Coupling Scientific and Humanistic Approaches to Address Wicked Environmental Problems of the Twenty-first Century: Collaborating in an Acoustic Community Nexus

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Abstract: Addressing serious environmental challenges, or wicked problems, locally and globally, we argue here that working collaboratively as scientist and humanist we are in a strategic position to help address biodiversity crises. We outline synergies that combine the strengths, tools, and fresh perspectives of soundscape ecology and sound studies in ethnomusicology. Our unique collaboration places sound at the core of our process but utilizes a community acoustics lens to bring both the sounds of nature and those of people together to couple our epistemologies, methodologies, and deep commitment to addressing the ecological needs today.

Résumé : Pour aborder les graves défis, ou sévères problèmes, environnementaux, aux niveaux local et global, nous avançons ici qu'en travaillant en collaboration en tant que scientifique et humaniste, nous nous plaçons en position stratégique pour contribuer à répondre aux crises de la biodiversité. Nous soulignons les synergies qui associent les forces, les outils et les nouvelles perspectives sur l'écologie des paysages sonores et les études sur le son en ethnomusicologie. Notre collaboration unique place le son au cœur du processus, mais a recours au prisme de la communauté acoustique pour rassembler tant les sons de la nature que ceux produits par les gens ensemble pour apparier nos épistémologies, nos méthodologies et notre profond engagement pour répondre aux besoins écologiques d'aujourd'hui.

As we reach the end of the second decade of the 21st century, it has become clear to many that the planet is facing unprecedented environmental degradation. Several of the environmental challenges society must confront have been labelled as "wicked problems," as their solutions are likely to be

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complex and require input from diverse perspectives (Rockström et al. 2009; Wilson 2016). These issues include addressing the current global biodiversity crisis, meeting the food and energy security needs of an ever-growing human population, and confronting the water scarcity problem that impacts all life on Earth (Koh et al. 2004; Schmidhuber and Tubiello 2007; Vörösmarty et al. 2000). As a landscape ecologist and an ethnomusicologist — scientist and humanist — our efforts to understand global change have been focused in environments rich in biodiversity. Regrettably, our respective investigations also reveal widespread biodiversity decline. Can our work, thus far conducted separately, be refocused to produce meaningful collaborations that confront this impending ecological and social disaster?

We argue here that two relatively new perspectives on sound — a new science, soundscape ecology, and re-invigorated scholarship in eco-ethnomusicology — offer the fresh perspectives needed. Soundscape ecology is a rapidly developing scientific approach to studying sound that is closely aligned with the discipline of landscape ecology, but also builds on the rich knowledge of the fields of animal communication and behaviour, biogeography, signal processing, data mining, and psychoacoustics (Pijanowski et al. 2011a, b). Soundscape ecologists explore diverse ecosystems using remote sensing technologies, such as passive acoustic recorders, to evaluate local biodiversity through sound. Building from the interdisciplinary field of landscape ecology means that investigations consider spatial variation of landscapes at different scales as well as the interplay of spatial pattern and ecological processes (Wu 2007); these scientists have sought links between biophysical and social scientific methods to address issues such as biological conservation. In contrast, emerging from ethnomusicology and ecomusicology (Allen and Dawe 2015), sound studies in eco-ethnomusicology address critical biodiversity issues utilizing contemporary ethnographic methods that value observational and participatory engagement with individuals and communities (Guyette and Post 2015). Many eco-ethnomusicologists draw on knowledge from diverse disciplinary areas, including the humanities, social sciences, and the sciences. Eco-ethnomusicological sound study research is influenced by studies of sound practice that address musical production and listening practices in social and geographic contexts (Gallagher and Prior 2014), as well as acoustic ecology (or acoustemology) of place (Feld 1996), political agency expressed in sound (Sakakeeny 2010), and sound knowledge and listening (Kapchan 2017).

What are the collaborative spaces that will allow us to use our disparate approaches to understand wicked environmental problems? We address this with an application of soundscape ecology and eco-ethnomusicology in the context of acoustic communities in which a set of diverse voices, methods,

and epistemologies can be combined to comprehend biodiversity change. We conclude this essay with a discussion of work in Mongolia, highlighting the gains in knowledge if we were to adopt our acoustic community framework collaborating together.

Defining Acoustic Community

We posit that an acoustic community can act as both a framework and context for studying sounds — a nexus if you will. When we consider how both ecologists and music scholars studying sound define acoustic community, we recognize similarities despite their differing areas of focus. Ecologists define acoustic community as "an aggregation of species that produces sound by using internal or extra-body sound-producing tools" (Farina and James 2016: 11). In biological research, data from an acoustic community may be used to gauge composition, identify characteristics, and determine functions in an ecosystem; ecologists also consider acoustic communities as valuable sources of information on habitats and vegetation (Gasc et al. 2013; Farina and Pieretti 2014; Farina and James 2016). In music, composer Murray Schafer defines acoustic communities as social spaces bounded by what their residents hear and interpret from within a given space (1994). For both sound and music scholars, acoustic communities receive and create acoustic information and thus are interactive and engaged with communication (Uimonen 2011).

If we combine the previous uses of acoustic community into a new structure, defined by problems and desired outcomes, a collaborative framework emerges (Fig. 1). Our research recognizes that a variety of *drivers* of global environmental change (Fig. 1A) create the current biodiversity crisis (Fig. 1B). However, planning and implementing collaborative scientific and humanistic work is challenging. Our methods differ, basic values related to the roles researchers play sometimes conflict, and analytical techniques and platforms are seldom the same. The unique alliance we propose places sound at the core of the discovery process, but within the lens of an *acoustic community* (Fig. 1C) which brings both the sounds of nature and those of people together to couple our epistemologies, methodologies, and diverse voices to address — and seek solutions for — problems society faces. The synergies of these two transformed disciplines (Fig. 1D) that we outline here combine the strengths, tools, and fresh perspectives of a new science, soundscape ecology, and re-invigorated scholarship in eco-ethnomusicology that has emerged from an integration of contributing disciplines (Fig. 1E). Our approach also engages the very people and places we wish to improve in a co-produced fashion (Fig. 1F) which we hope

will yield improved livelihoods (Fig. 1G). We describe the acoustic community within this broad collaborative framework in more detail next.

Component 1: Diversity of Voices and Discourses

A critical component of our acoustic community is the collection of voices and discourses. These include those that are studied (animals, landscapes, and people) and those of researchers as well (scientists and humanists) which, when combined, form synergies yielding co-produced knowledge. Recordings of animal voices are key, as these provide us with knowledge about biodiversity and animal activity patterns critical to our understanding of biodiversity loss. Discourses between scientists and humanists need to be continuous, building a sense of common ground and a shared vocabulary. We argue that discourses need to focus on collaborative modes for research, such as using the inquiry style of the eco-ethnomusicologist to address questions posed by scientists. There are also inquiry spaces where scientists and humanists can work together; scientists can, for example, participate in contextualized interviews and discourses with local community members while digital recordings of sounds (and songs) can be jointly analyzed by scientists and humanists. We argue that knowledge we gain through this process also needs to be co-produced (Table 1). For example, with the help of eco-ethnomusicologists, models and conclusions developed by scientists could be corroborated by local people. These new discourses should yield new insights into problems we seek to solve.

Component 2: Complementary Epistemologies

The differences in our scholarly pursuits epitomize the characteristic separation between scientific and humanistic epistemologies, including approaches to understanding human and non-human interchanges and to seeking answers for environmental problems. Our contrasting research models are reinforced by disciplinary expectations and paradigms. A scientific approach can be characterized by greater detachment from the subject of study, and an objective, quantitative, and predictive assessment, while a humanistic approach is more subjective, uses qualitative methods and practices, and relies less on projecting outcomes at the outset (Frodeman et al. 2017). However, many scholars commonly work together and employ mixed methodologies that "integrate the quantitative and qualitative research techniques, approaches, vocabulary and concepts within the same study" (Johnson and Onwuegbuzie 2004: 17).

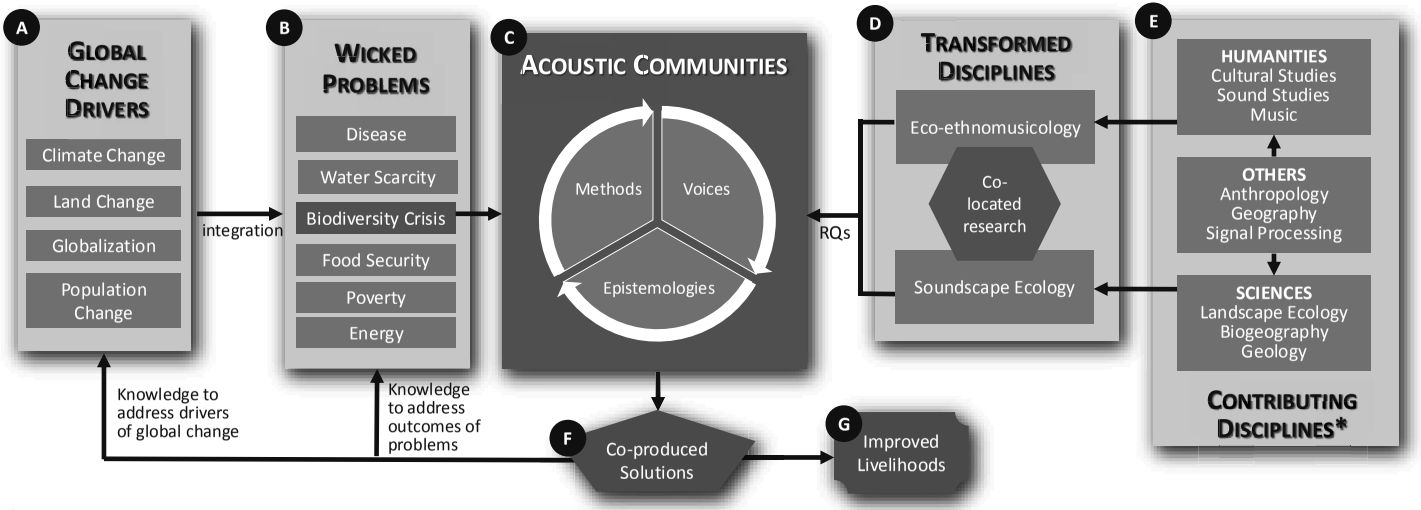

Fig 1. An acoustic community framework to address the biodiversity wicked environmental problem by combining the transformed disciplines of eco-musicology and soundscape ecology. This framework connects global change drivers with a set of contributing disciplines through the lens of a multi-component acoustic community, which we believe will produce solutions to improve livelihoods.

Sound activity	Effects	Sound practice	Methods	Relationship to biodiversity		Outcome (local)
Identifying	Automating (species recognition)	Sounds Listening (transects)	Sensors Narrative	Determine presence/absence of species of concern	SK NK	Policy
Causation	Relating (disturbance to acoustic diversity)	Soundscape	Sensors	Relate biodiversity to driver of change	SK NK	Policy
Rhythms	Characterizing temporal cycles (diversity and communication)	Sounds Soundscapes	Sensors Temporal	Determine temporal shifts in acoustic diversity and animal communication	SK NK	Policy
Quantifying	Sounds (animal) Diversity (species)	Soundscapes	Sensors Narrative	Acoustic diversity correlates with species diversity	SK NK	Policy Knowledge sharing
Evaluating	Using knowledge	Soundscapes Sounds Listening	Sensors Spatial Temporal Narrative	Evaluating data Evaluating place	SK NK EK LK	Scientific knowledge Local knowledge
Listening	Aesthetic Spiritual Transformative	Listening	Narrative	Engaging with sound	EK LK	Valuing sound and soundscape
Sounding	Communicative Aesthetic	Sounds Soundscapes	Sensors Narrative	Engaging in sound and place	EK LK	Sharing knowledge and maintaining practices
Communicating	Preserving lifeways Economic success Sharing knowledge	Sounds Soundscapes	Narrative Sensors	Sharing knowledge in a community	EK LK	Developing adaptive strategies
Mapping	Wayfinding Place-making	Sounds Soundscapes Listening	Spatial Narrative	Establishing locations Place-making	EK LK	Sharing acoustic community network knowledge
Remembering	Inspiring Reflecting	Sounds Listening	Temporal Narrative	Reinforcing history Reflecting	EK LK	Maintaining practices
Promoting	Educational Motivating Transforming	Sounds Soundscapes Listening	Sensors Narrative	Teaching and encouraging action Transforming	EK LK	Community support
Attributing	Curative Spiritual	Sounds Listening	Narrative Sensors	Wellbeing of individuals and communities	EK LK	Individual and community valuing of sound/soundscape

Table 1. Co-produced knowledge in acoustic communities offers information on sound activities and their effects or purposes; the type of sound practice (sound, soundscape, listening); current methods used for study (those linked to this essay include sensors, mapping, temporal patterns, and narratives); relationships to biodiversity issues; the knowledge sound carries (scientific [SK], natural resource [NK], ecological [EK], local [LK]); and examples of local outcomes of a sound activity. Information organized in this way can be used to explore modes of engagement with sound and presents potential pathways for collaborative research.

Biophysical scientists are now venturing into this field, often collaborating with social scientists to understand coupled human-natural systems using mixed method approaches, and these are yielding a better understanding of complex systems like the ones we argue are needed by our collaboration (Liu et al. 2007). Many forms of knowledge can be explored, including local knowledge (LK), ecological knowledge (EK), scientific knowledge (SK), and knowledge for natural resource management (NK). We recognize that there are difficult challenges to designing a humanistic-scientific approach, but they are not insurmountable.

Component 3: Joint Methodological Spaces

Although not exhaustive, we present several methodological spaces that we believe bring the scientist and humanist together to address many of the wicked problems confronting society.

Digital and Human Sensors

Collaborative soundscape study in acoustic communities uses both digital and human sensors as well as information exchange in discussions, interviews, and participatory action. Soundscape ecologists' recording devices measure acoustic composition to address factors such as acoustic diversity, species dominance, intensity, and acoustic partitioning, and some recordings identify sound signals used for animal communication. In contrast, the soundscapes and sound practices that eco-ethnomusicologists record are sources of information on local lifeways. Recorded interviews and discussions are used to learn how people evaluate and reflect on sound and soundscapes. Inviting local community members to act as human sensors — agents for sensing and reporting on sound and soundscape experiences — offers new opportunities to link the remote sensing data of soundscape ecologists with soundscape knowledge held by local peoples. When soundscape ecologists and eco-ethnomusicologists make adjustments to their site selection, such as when soundscape ecologists use an anthropogenic lens to concentrate on human socio-economic activities in their recordings, they will engage with a new range of sound sources. Similarly, when eco-ethnomusicologists engage with broader acoustic communities, they will experience new understandings of sound and space that they can discuss with local residents. Our collaborative lines of inquiry could include: how do changes in biodiversity, as assessed by passive acoustic recorders, compare to those shared narratively by a local

person? Based on eco-ethnographic analysis, can the scientist correlate suspected causal factors (i.e., drivers) to biodiversity loss?

For data analysis, computational models in landscape ecology offer one pathway for connecting quantitative data to both soundscape ecology and eco-ethnomusicology. Techniques using signal, symbolic, and semantic analysis have been used in conjunction with musicological and ethnomusicological analysis, although current models for application in what is at present called computational ethnomusicology are still in development (Gómez et al. 2013; Tzanetakis et al. 2007; and Cornelis et al. 2013). A new model constructed around a landscape ecology-ethnomusicology framework that enlivens techniques with more in-depth and multidisciplinary methods will need to be developed in order to successfully bridge our disciplines (Futrelle and Downie 2002; Clayton 2007; Abdallah et al. 2017).

Mapping Acoustic Communities

Sound mapping is another method that soundscape ecologists and eco-ethnomusicologists can share. As geographic information systems (GIS) are a principal tool of landscape ecologists (Turner and Gardner 2015) and, to some extent, soundscape ecologists (Pijanowski et al. 2011b; Pekin et al. 2012; Lomolino, Pijanowski, and Gasc 2015), we argue that the landscape, ecology, and cultural components of the soundscape in each acoustic community can be easily mapped and interfaced with information derived from both soundscape ecologists and eco-ethnomusicologists. Sound mapping has been adopted to describe the sound environment, demonstrate spatial variation, and, when combined with other data and methods such as behavioural observation, can contribute to understanding species' responses to sounds from different sources (Job et al. 2016). Sound mapping methods encompass a wide array of activities in diverse areas from which eco-ethnomusicologists draw. Computational methods may be used to correlate spatial and temporal data provided by recorded media, which can also include soundscapes, sound narratives, and song reproduction by local residents. References to space and place may also be coordinated with GPS coordinates to locate recordings made by soundscape ecologists. The collaborative mapping exercises we suggest could involve digital (e.g., GIS) and analog (e.g., paper) spatial analysis where the landscape and its features are associated with the information derived from eco-ethnomusicological assessment. Our questions might include: where are there biodiversity "hotspots" and how have these been managed historically compared to areas that have experienced noticeable change? Where are there environmental changes that have cultural significance?

Merging mapping tools such as geographical information systems (GIS) with qualitative tools used in the social sciences (such as NVivo and Atlas.ti) will lead to new ways to assess disparate datasets across space and time (Burrough 1986). Mapping these spaces and providing data on specific species of plants and animals, as well as their environmental health over time, offers opportunities for soundscape ecologists (with GIS and recorders), local residents, and eco-ethnomusicologists (recording and engaging in interactive interviews with members of the community) to create maps that take into consideration both quantitative and qualitative data.

Temporal Patterns

For soundscape ecologists, temporal patterns in an acoustic community are tied to biological events linked especially to time of day, season, and life histories of organisms in a location (Pijanowski 2011a). Patterns are exhibited at different elevations as well as during cycles of life, and can be extended to include responses to environmental changes. For example, some ecologists establish models of plant senescence connected to seasonal trends, which are then compared to those for biological sounds to quantify plant-animal interactions (Gasc et al. 2017). These are compared across sites that differ in levels of disturbance (e.g., undisturbed/reference conditions vs. highly disturbed locations such as areas that have been mined, are used to grow crops, or urban centres). Other soundscape ecologists (e.g., Xie et al. 2016) have focused on quantifying tempos exhibited by animals, such as tropical tree frogs, in an effort to estimate population densities or specific activity patterns. Temporal patterns on which eco-ethnomusicologists focus provide other significant applications to sounds and soundscapes. For example, temporal patterns in sound and music study are linked especially to perception and to other emotional and physical responses to sound, including entrainment (Stevens 2012; Clayton 2007). The groupings in sound that listeners perceive may have specific functions in acoustic communities, whether it be the tolling of a bell or a rhythmic sound of warning heard and used by residents at a site. Mapping responses to time in sound and music can also include gestural and other physical actions. Mobility and how movement shapes acoustic spaces and communities in connection with sound is another area of interest in sound studies with potential applications to soundscape ecology (Vannini 2012). Biodiversity loss frequently affects rhythms, including the movement of wildlife, the growth of plants, and the ability for peoples to use ecological knowledge to predict changes and warn of dangers. The impact of biodiversity loss on the presence of wildlife and the health of plant life also limits food support for both people and animals. Collaborative

research questions built with soundscape ecologists to address some of these issues include: What specific biodiversity changes have the greatest impact on life decisions for local residents? What patterns in the daily and seasonal lives of local animals can be correlated between ecological and local resident data?

Soundscape ecologists employ a variety of tools to quantify temporal changes, including time series statistical models such as Autoregressive Integrated Moving Average (ARIMA), to understand rhythms that are identified with specific organisms, times of day, seasons, and climates, as well as their disturbances. Humanities and social science research tools for qualitative data analysis (QDA), including NVivo and Atlas.ti, are used for transcription, analysis, coding, and content analysis, while video and audio annotation software (such as ELAN and ANVIL) are used for annotating and coding media. Mixed methods research and data analysis is possible using all of these tools.

Collaborative Narratives

Many contemporary scientists associate narratives with the qualitative work of social scientists with whom they sometimes collaborate. Yet the formative years of ecology were marked by careful, qualitative observations by eminent 19th- and 20th-century naturalists like Darwin, Wallace, Humboldt, and Leopold, who developed grand biological theories that explained mechanisms of evolution, causes of species ranges, global patterns of plant species diversity, and the need for people to have a conservation ethic. As modern-day ecologists, the necessity to transcend "big data" analysis to seek deeper relationships with what the digital data tell us about ecological processes, particularly the loss of species globally, will require the scientific community to find ways to integrate the qualitative narrative with massive digital data. Ecologists are traditionally poor analysts of qualitative information, and so collaboration with experts in observations, interviews, and exchanges will enhance their understanding of biodiversity loss and its potential impact on humans. Eco-ethnomusicologists' qualitative research methods commonly use narrative approaches that have historically been identified with anthropological studies in the 1980s (Turner and Bruner 1986; Geertz 1988). Ethnomusicologists explored narrative at this ethnographic juncture and recognized its value for engaging in and reporting on fieldwork. Jeff Titon suggests that when using narrative approaches, "ethnography becomes an experience-weighted genre in which narrative includes background information, interpretation and analysis, and above all one in which insights emerge from experience" (2008: 34). Narrative practice in ethnomusicology demonstrates that a researcher has maintained a dialogic approach, that the knowledge shared is the result of a partnership between researcher and local community

in discussions about practices as well as mutual engagement in performance. Narratives are also linked to history, and this provides the opportunity for individuals to express their experience in connection with memory, values, and interests. Since the acceptance of narrative as a widely-used approach in ethnographic work, it continues to have a decolonizing influence on disciplines. Exploring narrative as a collaborative tool, environmental policy scholar Raul Lejano posits that climate change knowledge maintained in community stories holds valuable information and can be employed strategically to encourage local engagement in environmental action (Lejano, Tavares-Reager, and Berkes 2013). Performed events also, like music or sound practices, articulate ideas in a socially and culturally structured format that can be employed for local projects (Post 2017). Questions linking acoustic communities, narrative information, and the research of both soundscape ecologists and eco-ethnomusicologists could draw on values expressed by local residents, such as: Do local residents feel a sense of responsibility as caretakers of the land? What does a collaboration between big data conclusions and human interest affecting local decisions about wildlife well-being look like? How does the ecological condition, as reflected in biodiversity, affect human well-being?

When documenting sound and music, ethnographers typically use tools that include audio and video recording equipment, recording face-to-face interviews and events. When these tools are paired with particular equipment, researchers and local partners can provide a wealth of documentary information that provides context for any contact taking place in conjunction with research. Engaging with narrative for collaborative work will involve merging disciplinary strategies and techniques to combine face-to-face research with some of the analytical tools used for spatial and temporal studies.

Discussion

We believe there are many potential places where the acoustic community nexus can help us to determine how biodiversity loss is fundamentally connected to human well-being through sound. Both authors have conducted sound-related research in Mongolia, where the largest remaining intact grasslands in the world can be found. The grassland biome is considered by ecologists to be the most threatened of all Earth's biomes because much of these lands are used to produce food (e.g., crop and livestock use) and biofuels (Hoekstra et al. 2005; Fischer et al. 2006; Jenkins and Joppa 2009). Less than 5 percent of the planet's grasslands are protected, which is the smallest amount of area needed to be considered a biome (IUCN 2018). Iconic Mongolian mammals

that are impacted by grassland loss, such as Przewalski's horses, Gobi bears, saiga antelopes, snow leopards, Siberian ibex, and argali sheep, are seriously endangered or near extinction (IUCN 2018). Many grassland birds are also severely declining due to land use and climate change (IUCN 2018). As the global human population is expected to reach 9 billion by 2050, we may need to use more of our global grasslands to sustain these additional 2 billion people, which in turn could lead to greater threats to the plants and animals that live in this ecosystem. Understanding how Mongolian pastoral lifeways have supported sustainable land use could provide useful solutions for addressing this current wicked biodiversity crisis.

Here, we briefly summarize the work each of us has conducted in Mongolia, within the context of how our proposed framework can address wicked environmental problems at each of our research sites. The individual work we present in this section can be used to determine how well we have answered some of the fundamental questions we posed. In the future, with opportunities to work in collaboration as scientist and humanist at these and other research sites, we will be able to test and refine our acoustic community framework more fully.

Mongolia's grasslands are rich in biodiversity and its sounds and soundscapes are key indicators of environmental health. Six major vegetation zones provide habitats for plant and animal species that contribute to acoustic communities of animals and people in each location where mapping these spaces and sounds has begun (see Fig. 1). The multifaceted acoustic experiences in communities of humans, animals, plants, and landforms occur as groups of herders settle in locations, and as they move seasonally from place to place seeking prime grazing land for their livestock. In their encampments, soundscapes are also impacted by population density, ethnicity, and type of settlement. Sound knowledge and production is adapted in response to the changing climate, a major driver of global and local change. Within each acoustic community, sounds are used in daily life as a form of communication between animals and humans about significant events — an animal-human-animal discourse — which provides information about *temporal* change including seasonal changes, dangers to livestock, the character of the land, and the social roles of family members. Sounds related to meteorological events also provide information about changes and encourage herders to take action. Sounds are also used to support the well-being of humans and animals, while narratives explain or articulate an understanding of the world with shared beliefs and values. Altogether, this use of sounds helps to maintain a balance in an increasingly threatening environment characterized by unpredictable weather and the intrusion of unwanted sounds, including acoustic disturbances that

mask valued and more "readable" sounds. Many local populations are extremely vulnerable, and lifeways are exhibiting a breakdown of productive human/non-human relationships. This crisis affects the ability of human actors in acoustic communities to maintain constructive ecological practices using knowledge transmitted from generation to generation, and thus to act supportively toward their environment.

Scientists have been studying the relationship between landscape condition, livestock pressures, and biodiversity in Mongolia for the last several years and there is conflicting evidence on whether herders manage their pastures sustainably (Fernández-Giménez et al. 2017). A 2015 soundscape ecological study by Pijanowski in Mongolia was designed to determine whether grazing intensities impacted the biodiversity of herders' lands using acoustic sensors as an indicator of ecosystem health. The three-month study was conducted in Hustai National Park and the Tuul River Valley in cooperation with park rangers and local herders, important voices that guided the research design. Nine sensors were placed across the landscape: three in one area (Marmot valley) serving as a reference condition (where Przewalski's horses are being protected); another three sensors at a water well installed at the edge of the park for use by herders on an "as need basis" (moderately grazed); and a third set of three in an area near the Tuul River where intense livestock grazing had occurred the previous two years, but that was set aside during the summer of our study to "rest." These are currently being mapped to landscape conditions obtained from satellite imagery from a Moderate Resolution Imaging Spectroradiometer (MODIS). We calculated a variety of soundscape ecology metrics that quantify biological sounds within temporal windows and within the acoustic breadth of frequencies (Fig. 2). These boxplots show that grazing intensity may not reduce biodiversity below that of reference sites. However, detailed information about specific management practices and how these practices have been developed require the narrative toolkit of the qualitative scholar along with discourses about how biodiversity has changed in the park and in intensively grazed areas. Such narratives should improve scientists' understanding (i.e., expand the epistemological depth and breadth) of critical cause and effect relationships between *drivers* and *problems*.

Ethnomusicological research in Mongolia has focused in recent years on musical production in both rural and urban communities. There is increasing interest in the impact of the movement of rural peoples to semi-urban and urban locations, especially Ulaanbaatar, the capital city that now holds more than half the country's population (Marsh 2006, 2009; Yoon 2011). A significant number of pastoralists move to cities in response to changes in local landscapes and ecosystems, and this new mobility has affected rural human and

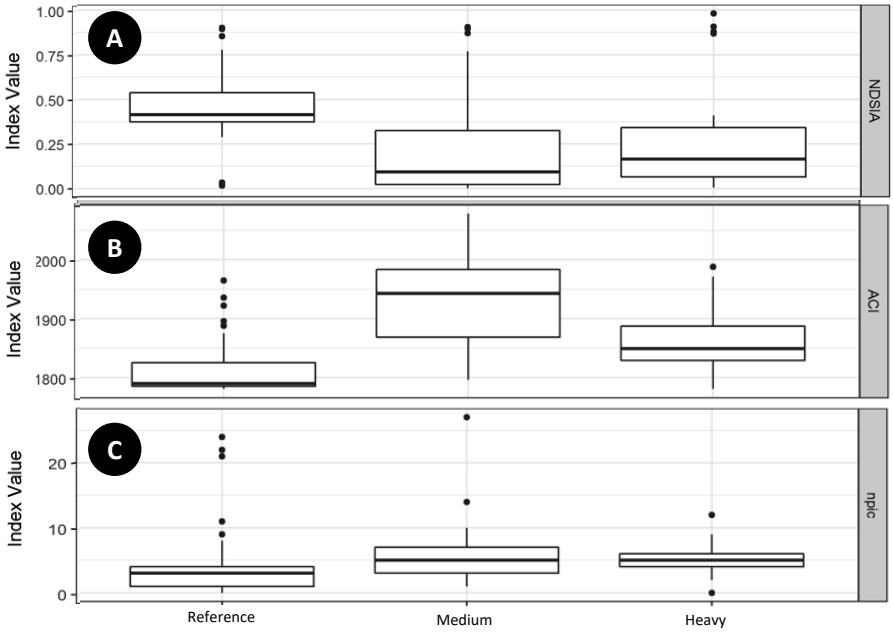

Fig 2. Three soundscape ecology indices for no grazing (Reference), a water well (Medium grazing), and at the location of formerly heavily-grazed sites (Heavy). A=NDSIA, which provides a ratio of low frequency sounds, like wind and traffic, to biological sounds; B=ACI or Acoustic Complexity Index, which measures modulation patterns common in animal communication; and C=number of peaks, or the count of amplitude peaks in a file.

environmental well-being (Post 2014). In the westernmost province of Bayan-Ölgii, eco-ethnomusicological research by Post in pastoralist families reveals the impact of climate change and other disturbances on music and sound production (2017, 2018). Bayan-Ölgii is located in the Altai-Sayan Ecoregion, a significant ecological site for biodiversity conservation that spans Russia, Mongolia, Kazakhstan, and China. Alpine grasslands in Bayan-Ölgii near the Mongolian Altai Mountains bordering China and the Saylyugem Mountains on the Russian border are critical to the livelihoods and lifeways of Kazakh and Tuvan herders who comprise over 90 percent of the provincial population. Fieldwork in these and other regions conducted during the last 15 years uses ethnographic methods that include engaging with family activities related to herding and social/cultural production, recording musical performances and local soundscapes, and asking open-ended questions about the significance of music and sound in the daily lives of residents. The increasingly unpredictable weather patterns and the subsequent difficulties herders have had maintaining

consistent practices are challenging, and some have chosen to leave the land for urban places. While all pastoralists learn adaptive strategies, the current local conditions that include extreme cold, drought, flooding, and other weather events have made it difficult for residents to manage using skills transmitted from earlier generations.

Post's research addresses sounds, soundscapes, and sound practices (including music) in and near alpine grasslands as herders evaluate and use their acoustic environment and other sensory sources of knowledge to manage and care for their livestock. How do herders settled near grasslands in spring, summer, and autumn months engage with their acoustic communities? What specific sound-related relationships do they have with their livestock, family groups, plant life, wildlife, and weather events? What sound and music-related strategies have they employed to address recent climate change events and other disturbances? For example, herders' sources of information about weather events may come from birds, and discourse with livestock and wildlife may contribute to ecological (and economic) well-being. Poor grasses and lower milk quantities combined with severe winters and the loss of domestic animal herds have made livestock more precious. In both Tuvan and Kazakh encampments, herders listen for goats spitting loudly at night, a signal that wolves are nearby; a wolf visit in the night can result in the loss of lambs and kids, a huge economic blow to a family. Stylized sounds used to scare wolves away occur in response to the goats' warnings (Fig. 3), as Tuvan herder Olonbayar Urtnasan demonstrated at the base of the Tavan Bogd Mountains with a call he learned in his family when he was young (interview, June 21, 2017).

Responding interactively to an environment using sounds learned over time offers herders some control over their circumstances and contributes to a balanced set of human/non-human relationships. In another example, Bhaktjan Köshen at Dayan Lake measures the height of grass and the speed of its growth over time and notes that there has been appreciable change in recent years:

> When I was young, we would throw a tree branch on the ground and the grass would grow around it very quickly (in 3-4 days), covering the branch. There were sounds of *phssh*. Now because there is less rain and the weather is dry, it grows more slowly and I can't hear this sound of growing coming from the water inside the grass. (interview, June 24, 2017)

He links changes in the sound, quality, and height of grasses to lower levels of milk production in his livestock, and even to lower birth rates in his sheep, evidenced by the diminishing presence of particular sounds made by sheep

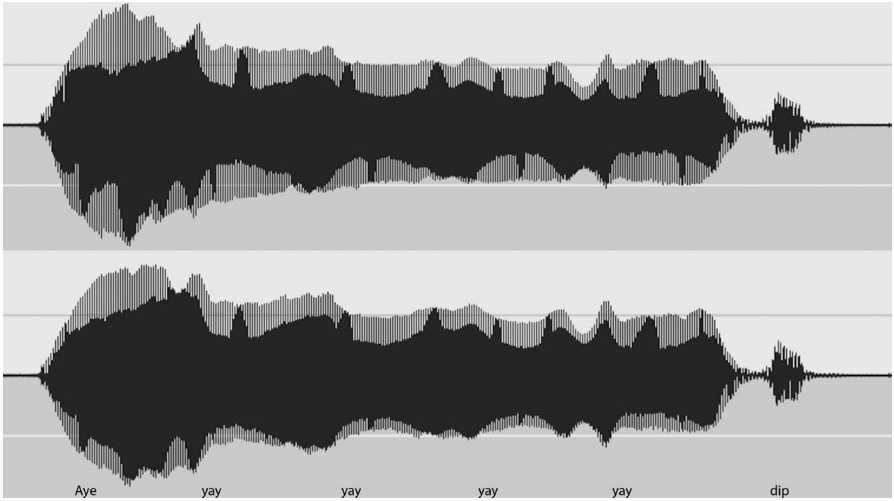

Fig. 3. Tuvan herder Olonbayar's call to scare away wolves at night in western Mongolia.

as they look for their lambs. While information about relationships between herders and sounds is useful in eco-ethnomusicological research, correlating acoustic data from science, ethnography, and local residents will contribute to improved understanding of patterns in the daily and seasonal lives of animals and plants that can then be applied more directly to research on biodiversity loss.

As teams of eco-ethnomusicologists, soundscape ecologists, and local pastoralists work together to address the drivers of change affecting Bayan-Ölgii grasslands, selecting effective methods will require collaborative teamwork among all interested groups. A good starting point is to employ mapping strategies to join qualitative and quantitative information to link remote and human sensor data with spatial data informed by human perception and experience expressed in discussions and interviews. Mapping will also help identify (1) correlations between human and ecosystem health and well-being by drawing from the big data of soundscape ecologists to establish one view of ecosystem conditions, (2) the sound and soundscape recordings of ethnographers directed and informed by local community members to provide additional spatial and temporal information on human and nonhuman conditions, and (3) the narrative information from local pastoralists offering in-depth case studies to evaluate and potentially add new parameters for the team to consider.

We believe that in Mongolia — and in many other locations around the world — some of the solutions for the biodiversity crisis can be found in acoustic

communities and their dynamic social, cultural, and ecological networks. It is unfortunate that collaborative research of the kind we discuss in this paper is so rare because scientist-humanist community partnerships, as we have described in our acoustic community framework, are key to a better understanding of biodiversity decline and for identifying solutions. Successful partnerships of the kind we propose require agencies such as NSF and NEH to recognize the value of this kind of research by offering their support, especially in areas of rich and/or unique biodiversity. In our collaborative research plan, scientists will benefit from discourse with local people who will share their ecological knowledge based on their years of experience in a given location. Eco-ethnomusicologists will add an ethnographic dimension to a project using digital and human sensor data along with face-to-face interviews that focus on spatial and temporal issues and draw on some of the research questions that emerge from collaborative opportunities in the field. This is a chance for ethnomusicologists to become more fully immersed in biological and geophysical aspects of the environment — an experience that is a companion to, not a replacement for, in-depth studies concerned largely with human systems. It is also a chance for ecologists to embrace the important social and cultural relationships that occur when the whole — the soundscape — is not simply an aggregation, but is instead understood as sounds providing valuable information about their associated landscape. We must emphasize the urgency of this collaborative work, however, given the wicked problems confronting communities in many locations. Indeed, not doing this work means that the local, place-based solutions we desperately need to create a sustainable lifestyle may be lost forever. We need people to live harmoniously with their environment and share their knowledge with all — scholars, policymakers, and the rest of society.

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