telling us before it is gone.

TREK AUDIO TRANSCODING

To model how an auditory notification system reactive to factors such as speed, elevation changes, and time would function during winter sport activity, SonEco uses a Max8 patch transcoding existing previously live recorded data from eight ski Treks over the 2022-2023 ski season in Colorado. The patch reads the selection of one speed TXT file, one altitude TXT file, one elevation change TXT file, one minutes elapsed TXT file, and one 30-minute interval TXT file from any one Trek and should be adjusted to count through the appropriate number of waypoints for that Trek. Speed waypoints are transcoded to affect the playback volume and speed of bird song audio clip 2.2.4, where the indicator triggers louder and at a higher frequency the faster the movement is recorded above 25 miles per hour. Bird song audio clip 2.2.18 is transcoded to play through each time a 30-minute interval is surpassed throughout the Trek's duration. The elevation change between each waypoint is transcoded to influence the playback speed and volume of bird song audio clip 1.2.6, where the audio notification will signal at a higher volume and speed for changes surpassing 17 feet.

The presentation view of the SonEco Max8 patch takes a user through the following instructions. First, the counter should be adjusted to cycle through every waypoint in a given Trek. An overview list of total waypoints per Trek is included. Second, each file should be selected top to bottom respectively to preserve its responding system: speed, minutes, 30minTrig, elevation, and elevationChange. After all of the files have been chosen, audio clip files for the speed and elevation change systems should be started with the play button and set to loop. Next, clicking the speaker button will ensure the audio playback is on, and clicking the X button will begin the data read-through. The fifth instruction given is to adjust the speed at which the system will read through waypoints. Because each data file varies so greatly in how many waypoints were recorded per minute, there was no perfect method for synchronizing the model system to run in real-time. For example, Trek 8 records 44 waypoints throughout the 23rd minute of tracking and only 11 waypoints throughout the 24th minute. Finally, the overall playback volume of the auditory notification system model can be adjusted.

Figure 6: Presentation view of SonEco Max8 patch running audio notifications for Trek 1



The result of running this Max8 patch per its instructions is essentially a sound map of each of the eight Treks, with reactive audio signals mimicking the natural soundscape where the Treks occurred. A data dashboard shows below the upload instructions to help visualize what the signals being heard actually mean as they are read by the Max8 transcoding system. After becoming familiar with which bird sounds mean what, it becomes fairly simple to recognize them even without seeing the numbers, much like different ‘dings’ from a cell phone can indicate different applications.

Each Trek’s system model running has been exported as a video and audio reading 60000 waypoints per minute for condensing, while also including a short section of a slower rate. Trek 1 plays through at the static 60000 waypoints per minute. Trek 2’s audio and video adjusts reading to 62.5 waypoints per minute from point 3202 through 3297 (trek2_systemPlaythrough 02:14-03:40) and 93.75 waypoints per minute from point 3297 through 3467 (trek2_systemPlaythrough 03:40-05:29). Trek 3’s playback begins

with reading 250 waypoints per minute through point 871 (trek3_systemPlaythrough 00:00-03:28). Trek 4's playback adjusts reading to 75 waypoints per minute at point 971 through 1117 (trek4_systemPlaythrough 00:41-02:38). Trek 5's playback adjusts reading to 250 waypoints per minute from point 3585 through the last of the 3765 (trek5_systemPlaythrough 02:26-03:09). Trek 6's playback adjusts reading to 60 waypoints per minute at point 766 through 981 (trek6_systemPlaythrough 00:30-04:06). Trek 7's playback also adjusts reading to 60 waypoints per minute at point 1359 through 1512 (trek7_systemPlaythrough 00:54-03:27). Trek 8's playback primarily reads at 100 waypoints per minute, starting at point 1176 and continuing through the end (trek8_systemPlaythrough 00:46-20:14).

FUTURE PRESENTATIONS

While the scope and timeline of this research project were limited to the 2022-2023 academic year, the hope is to lay a foundational understanding of how innovations in technology might assist in provoking and encouraging environmental awareness with the use of aural indications. Training the ears to recognize naturally occurring environmental sounds as an individualized, digitized canary in the coal mine. Furthermore, it aims to meet the needs of the current Western systems while also incorporating ecofeminism's deep understanding of connection to nature.

SonEco and it's supporting research can open a discussion about how to emerge a more equitable and sustainable future. It can also help to create a more thoughtful and informed population that is better equipped to make informed decisions about individual environmental awareness. Aural mapping, cybercartography, and adaptive and generative technologies have expansive opportunities in how environmental awareness can affect different user populations, though primarily hearing-abled. The suggestions below describe the iterations of this project's overall concept for specific users such as the visually impaired and outdoor enthusiasts but are not limited here. Beyond emerging technological innovations, this project provides an understanding of field recording and areas to improve soundscape capturing for future trials.

SOUND MAPPING FOR ACCESSIBILITY

Sound mapping for accessibility is an emerging field that has the opportunity to significantly impact the lives of individuals with visual impairments. Through sound mapping, the environment can be mapped out using audio cues. This can help individuals to navigate their surroundings more easily and safely. It can also help people to identify

objects and make decisions about actions more quickly. The potential of sound mapping has not yet been fully realized.

Future research should focus on developing more accurate and comprehensive sound maps that take into account the unique accessibility needs of different levels of seeing ability. It will be imperative to engage with individuals with visual impairments throughout the research process to ensure they are accurately and appropriately represented and supported by such a system. Researchers can contribute to creating a more inclusive world for individuals with visual impairments and how they have agency in all environments by innovating sound mapping capabilities.

These expansions on this project's use of environmentally driven auditory notifications based on historically recorded data could explore machine learning and artificial intelligence to analyze and interpret sound data in real time. They should discover ways of integrating a naturally occurring environmental sound with slight modifications to enhance the understanding and awareness of the soundscape without interfering. Finally, researchers should work to develop more effective methods of presenting sound maps to users, such as the advancements in adaptive and generative audio technologies and seamless integration with existing mainstream mapping applications.

OUTDOOR ACTIVITY & SAFETY ATLASES

With interests in fringe sports like hiking, skiing, snowboarding, and mountain biking rising in popularity, the protection for nature should be fostered alongside that. More people interacting with alpine environments leads to increasing amounts of disturbance to the habitats and ecosystems. Not only should beginner explorers have the

option to start hiking if they want to, but they should be able to do it safely. If this indication system model is synced to real-time movements rather than historical data of live movements over time, there is an opportunity to influence real-time decision-making while on exhibitions. Other data indicators could also be included such as air quality index (AQI) from altitude pressure tracking to smoke and fire warnings, temperatures, wildlife closures or detours, and natural disaster warnings to avoid landslide and avalanche zones to inform users of potential risk components associated with outdoor exploration.

Many explorers find interest and curiosity in discovering new environments. While there is often an Information Center and map board at the entrance to a National Park, there is a new opportunity to identify specific landmark details and deliver them aurally based on a user's locations by further advancing this modeled notification system. In its current state of providing bird songs, a more educational feature could be incorporated to describe the types of birds and their behaviors in the given environment. Landmark, animal, and environmental stewardship details can be stored as cybercartographic atlases of aural educational information to further enhance outdoor activity.

An example of this using the University of Denver's James C. Kennedy Mountain Campus (KMC) would be a phone application that users can 'play' in the background as they freely explore the forested private property. This system would give an auditory notification if a user's location neared drastic changes in elevation and temperatures, if a mountain lion or moose had been spotted near an area, or if the air quality poses

significant risks for any groups. Additionally, different educational tour modes could be activated to inform of history, biodiversity, and stewardship lessons based on the user's interests. It could be tailored to the boundaries of the KMC property and its skill levels, primarily to enhance how students are able to interact while maintaining the integrity of the naturally occurring environment.

FIELD RECORDING SOUNDSCAPES

Where the recording devices in this research deployment were not fully successful in capturing the soundscape in Salida, Colorado proves opportunities to improve in future iterations. To ensure that the device will have power through the entire duration of the recording period, the batteries should be better secured to the device with more Velcro, especially in winter conditions. The cases should have been reinforced to their locations with additional cable ties to prevent any movement noise. Finally, implementing a windshield to the case or device or deadcat to the microphone on the device to clarify the environmental soundscape being captured will enhance the recording quality altogether.

The use of AudioMoth devices should be explored in understanding more of the alpine regions to expand environmental awareness. Soundscape recordings from the different microclimates occurring in the ridges and seasonal shifts with snow melts and ice cracking can be captured to provide knowledge of these ecosystems. As the climate crisis advances, the state of weather conditions in the mountains is everchanging. A clear recording of the environmental soundscape from year to year will clarify how the ecosystem is changing and adapting.

BIBLIOGRAPHY

Abbott, Lauren C., Derrick Taff, Peter Newman, Jacob A. Benfield, and Andrew J. Mowen. "The Influence of Natural Sounds on Attention Restoration." *Journal of Park and Recreation Administration* 34, no. 3 (2016): 5–15. https://doi.org/10.18666/jpra-2016-v34-i3-6893.

Breve, Bernardo, Stefano Cirillo, Mariano Cuofano, and Domenico Desiato. "Enhancing Spatial Perception through Sound: Mapping Human Movements into Midi." *Multimedia Tools and Applications* 81, no. 1 (June 18, 2022): 73–94. https://doi.org/10.1007/s11042-021-11077-7.

Cariñanos, Paloma, and Manuel Casares-Porcel. "Urban Green Zones and Related Pollen Allergy: A Review. Some Guidelines for Designing Spaces with Low Allergy Impact." *Landscape and Urban Planning* 101, no. 3 (June 2011): 205–14. https://doi.org/10.1016/j.landurbplan.2011.03.006.

Coburn, Katherine. "The Last Canary in the Coal Mine: Small, Yellow, and Ominously Silent." SCQ. The Science Creative Quarterly, May 30, 2007. https://www.scq.ubc.ca/the-last-canary-in-the-coal-mine-small-yellow-and-ominously-silent/.

Davis, Bruce. "FM Radio as Observational Access to Wilderness Environments." *Alternatives: Perspectives on Society, Technology and Environment* 4, no. 3 (1975): 21–27. https://doi.org/https://www.jstor.org/stable/45030032.

Farina, Almo. "Ecoacoustics: A Quantitative Approach to Investigate the Ecological Role of Environmental Sounds." *Mathematics* 7, no. 1 (December 26, 2018): 1–16. https://doi.org/10.3390/math7010021.

Fretwell, Kay, and Alison Greig. "Towards a Better Understanding of the Relationship between Individual's Self-Reported Connection to Nature, Personal Well-Being and Environmental Awareness." *Sustainability* 11, no. 5 (2019): 1386. https://doi.org/10.3390/su11051386.

Gaard, Greta. "Ecofeminism and Climate Change." *Women's Studies International Forum* 49 (2015): 20–33. https://doi.org/10.1016/j.wsif.2015.02.004.

Goodman, Steve, Toby Heys, Eleni Ikoniadou, and The Occulture. "The Auditory Hallucination." Essay. In *Audint Unsound: Undead*, 109–12. Falmouth, United Kingdom: Urbanomic, 2019.

Hill, Andrew P., Peter Prince, Evelyn Piña Covarrubias, C. Patrick Doncaster, Jake L. Snaddon, and Alex Rogers. “Audiomoth: Evaluation of a Smart Open Acoustic Device for Monitoring Biodiversity and the Environment.” *Methods in Ecology and Evolution* 9, no. 5 (May 15, 2018): 1199–1211. https://doi.org/10.1111/2041-210x.12955.

Hutchings, Patrick Edward, and Jon McCormack. “Adaptive Music Composition For Games.” *IEEE Transactions on Games* 12, no. 3 (September 2020): 270–80. https://doi.org/10.1109/tg.2019.2921979.

Hutson, Matthew. “Watch out, Birders: Artificial Intelligence Has Learned to Spot Birds from Their Songs.” *Science*, July 18, 2018. https://doi.org/10.1126/science.aau8247.

Kovacs, Ilona. “Music Delivery Revolutions.” Web log. *Designed by IKO* (blog), March 15, 2022. https://ilonako.wixsite.com/portfolio/post/music-delivery-revolutions.

Krakauer, David C., John Lewis Gaddis, Kenneth Pomeranz, and David Christian. *History, Big History, & Metahistory*. Santa Fe, NM: SFI Press, 2017.

Lockwood, Annea. “A Sound Map of the Danube.” Annea Lockwood, July 14, 2017. https://www.annealockwood.com/compositions/a-sound-map-of-the-danube/.

Mace, Britton L. “Environmental Psychological Research with Undergraduates in the National Parks,” n.d.

“March 2023 Weather History in Salida Colorado, United States.” Salida March 2023 Historical Weather Data (Colorado, United States) - Weather Spark. Cedar Lake Ventures, Inc. Accessed April 25, 2023. https://weatherspark.com/h/m/3522/2023/3/Historical-Weather-in-March-2023-in-Salida-Colorado-United-States#Figures-Temperature.

María Puig de la Bellacasa. *Matters of Care: Speculative Ethics in More than Human Worlds*. Minneapolis, MN: University of Minnesota Press, 2017.

McGroarty, Beth. “Wellness Music.” 2020 Wellness Trends, from the Global Wellness Summit. Global Wellness Summit, January 29, 2020. https://www.globalwellnesssummit.com/2020-global-wellness-trends/wellness-music/.

Meis-Harris, Julia, Kim Borg, and Bradley S. Jorgensen. “The Construct Validity of the Multidimensional AIMES Connection to Nature Scale: Measuring Human Relationships with Nature.” *Journal of Environmental Management* 280 (2021): 111695. https://doi.org/10.1016/j.jenvman.2020.111695.

Open Acoustic Devices, The Team. “Using Audiomoth with Filtering and Triggered Recordings.” GitHub. Open Acoustic Devices, May 11, 2022. https://github.com/OpenAcousticDevices/Application-Notes/tree/master/Using_AudioMoth_with_Filtered_and_Triggered_Recordings.

Platt, John R. “The Lord God Bird and Dozens of Other Species Declared Extinct in 2021.” The Revelator, January 6, 2022. https://therevelator.org/species-extinct-2021/.

Prince, Peter, Andrew Hill, Evelyn Piña Covarrubias, Patrick Doncaster, Jake Snaddon, and Alex Rogers. “Deploying Acoustic Detection Algorithms on Low-Cost, Open-Source Acoustic Sensors for Environmental Monitoring.” *Sensors* 19, no. 3 (January 29, 2019): 553. https://doi.org/10.3390/s19030553.

Sadri, Sean R., Nicholas R. Buzzelli, Patrick Gentile, and Andrew C. Billings. “Sports Journalism Content When No Sports Occur: Framing Athletics amidst the COVID-19 International Pandemic.” *Communication & Sport* 10, no. 3 (March 17, 2021): 493–516. https://doi.org/10.1177/21674795211001937.

Schafer, R. Murray. *The soundscape: our sonic environment and the tuning of the world*. Rochester, VT: Destiny Books, 1994.

Shearer, Rhonda Roland. Review of Ecofeminism by Maria Mies, Vandana Shiva; Ecofeminism and the Sacred by Carol J. Adams; Ecofeminism, Women, Animals, Nature by Greta Gaard; Women, the Environment and Sustainable Development: Towards a Theoretical Synthesis by Rosi Braidotti, Ewa Charkiewicz, Sabine Häusler, Saskia Wieringa, . *Signs* 22, no. 2, (1997): 496–501. https://www-jstor-org.du.idm.oclc.org/stable/3175296?seq=1#metadata_info_tab_contents.

Sunder, Kaushik, Jianjun He, Ee Leng Tan, and Woon-Seng Gan. “Natural Sound Rendering for Headphones: Integration of Signal Processing Techniques.” *IEEE Signal Processing Magazine* 32, no. 2 (March 2015): 100–113. https://doi.org/10.1109/msp.2014.2372062.

Taylor, D.R. Fraser. “Cybercartography Revisited.” Essay. In *Modern Cartography Series* 7, edited by Erik Anonby and Kumiko Murasugi, 7:3–23. Academic Press, 2019.

Vakoch, Douglas A., Nicole Anae, and Nibedita Mukherjee. “Ecofeminism in Assamese Literature.” Essay. In *Indian Feminist Ecocriticism*, 51–64. Lanham, MD: Lexington Books, 2022.

Vakoch, Douglas A., Nicole Anae, and Panchali Bhattacharya. “Indigenous Ecofeminism and Contemporary Northeast Indian Literature: Lessons in Eco-Swaraj.” Essay. In *Indian Feminist Ecocriticism*, 79–92. Lanham, MD: Lexington Books, 2022.

Westerkamp, Hildegard. “The Disruptive Nature of Listening: Today, Yesterday, Tomorrow.” *Sound, Media, Ecology*, July 3, 2019, 45–63. https://doi.org/10.1007/978-3-030-16569-7_3.

Westerkamp, Hildegard. “Soundwalking as Ecological Practice.” *The West Meets the East in Acoustic Ecology*, November 3, 2006.

Williams, Ben, Timothy A.C. Lamont, Lucille Chapuis, Harry R. Harding, Eleanor B. May, Mochyudho E. Prasetya, Marie J. Seraphim, et al. “Enhancing Automated Analysis of Marine Soundscapes Using Ecoacoustic Indices and Machine Learning.” *Ecological Indicators* 140 (July 2022): 108986. https://doi.org/10.1016/j.ecolind.2022.108986.

Wilson, Edward O. *Biophilia*. Cambridge, MA: Harvard University Press, 1984.