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The interdisciplinary Development of the Term "Soundscape"; Tracing its Ecological Roots

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A U T H O R S I N F O

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A B S T R A C T

Even though the term "*soundscape*" is strictly ecological, it has been incorporated in various interdisciplinary studies. The definitions attributed to this term to date, in chronological order, reveal its ecological roots. Nevertheless, the ecological background of soundscapes did not pose as a barrier towards its expansion, but was rather beneficiary towards environmental sciences and other disciplines. These incorporations are the reason for the theoretical broadening of the term. This specific review highlights the use of an ecological term in non-ecological disciplines. Furthermore, the mapping of this extension over the years as well as the identifying any trends in the term's use per discipline, haven't been researched to date. In order to answer these questions, we initially assessed all publications appearing between 1969 and 2011 that incorporated the term "soundscape" in their title (about 3,200 references). Multiple and non-scientific entries were excluded from the research by filtering the results. The final dataset (979 entries) was classified regarding year of publication and scientific sub-discipline. Our results indicate "outbursts" regarding publication number in soundscape literature that could be attributed amongst other reasons, to several legislative developments concerning the assessment and management of environmental noise.

K E Y W O R D S (in alphabetical order): *Acoustic Ecology*, *Soundscape*, *Soundscape Ecology*, *Soundwalk*
Highlights

1. Introduction

Since R. Murray Schafer in the early 70's introduced the term "soundscape", the interdisciplinary development of its use seems to follow a significantly increasing trend. Soundscape studies are a major area of research on the scientific field of acoustic ecology. The World Soundscape Project (WSP) that was established by R. Murray Schafer at Simon Fraser University in the late 1960s-early 1970s, produced several publications including "*The Tuning of the World*" (Schafer, 1977) and Barry Truax's reference work for acoustic and soundscape terminology "*Handbook for Acoustic Ecology*" (Truax, 1978). The term "soundscape" in Truax's handbook is defined as the "*environment of sound (or sonic environment) with emphasis on the way it is perceived and understood by the individual, or by a society*". This definition was adopted by the technical committee on acoustics (TC 43) of the International Organization of Standardization (ISO) Working Group 54, regarding the perceptual assessment of soundscape quality ('Committee ISO/TC 043 "Acoustics"', 2008). Furthermore, the field of ecoacoustics, which studies biological and non-biological sounds along a broad range of spatio-temporal scales, includes soundscape ecology and examines the ecological processes of a soundscape under several environmental pressures (Sueur & Farina, 2015).

"*Only silence lay over the fields and woods and marsh*'', were the words of Rachel Carson in her book 'Silent spring' (Carson, 1962). The alteration of a soundscape which was described in Carson's memories was the trigger for the 'awakening' to major ecological issues. The loss of biophony over the fields, woods and marshes is equivalent to the anthropophony increase in the cities, which poses a warning regarding the acoustic quality of urban soundscapes and the well-being of its residents. Cities have changed dramatically over the years, shaping the acoustic and visual domain in both positive and negative ways. Several sounds that are associated with specific urban practices (e.g. transportation) might have changed over the years due to technological advancements. Nevertheless, cities have always been noisy places and despite the fact that particular urban sounds and their sources differentiate, the reason of propagation is still the same (Garrioch, 2003). Ecological, social, political, economic and even religious factors, contributed in the shaping of a city's soundscape. Cultural habits for example, originating from the fourteenth century (like the Christian church bell ringing and the Muslim mosque calls) served as influential factors regarding the religious acoustic profile of Europe (Garceau, 2011).

The subjective dimension of acoustic perception has resulted in different attitudes and "feelings" towards soundscapes. The positive or negative reaction on a sound does not depend entirely upon the sound itself but also upon the associated behaviors and experience of the listener, the visual context, the related memories associated with the sound and the emotions

which could be either positive or negative (Liu & Kang, 2016). The philosophical dimension of sound perception has troubled thinkers for many decades. The well-known philosophical thought experiment "*If a tree falls in a forest and no one is around to hear it, does it make a sound?*" appeared as a reader's question in the Scientific American magazine (Scientific American, 1884). Furthermore, the same "rhetorical" question reappeared in the book "*Physics*" by Charles Riborg Mann and George Ransom Twiss, in 1910 (Mann & Twiss, 1905). This question was addressed by giving a technical answer regarding acoustics, stating that undoubtedly there will be vibrations yet no sound -since there will be no one around to accept and interpret the aforementioned vibrations. It is now known that the generation, propagation and perception of sound is strongly connected with mechanical vibrations and oscillations that result to sound waves (Kuttruff, 2007). Nevertheless, the answer to the same question would be different if the issue of annoyance was incorporated. If there is no witness to confirm "the tree's fall", its fall does make a sound but it surely does not make a noise. The presence of any form of life, human or animal, so that annoyance can take place, is essential for the subjective transition from sound to noise. Sound wave propagation is an objective matter due to the fact that nature does not require a spectator in order to function. However, noise is subjective, entirely depending on the receiver's tolerance and preference.

1.2. Soundscape Definitions

Several versions of the term "soundscape" were used over the years in scientific literature. Almo Farina, in his book "*Soundscape Ecology: Principles, Patterns Methods and Applications*" (Farina, 2014) defines the soundscape as the entire sonic energy produced by a landscape. The foreground and background sounds, in relation to the sound source and the position of the listener, outline the association between the soundscape and the landscape. The unpredictability and temporal variability of foreground sounds that create an immediate reaction to the listener are less connected to the landscape configuration. Therefore, the background sounds which refer to the low-level sounds that result from the blend of several individual sound sources are highly associated with the landscape. The spatio-temporal overlap of geophonic, biophonic, and anthrophonic foreground sounds creates the "sonotopes" that when further shaped by vocal organisms create the "soundtopes" (Farina, 2014). Soundscape ecology, as a promising field of ecological research, emphasizes the ecological characteristics of sounds and their spatiotemporal patterns as they emerge from landscapes (Pijanowski et al., 2011b). Moreover, it is described as the study of sound in the landscape and its effects on organisms and how different acoustic sources interact at spatial and temporal scales (Pijanowski et al., 2011a).

The link between landscape and soundscape ecology in natural acoustic environments highlights the connection amongst the

"soundscape" and the "eco-field". The "eco-field" concept refers to the physical space and the associated abiotic and biotic characters perceived by a species when a functional trait is active (Farina, 2000). The connection with the soundscape concept derives through the biosemiotics approach to avian acoustic communication, which refers to the study of sound patterns structured into syllables, phrases, verses and strophes, along with the combination of these elements (Farina & Belgrano, 2006).

Transportation noise, industrial noise, recreational noise, noise produced by animals and sounds like rain and the reflection of the wind on various surfaces, are part of the "acoustic field" (Brown & Lam, 1987). The information of the dynamics of an ecosystem in a specific time and place and the effects of anthrophony and geophony to the ecosystem as a whole, are described by (Krause, 1987) as the unique "acoustical bio-spectrum". One of the most recent definitions given to "soundscape" is "*the collection of biological, geophysical and anthropogenic sounds that emanate from a landscape and which vary over space and time reflecting important ecosystem processes and human activities*" (Pijanowski et al., 2011a)

Soundscapes represent a group of immaterial resources that are ecologically, culturally and economically valuable (Farina & Pieretti, 2012). Research on the visual qualities of a landscape, demonstrates the strong connections between sense of place and sound. In cultural landscapes, the soundscape is the result of mutual progress between human culture and natural processes (O'Connor, 2008). Sounds are considered essential factors of place making. Hence, cultural soundscapes should be protected and preserved as cultural heritage.

2. Methodology

In order to study the career of the term "soundscape" in the academic literature, all publications appearing between 1969 and 2011 that incorporated the term "soundscape" in their title (about 3.200 references), were assessed through the global literature. The databases used for this research were: a) Google Scholar, b) Web of Science (formerly known as "web of Knowledge") and c) Google Search. Due to the vast amount of data collected, a customized script was used in order to transfer data in an sql database and then to an open-source reference management software ('Zotero') in order to clear multiple and non-scientific entries. The final, cleared, dataset (979 entries) was classified by year of publication and scientific discipline. The subcategories were then grouped into three main categories of: a) Natural Sciences, b) Technology and c) Social Sciences – Arts. The final, main category, results were introduced in the statistical analysis software SPSS v.19, in order to describe trends.

The "soundscape", as a term, has conceptually extended, as it is evident from the fact that it is used by a wide variety of interdisciplinary areas in global literature. For

almost 50 years since 1969, where the term "soundscape" was first introduced by R. Murray Schafer (Schafer & Murray, 1969) the scientific areas of: a) social sciences, arts and humanities, b) engineering, computer science and mathematics, c) biology, life sciences and environmental science, incorporated the soundscape terminology. These incorporations are the reason for the theoretical broadening of the term. The tracking of this extension over the years, as well as identifying any trends in the term's use per discipline, haven't been researched to date. Establishing these facts could lead to numerous conclusions regarding development in the field of acoustics. Several examples highlighting concerns which induced research topics across the various disciplines are listed below, regardless the year of publication.

3. Disciplines of Interest

3.1. Social Sciences, Arts and Humanities

The relationship between individuals in a soundscape context and the positive or negative effects of soundscapes in human societies generated numerous publications in the field of social science. Several sub disciplines of soundscape and acoustic ecology emerged in order to tackle the ever increasing noise related concerns. Psychoacoustics is a major field of research that deals with issues of acoustic perception. It refers to the study of the psychological and physiological responses of human beings and other forms of life to their acoustic surroundings. One of the pioneers in the field of psychoacoustics was the Hungarian biophysicist Georg von Békésy who was awarded the Nobel Prize in Physiology or Medicine in 1961 for his research on the function of the cochlea in the mammalian hearing organ. Apart from his work on the physiological responses on hearing, Georg von Békésy also published various research in the field of psychophysics, including publications dealing with the senses of hearing, balance, vision, touch, taste, and smell (Moore, 2012). Several psychoacoustic semantics (word meanings) like "loudness", "quietness" and "sharpness", are used in order to describe acoustic comfort in soundscapes (Kang, 2010). Furthermore, the relationship between the individual experience and subjectivity with a physical and a socio - cultural perspective is important for the assessment of the perceptual, psychoacoustic and acoustic properties of soundscapes (Hall et al., 2013).

The concerns regarding acoustic perception could be dealt with using several techniques that are able to assess the subjective and personal act of hearing. Qualitative surveys, that most regularly are accompanied by quantitative data (e.g. noise level measurements), are the basis of acoustic perception assessment. Recent surveys regarding soundscape preferences have concluded that natural sounds are not only the most preferable sounds in a landscape but also the most influential soundscape element of acoustic perception (Marry & Defrance, 2013). Furthermore, natural soundscapes that include

biotic sounds (e.g. bird songs) could have stress-relief potentials (Ratcliffe et al., 2013). Nevertheless, natural sounds and soundscapes could still cause undesirable emotions if associated by individuals with negative experiences (Ismail, 2014). Research on the positive sounds (i.e. that shape soundscapes positively), is a major issue of the field. Recent studies concluded that individuals perceive positively the water sounds (Axelsson et al., 2014).

A key feature of an acoustically healthy city is the degree of awareness amongst its inhabitants regarding ecological issues. Methodologies such as soundwalks, directly involve stakeholders by promoting awareness regarding the individual contribution to the quality of the acoustic environment (Jeon & Hong, 2015). According to Hildegard Westerkamp, a soundwalk is any excursion whose main purpose is listening to the environment. The three states of listening, listening in search, listening in readiness and background listening (Truax, 2001); (Jennings & Cain, 2012) could contribute to a better understanding of the personal act of listening at a broader scale. The purpose of this procedure is soundscape evaluation, by using primarily the sense of hearing.

The landscape attributes of a public space, either natural or man-made, influences the acoustic perception of its users (Matsinos et al., 2008). Furthermore, the quality of soundscapes could be improved if the spatial arrangements of different landscape elements are considered in landscape and urban planning (Liu & Kang, 2016). The soundwalking practice has proven to be a valuable tool for soundscape studies and could set the ground for future soundscape remodeling. "Soundwalking" consists of a pre-selected route with several stops representing a variety of soundscapes. A group of stakeholders follows that route in silence, surveying both the soundscape and landscape. The flexibility of its methodology allows novel alterations that could serve different purposes regarding the scope of each research. The soundscape and landscape variety of each soundwalk and the objectives of each research are the main reasons of procedure modifications. A good soundwalk example is the positive soundscape project (Adams et al., 2008; Davies et al., 2013) that highlighted both the negative and positive acoustic aspects of Manchester, UK.

Finally, a major development in social sciences and humanities has been the emergence of sound studies. This relatively new interdisciplinary field assesses the differentiation of aural culture though history and evaluates the way that humans interact with their acoustic environment, in order to "learn" to judge a society by its sounds (Attali, 1985); (Thompson, 2004); (Pinch & Bijsterveld, 2011). Noise studies isolate sound from the way human beings understand it and they treat sound as a signal to be processed rather than as information to be understood (Truax, 1978). Instead sound studies examine the entire continuum of sound,

including both the negative and positive qualities of the soundscape (Porteous & Mastin, 1985).

3.2. Engineering, Computer Science and Mathematics

The 2002/49/EC directive (*2002/49/EC Directive on the assessment and management of environmental noise*, n.d., p. 49) has given the necessary guidelines for the assessment and management of environmental noise. The definition given regarding environmental noise in the Environmental Noise Directive (see above) is "the unwanted or harmful outdoor sound created by human activities, including noise emitted by means of transport, road traffic, rail traffic, air traffic, and from sites of industrial activity". A type of environmental noise is the background or ambient noise, which refers to any sound other than the sound under consideration. Even though background noise is not limited to anthropogenic sounds, it is widely acknowledged that it refers to a form of noise pollution or interference from a main objective, mainly in the field of acoustic engineering.

Soundscape studies rely on technological advancements to address the needs of noise abatement. A common method for the visualization of changes in a soundscape, caused by human actions, is noise mapping. According to END (Environmental Noise Directive) all EU Member States are required to produce strategic noise maps in their main cities, in order to visualize the propagation of transportation and industrial noise and assess population exposure. Noise modeling processing, in combination with noise cartography software, is used in order to portray noise pollution in urban and rural environments for future decision making. Traffic noise which is a major issue in human wellbeing and the quality of the environment is assessed using cartographic data and traffic flow rates. Noise mapping software similar to the Computer Aided Noise Abatement software ('DataKustik: CadnaA', n.d.) could be used in order to address noise issues in urban soundscapes. Traffic flow data, building height and structure, population density, façade exposure, road classification (Suárez & Barros, 2014) and verification via noise measurements (Fiedler & Zannin, 2015) are all crucial information needed for the noise modeling scenarios.

Complexity and diversity of agglomerations is an obstacle when addressing the common problem of noise assessment. Noise modeling processing could be a challenging task due to urban structure peculiarities (Nega et al., 2013). The road networks that differ in road geometry and driving habits in combination with the urban structure could form street canyons which are one of the largest causes of noise propagation in urban soundscapes (Janczur et.al. 2006; (Abhijith & Gokhale, 2015; Janczur et al., 2006). Noise abatement policies have adopted various noise mapping techniques in order to address issues in noisy soundscapes and upgrade the degraded acoustic environment. The technological advancements could allow noise modeling and mapping in larger scales for

various purposes and even be the stepping stone for future soundscape creation (Vogiatzis, 2012; Vogiatzis & Remy, 2014).

3.3. Biology, Life Sciences and Environmental Science

Under specific conditions, high intensity sounds could be perceived as noise. It is generally understood that human beings are not the only species that are affected by noise. The specific environmental pressure, amongst other issues, affects the communicational process of organisms. For example, anthropogenic sounds could create an inhospitable soundscape for several animal species that become more vulnerable to their predators due to the fact that their attention is distracted (Chan et al., 2010). The mating system of several songbirds and of other vocal species that use auditory signals could be affected by the increase of environmental noise, eroding the strength of sexual selection and possibly their genetic structure (Swaddle & Page, 2007). Previous studies have concluded that communication in noise conditions and the ability to extract information in the presence of background noise could have numerous effects (Brumm & Slabbekoorn, 2005). The difficulty to recognize and interpret sound signals in a noise environment is common in human beings and animals and is also called "the cocktail party" problem (Bee, 2008). Noisy environments could cause shifts in signal amplitude but also in the minimum frequency domain (Slabbekoorn & Peet, 2003); (Nemeth & Brumm, 2009).

Soundscapes play a major role in vocal communication in which many animal species rely on. Especially in urban soundscapes, the increased background or ambient noise that could mask vocal signals (Mendes et al., 2011) and cause frequency adjustments (Hu & Cardoso, 2010) along with the loss of habitat features could be the reason of disappearance of several urban bird species (Slabbekoorn & Ripmeester, 2008).

Habitat-dependent patterns of sound transmission, effects of noise, signal perception, and signal interpretation are the major communicational problems that birds and especially song birds (Beckers et al., 2003) as senders and receivers need to adapt to, in order to "get the message across". Signal degradation between emitters and receivers has been an inspiring subject for evolutionary issues in animal communication.

Anthropogenic noise is not the only "type" of noise that could cause communicational issues. There are many natural sources of noise, including streams, wind and other animals (e.g. insect choruses), providing opportunities for elevated noise levels (Warren et al., 2006).

In comparison to human generated noise, natural noise is handled by organisms in a different way. Anthropophony produces annoyance, chronic stress and hearing loss, while natural noise (e.g. noise from a waterfall) can be either physically avoided by an organism, or this

organism could be adapted to filter it out. The above statement could be attributed to both human beings and animals. Previous studies have concluded that natural or ecological sounds induce positive emotions to human beings (Ferri et al., 2015). Nevertheless, human response and emotion to natural sounds or noise could possibly be irrelevant to the physical effects of noise that creates disturbances in communicational processes, masking the signal's frequencies.

4. Results and Discussion

The soundscape concept in direct correlation to ecology is used with much more interest from all other disciplines than natural sciences (Figure 1). Even though the "soundscape" term could be credited to natural sciences the lack of interest in that field could lead to various conclusions. The rapid technological advancements in areas like signal processing, could explain the upward trend regarding the related publications in computer sciences since the year 2000. The upward trend regarding social sciences and arts observed almost since the beginning of the records, could be attributed to the "creator's" status as a music composer and social scientist. Furthermore, the personal act of hearing and the individual interpretation of a "soundscape" could have steered towards an increase of interest as far as the social sciences are concerned.

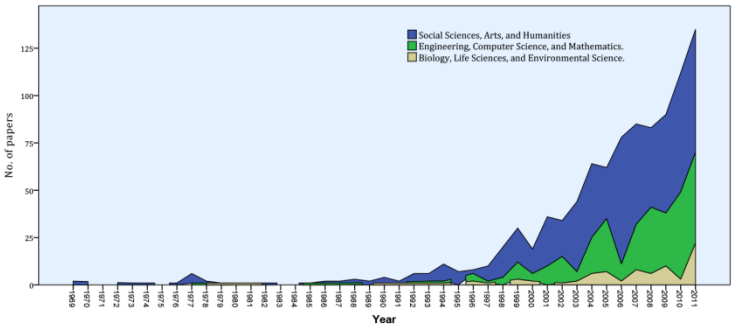

Figure 1*: N_o of publications per disciplinary category between Yrs 1969-2011, regarding the use of the term "soundscape" in global literature*

Finally, a sudden upwards trend is clearly observed for all disciplines after year 2006. A reason for this event could be the direct connection of acoustic and soundscape ecology to issues concerning environmental noise. In the 2002/49 directive (article 10.1), the need was stressed for member states to submit (by January 2004) a report on existing community measures relating to noise issues. This act by the member states was to be completed by the implementation of legislative proposals regarding the same issue, no later than the year 2006**.**

Furthermore, just by observing the relative literature of each year's scientific publications it is obvious that interests shifted towards soundscape – based issues mostly in urban communities. Researches on the quality of soundscapes (De Coensel & Botteldooren, 2006; Guastavino, 2006; Nilsson & Berglund, 2006) have concluded upon the ideal acoustic conditions on rural and urban areas. Noise

annoyance and sleep disturbance issues (Botteldooren et al., 2006), noise mapping techniques (Klaeboe et al., 2005) for urban areas, socio-acoustic surveys regarding traffic noise in order to assess quiet soundscapes (Öhrström et al., 2006) and soundscape planning for therapeutic activities (Yamada, 2006) were some of the interests regarding publications in 2006.

The direct association of the term "soundscape" with the ecologically-derived concept of landscape is indubitable. Furthermore, acoustic and soundscape ecology use terms similar to the acoustic niche hypothesis (Krause, 1987) that are borrowed from, and later on adjusted by, the conceptual framework of ecology. Nevertheless, the observed declining share of references to this ecological term in the environmental sciences' literature vis-à-vis other disciplines should not only be interpreted as a "lack of interest" amongst ecologists. Acoustic and Soundscape ecology should be considered as inherently ecological academic disciplines that contribute equally in the vast of field of ecology.

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