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The sound territories of diversity, between humans and non-humans

An anthropological-biodiversity approach of the soundscapes territorialization in urban resourcing areas

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Abstract :

This research is part of the LIFE Biodiver'City et Résilience (BCR) ecological restoration project for residents, whose acoustic dimension refers to the “quiet areas” component of Bordeaux Metropolis's Environmental Noise Prevention Plan (PPBE). It presents a multidimensional landscape indicator; the sound source's *presence spectrum*, designed to capture the spatial evolution of the bio- and anthropophonic qualities of the living environment within "resourcing" urban territories. This hybrid method, tested on the *Burck wood* in Mérignac (France), is currently being extended to other quiet areas (as defined by the European directive 2002/49/-EC) - woods, forests, parks and gardens - in the Bordeaux metropolis. The results are sometimes unexpected, about the territorial sharing of sound practices between humans and non-humans. Ultimately, this ambient analysis model will evolve into a tool for observing and spatially qualifying these “quiet areas”, facing urban responses to climate change.

Introduction: anthropization of territories and deafening of natural landscapes

Assessing biodiversity is one of the major challenges in ecology of the manifestations of wildlife and human activity in urban and peri-urban environments. Thus, the use of sound constitutes one of the most accurate observation techniques. As birds and bugs are the main sound emitters in nature, they exploit distinct “acoustic niches” throughout an intelligible

sound spectrum, even when immersed in anthropo¹- or even technophonic landscapes (mechanical noise from motorized traffic). Biophony as a natural acoustic space composition should therefore design the species environment by minimizing sonic overlapping effects between the biotope actors. These sound sources play an important role in resourcing experiences in quiet peri-urban areas, making them a major part of the natural landscapes of our cities.

This study aims to test the validity of new bio- and anthropodiversity indices based on an acoustic analysis of the choruses produced by animal and human communities within soundscapes. Their cartographies enable biophonic (birds and bugs in particular) and anthropophonic (human activity) analysis of the city's quiet areas.

Anthropo- and biophonic metropolitan territories analysis through bird song spatialization

The massive anthropization of natural areas has as great impact on animal and plant biodiversity in terms of functional territorialization (reproduction, food chain, etc.). The resulting sound compilation reveals the problems of habitat fragmentation between humans and animals.

Birds' audibility in our cities is a growing indicator of the current decline in urban biodiversity over the last 25 years (Gasc et al., 2017). A study led by scientists from the University of East Anglia², who reconstructed the soundscape of over 200,000 sites over 25 years, points to reproduction and food chain disruption of birds. The study reveals a considerable weakening of birds acoustic messages, which could damage the already endangered relationship between humans and non-humans.

According to a recent study published in *Nature Communications*³, climate change is also responsible of the decline of avian populations, by causing an imbalance of the species distribution in various natural habitats (Morrison et al., 2021). The large decrease in the bird population affects the quality of perceptual experiences relating to nature's manifestations. The perception of the presence and diversity of avian fauna is better described by its sound than by its sight. This is why analyses of resident avian populations sound presence constitutes one of the best ways to evaluate biodiversity.

Thus, birdsong soundscape - birdscape - is a reliable and explicit indicator of the biodiversity decline in terms of sound abundance decrease in natural urban spaces. The regenerative impact of bucolic soundscapes delivered by green urban spaces is therefore drastically reduced by this "loss of audibility" of city natural actors. However, quiet regenerating areas are crucial for anthropic adaptation to the new living conditions provided by increasing urbanization. By providing benefits for biodiversity and ecology, the sanctuarization of quiet areas⁴ in urban spaces have noticeable advantages regarding to the well-being and environmental psychology of inhabitants. The urban model of acclimatization represented by these resourcing areas ensures viability for our noisy, dense cities.

Animal reactions depend on the qualities of perceived threats rather than on the intensity of the resulting noise, not only when the sound is produced by humans (anthropophony) and their technology (technophony), but also when another animal species expresses itself sonically.

¹ Niche hypothesis ; biophonic, geophonic or anthroponic (Krause, 1987; 2002) sounds compete for spectral space at given times.

² <https://www.uea.ac.uk/about/news/article/study-reveals-the-shifting-sounds-of-spring>

³ <https://www.nature.com/articles/s41467-021-26488-1>

⁴ Sanctuarization recommended by the "quiet areas" section of the European Noise Directive 2002/49/EC.

Therefore, physical approaches of noise quantification (sound level measurement) are unable to reveal soundscapes parameters of this biotic sensitivity to the threats, notably caused by anthropogenic activity. The use of sensory evaluation methods to evaluate ambient components like sound in the environment would be more efficient for that purpose. Thus, we opted for a reduced listening approach (in P. Schaeffer's terms) of the soundscape sources components to reveal the spatial dynamics of territorial sharing between humans and non humans. This establishes the *presence spectrum* method, developed to describe the extent of inter-species (animals and humans) territorial conflicts, particularly in quiet areas (Bradfer-Lawrence, et al., 2019). This acoustic space fractioning method can be operated by a statistical analysis of sound sources cross-observation protocol we present here.

Bordeaux ReSonA “Ressourcement - Sonorités - Ambiances”: quiet areas in Bordeaux

The present research on natural urban environment sound territoriality is part of the ecological restoration project for the benefit of residents through the *LIFE Biodiver'Cit  and Resilience* (BCR) program. The acoustic dimension refers to the “quiet areas” component of Bordeaux M tropole's Environmental Noise Prevention Plan. Our approach develops a multi-dimensional hybrid landscape indicator, the *presence spectrum* of sound sources and events, designed to modelize the spatial evolution of the bio- and anthropophonic qualities of the “resourcing” areas (Woloszyn and Ikni, 2023). This method, which has been tested in M rignac's *Bois du Burck* in 2023, has currently being extended to other quiet areas - woods, forests, parks and gardens - in Bordeaux metropolis. As with any innovative method, this observing tool sometimes delivers unexpected results concerning the “resourcing” territorialization of humans and non-humans sonic practices

Soundscape indicators in quiet areas in Bordeaux: presence spectrum, audibility and proxemics

We will use presence as a tool to assess the overall sensation generated by the combination of perceived sound level and object spatiality in the perceptual sphere. It allows us to transcribe the elements in the sound scene by evaluating the listener's *cognitive distance*⁵ to the elements of the ambient scene. After being applied to the *Bois du Burck* in Bordeaux-M rignac, four Bordeaux sites' soundscapes has been evaluated using presence spectrum indicators within those locations : *Berges de Garonne, Taillan forest, Bourghail forest and B gles Plaine des sports*.

To characterize the spatial soundmark in the semi-urban space of resourcing areas, we use anthropocentric survey techniques to identify the elements constituting the soundscape. For mapping purposes, we deploy a descriptive methodology of the soundscape that combines the enumeration of the sounds heard and the notation of the presence parameters relative to each sound object. The notion of sound presence implies that an ambient object (Woloszyn and Siret, 1998) - in this case, sound - approached by taking into account two main parameters: the perceptual space in which it unfolds: the dimension (D), and the intensity perceived by the listener: the value (V). The sound presence measurement plane is then represented between the two axes D and V as shown in figure 1:

⁵ Introduced by Wuits and Nooteboom (2005), the notion of cognitive distance describes the experiential and cultural differentiation of inter-individual perception. It is used here to define the individual's level of involvement within the perceptual act.

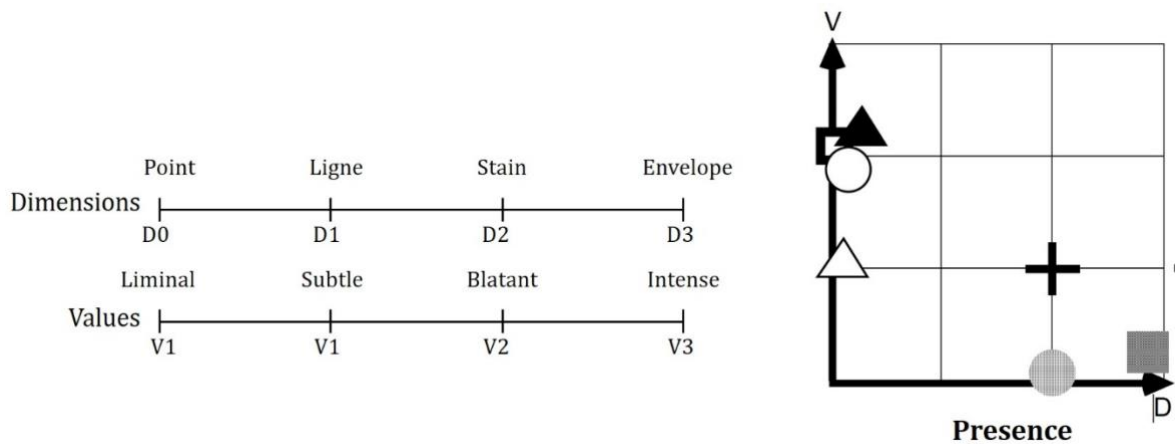


Figure 1: Axes and dimension-value plan, subjective measurement of presence

Presence is an important indicator of the morphological balance between the sources of the soundscape at any given moment. As a result of hybridizing the S.A.C.S.SO⁶ method of sound sources analysis with the descriptive method of ambient objects, presence indicator qualifies the *audibility* of the experienced soundscape elements from the sound scene foreground to the background, as well as the *proxemics*, qualifying the subjective distance from the sound object to the listener (figure 2).

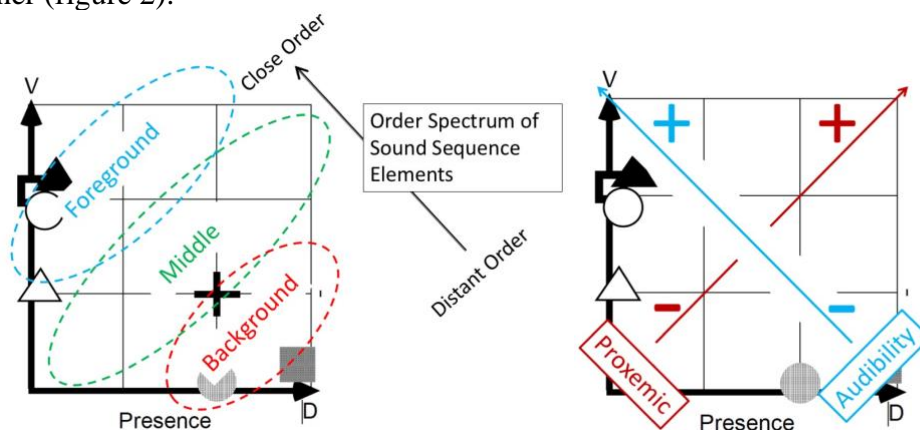


Figure 2: Morpho-hierarchy of sound objects in a soundscape: order spectrum, listening plans, audibility and proxemics.

After the processing of the descriptive elements, the results data of the presence spectrum of all the analyzed points are exported to a geographic information system to create a map. The latter is designed to reveal the sound sources territoriality of the site.

This cartographic approach of anthropophonic and biophonic sound sources allows us to discretize the sound territories through a dialogical analysis between nature sounds - essentially by distinguishing bird sounds from bug sounds - and the sounds of human activity - essentially linked to traffic noise.

The source-soundmap, territorial battlefield of sonic actors ? the example of the Taillan forest site

Forests are a significant part of *Le Taillan Médoc* township, taking up 25% of its expanse. They cover 451 ha, of which 139 ha belong to the township. Le Taillan's communal forest is made

⁶ Sound Sequence Composition Analysis System is a methodology for psycho-acoustic analysis of the urban sound environment which is developed by Alain Leobon. See (Léobon, 1995).

up of hardwoods and maritime pines, with a fairly rich fauna. There are 21 species of terrestrial mammals, 6 species of amphibians, 6 species of reptiles, 71 species of breeding birds, 74 wintering birds, 25 odonates, 6 reptiles, 6 amphibians, 7 chiropterans and 55 rhopalocerans (LPO Aquitaine and Direction de la Nature Bordeaux Métropole, 2015).

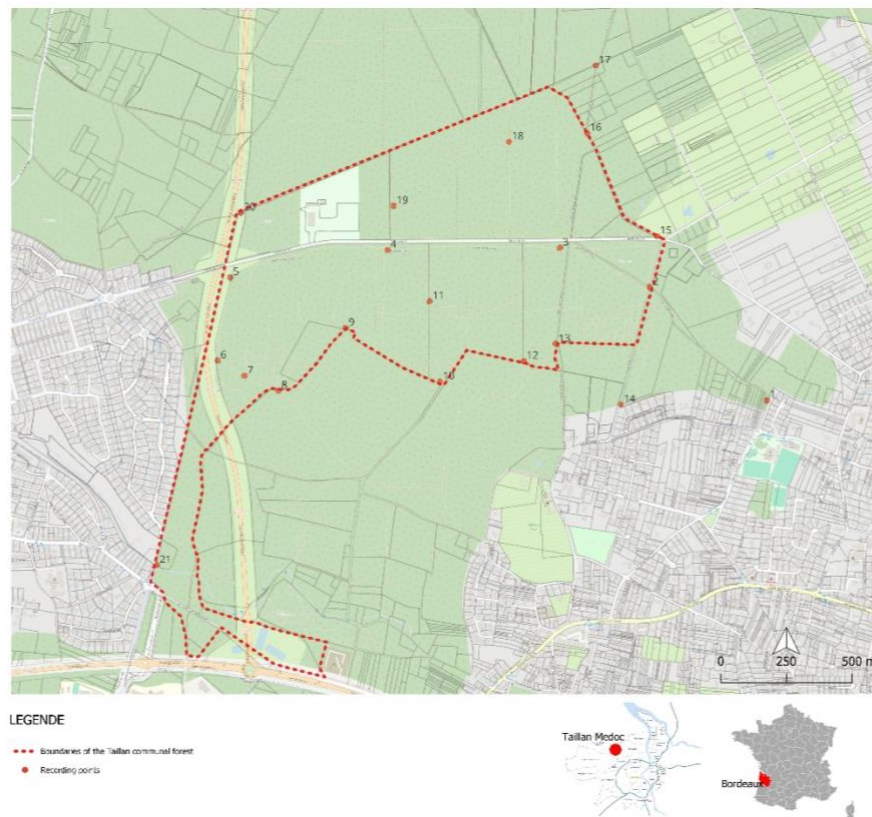


Figure 3: Taillan forest situation with recording points.

First conclusions on the sound sources territorialization in the Taillan forest

Following our field surveys, we established several maps showing the location of sound sources audibility level at different times of day: early morning, late morning and afternoon. The sounds of nature are represented here by two separate maps, showing respectively bird songs and bug stridulations figure 4:

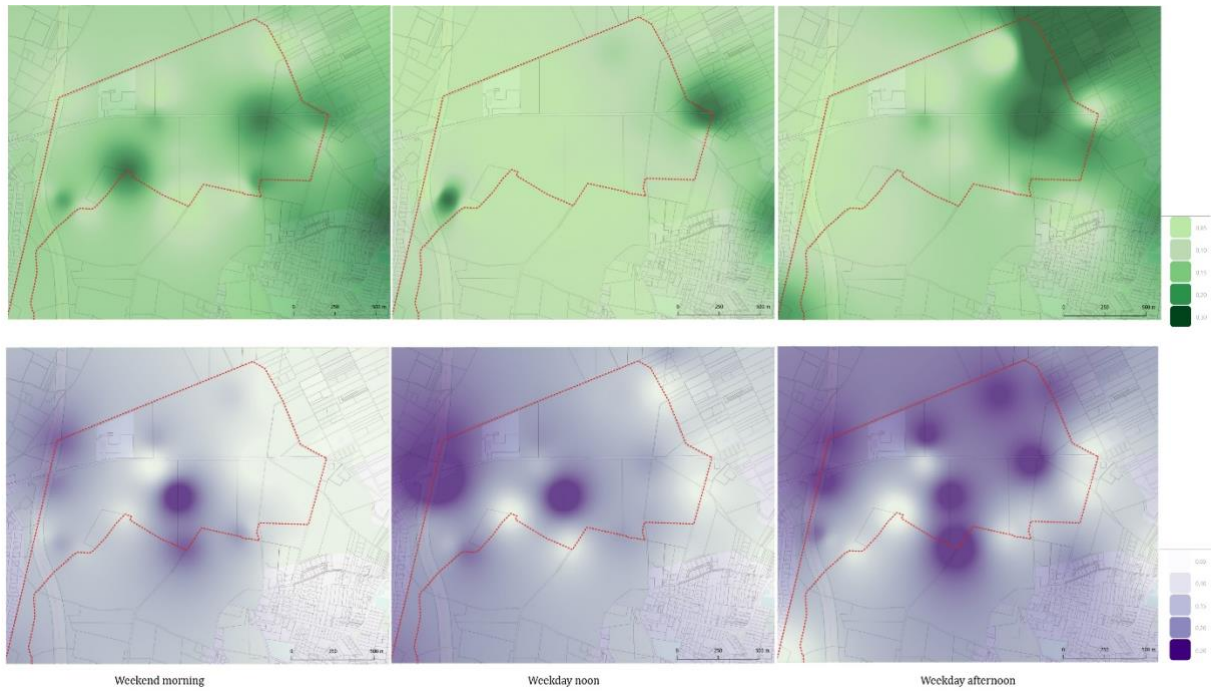


Figure 4: Maps of birds (green) and bugs (purple) audibility.

These maps reveal a systematic territorial division, at any time of the day, between the two types of animal sound sources: bird habitats seem to cluster at some distance to the road, i.e. to the east of the territory. In contrast, bugs seem to accommodate close road noises (figure 5): the food chain between these two soniferous biological groups provides a first explanation of this territorial division.



Figure 5: Maps of urban activity audibility.

As the surveys were carried out in fine weather, the bugs naturally congregated in the sunniest parts of the site, the forest bordering the road. Finally, the acoustic adaptation hypothesis (AAH hypothesis) points to an optimal acoustic niche for bugs: indeed, their stridulations seem to adapt better to road noise than birdsongs⁷... A number of functional ecology studies even confirm that locusts adjust the volume of their stridulation, particularly in the low-frequency part of their spectrum to adapt their communication when confronted with road noise⁸.

⁷ For birds, the Acoustic Adaptation Hypothesis (AAH) proposes that songs with lower frequencies, narrower frequency ranges and longer inter-element intervals occur more frequently in densely vegetated areas than in herbaceous habitats. See : (Boncoraglio, Saino, 2007).

⁸ For bugs, and locusts in particular, the ability to adapt acoustically to the surrounding environment is relative to their ability to modulate intra-species communication signals. See (Lampe et al., 2012; Lucas, 2019).

Ultimately, the explanation for this territorial partitioning between birds and bugs can certainly be explained these following three factors: food chain, sunlight and song emergence capability.

The evolution of the presence of sound sources over the course of the day confirms a strengthening of animal sources in the afternoon, which seems *a priori* counterintuitive: bird songs are usually louder at the start of the day. This finds its explanation in the simultaneous presence of bugs, their favorite food, strengthened in the afternoon by the more intense sunshine on the open ground near the road... Moreover, the increase in traffic noise in the afternoon (figure 5), while keeping bird populations away, does not affect the concentration of bugs.



Figure 6: Maps of the proxemics of human presence

Besides this, the anthropogenic territorial layout, divided between traffic noise and human presence (figure 6), confirms the relative absence of the latter. While bugs seem to adapt perfectly to traffic noise, they don't seem to enjoy human sound sources, particularly voices. At certain locations within *Le Taillan* forest site, when human presence is at a high level, Bugs remain silent (figures 4 and 6), regardless of the observation period. This fact was confirmed during our soundwalks, when bugs waited for a moment to start chirping again because our arrival at the observation point. Moreover, the impact of these anthropophonic sources does not seem to disturb birds... This could be explained by the dynamic sound structure of human voices which could be assimilated to a predatory sound manifestation for bugs. This is obviously not the case with road noise, which, despite its loudness, can be assimilated to band noise, i.e. white noise without modulation over time, excluding a possible assimilation to a predatory sound emission...

Conclusion : soundmaps for landscape planning ?

This technique allows us to illustrate the way sounds of nature are inserted into human environments - in this case, essentially mechanized - and to draw conclusions about the logic of urban - or landscape - planning. A first conclusion could concern reasoned mowing of roadsides, which takes on its full meaning here: indeed, the configuration we just observed seems to assimilate roadsides at the edge of forests with privileged natural biotopes for bugs. In fact, bugs are sonically protected by road noise, which keeps their main avian predators away. They seem perfectly able to adapt their stridulations to communicate with their congeners for feeding and, above all, reproduction purposes in circulated environments. Following those "ideal" conditions, roadsides seem to constitute natural reservoirs for stridulating bugs, insofar as wild flora and vegetation are neither treated with pesticides nor eliminated by humans...

Thus, soundscape is a reliable and explicit indicator of the co-evolution of biodiversity in resourcing areas. Soundscape analysis makes it possible to process vital information for the

anthropic reallocation of natural areas, which can be seen as the side effects of climate change, which is commonly “*silencing nature*”. This tool for spatial observation of the evolution of living sonic territories opens up the instrumental perspectives of a bio- and anthropophonic observatory on an urban scale, to detect the co-evolutionary factors of the ecological functioning of soundscapes, thus facing the effects of anthropogenic disturbances on the urban resourcing environments biodiversity.

Artificialization, climate change, light and noise pollution are just some examples of the threats that affects biodiversity in today's cities. By targeting several pilot sites in Bordeaux as experimental laboratories, the aim is twofold: to keep and raise citizens resourcing needs and to promote biodiversity by focusing solely on one taxon (avifauna). Annually monitoring an abundance indicator will allow us to draw a parallel between sound ambience and the assessment of animal species.

This research has demonstrated that the evaluation of sound sources presence is important to assess the weight of each species in the living space shared between humans and non-humans. Each family of sources' intrinsic richness is reflected in the diversity of sounds within each species, including birds and bugs. To explain certain phenomena, this type of information is crucial to evaluate the richness of the soundscapes we are listening to.

Furthermore, this research opens up the instrumental perspectives of a bio- and anthropological observatory. It is likely to detect the factors that influence the ecological evolution of soundscapes facing the environmental disturbances due to the anthropization of our landscapes.

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