SOUNDSCAPE: AN APPROACH TO RELY ON HUMAN PERCEPTION AND EXPERTISE IN THE POST-MODERN COMMUNITY NOISE ERA

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The term "Soundscape" seems like magic compared with standard measurement methods in community noise, since it considers people's minds as measuring instruments having the same relevance as "real" measurements. However, even in the 1970s, Murray Schafer's message about noise-abatement legislation brought awareness of the necessity and opportunity to consider not just noise alone, but also its perception by the experts who are affected by noise: those who live in the soundscapes—a term Schafer coined. He clearly stated, "early noise abatement legislation was selective and qualitative, contrasting with that of the modern era, which has begun to fix quantitative limits in decibels for all sounds…the study of noise legislation is interesting, not because anything is ever really accomplished by it, rather because it provides us with a concrete register of acoustic phobias and nuisances. Changes in legislation give us clues to changing attitudes and perceptions, and these are important for the accurate treatment of sound symbolism." [1]

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During the past 30 years, advances in policy development include the introduction of community-based environmental protection. This process makes the locally-affected community a major stakeholder in the crafting of effective public policy. The techniques of Soundscape are ideally suited for the development of community-based noise policy.

After consensus had been reached about the European Union (EU)-directive on environmental noise in 2002, there remain several major challenges to overcome:

(1) Presently, only the effects of a single noise source are assessed, while typically several sound sources are present simultaneously.
(2) Only mono-sensory sound perception is taken into account, while in reality other sensory qualities (e.g., visual or very low frequency vibrations) contribute.
(3) On the basis of the present standards, it is not yet possible to predict the effects of changes in the urban soundscape—difficult because data are only valid for "steady-state" conditions.
(4) It will become necessary to make generalizations—but there are very substantial differences in context.
(5) Presently, noise mapping is state of the art—but what is really needed is some form of annoyance mapping.

For more than ten years the multidisciplinary approach has been applied to the study of community noise to explain people's reaction to noise, including context related evaluation. The context-bounded approach was the crucial step to reach the definition of "Soundscape," using its fundamental knowledge and procedures.

The soundscape approach provides a method to develop acoustical indicators and parameters into a database that describes urban and other outdoor living areas with respect to their physical conditions and their relevance for life. Those parameters will reliably allow the measurement of outdoor sound quality, which will take into consideration not only the sound pressure but also the characteristics of the sounds which lead to specific human reactions, both positive and negative: calmness, inspiration, annoyance, discontentment, anxiety, etc. as well as the pathogenic effects. Emission and immission measurements must be performed to document the physical conditions of the examined living area. In particular, the contribution of important sources like traffic noise to the overall sound exposure and its influence on the evaluations by residents must be determined. Moreover, the question is, to which degree does a single source determine the soundscape of the environment with respect to perception and evaluation? Therefore, diverse boundary conditions should be taken into account to reflect adequately the circumstances of everyday life.

The application of Soundscape in community noise is rapidly evolving, and has been discussed at numerous recent conferences within the Acoustical Society of America (ASA), and at a workshop on methods for community noise and annoyance evaluation held at the149th

ASA meeting in Vancouver, Canada on May 16, 2005. Areas identified for further development at this workshop included: economics/noise policy-standards, combined effects, common protocols/cross cultural studies and education about soundscape. Other areas identified include: improve combined measurement procedures: qualitative and quantitative parameters—including the character of sounds and cross-cultural questionnaires. The importance of survey site selection was emphasized. The combined soundscape approach requires that physical noise criteria match qualitative descriptors. There is a need to correlate complaint language with metrics for policy, and to introduce the qualitative methods of psychology and sociology to engineering analysis, combining quantitative and qualitative tools for land use planning. Soundscape analysis should place sound in context, with noise and sound linked to activity at realistic study sites. We must distinguish the totality of soundscape from the limited idea of a *quiet zone*. The connection between research and design for communities is a creative process. To complete this connection we need methods to: measure and identify design values, develop a lexicon of qualities/values for soundscape design, investigate a subject's control/non-control over the environment, understand the motivation of people to choose a particular environment, and create soundscape simulations of proposed sites for evaluation by officials and the public. Continuing soundscape research should provide practical data that can be applied by designers to create pleasing acoustical environments.

This article describes a range of measures and solutions needed to identify an integrated model to design/improve soundscapes and enhance urban planning concepts. Of course, we are aware that these are early steps and scientific and applied work is still to be done.[2]

Community noise assessment is an increasingly important means by which to improve the quality of modern life, particularly in urban outdoor settings. The effects that community noise has on residents, businesses and other stakeholders must be assessed accurately to create the political and cultural climate needed to positively affect the environmental soundscapes. This climate includes an effective policy structure which recognizes the impacts of sound on the community, planning, and design principles which can be applied to specific projects and settings.

Soundscape analysis combines the physical measurement of sound with a scientific investigation and evaluation of the community perception of sound. The methods of soundscape analysis can provide the practical tools for achieving beneficial results in outdoor sound quality through the application of thoughtful community noise policy, environmental planning, and design.[3–6]

Combining physical, psychoacoustical, and perceptual measurements

In the context of community noise, there is a common consent about the necessity of additional parameters beside the A-weighted sound pressure level (SPL). The A-weighted and energy-equivalent Intensity Level (IL) and loudness measurements are not sufficient for understanding human perception or for adequate description of an urban soundscape. Essentially, the introduction of new parameters, the more sophisticated use of existing parameters, and a *merged* approach from different measurement procedures appear to be inevitable.

Physical and psychoacoustical measurements

The physical measurement of relevant acoustical parameters in an outdoor setting is a requisite first step in evaluating that environment. These methods of measurement and analysis are becoming increasingly sophisticated. They range from the simple measurement of overall A-weighted level samples, time histories, statistical and spectral analyses, through the compilation of time-variant Zwicker loudness tableaus and further psychoacoustic evaluation and analysis.

Therefore, psychoacoustic parameters should be applied to measure and assess environmental sound more properly. With the help of psychoacoustic parameters that are mainly based on standardized procedures of measurement and analysis, it may be possible to explain why some environmental sound sources are more annoying—or pleasing—than others.

Relating human hearing and objective measurement

Human hearing differs in many fascinating (and sometimes frustrating) ways from conventional acoustic measurement devices and processes. It is spatially- and pattern-sensitive, easily detecting small changes in its sonic "surroundings" in any combination of level, location (including movement), time or frequency. A physically small source in a context of sounds coming from many directions can dominate attention by fluctuating and/or moving, even though its power contribution is a small fraction of the whole.[7] Consider the visual analogy of driving at dusk and distinctly noting the flashing LED taillight of a bicycle in the moderate distance—a pattern drawing your attention—and its significance (a "human weighting"). Were the light not flashing, the chances are that you would not have noticed it until getting much closer. Even in low dusk, its energy contribution to the scene is tiny, yet it is readily recognized. Such fluent and situation-dependent signal processing and weighting by the "human measuring system" challenges the selection of appropriate technical methods to quantify sound situations and their objective significance in soundscapes.

Some options for matching measurements with perceptions include levels and spectra *versus time*, rather than overall A-weighted L_{eq}, which are valuable in soundscape measurement. Note, L_{eq} is not representative of the subjective impression and contextual evaluation.

Psychoacoustic measures versus time—loudness, sharpness (essentially the ratio of high-frequency loudness to overall loudness), roughness (quick fluctuation), fluctuation strength (slow fluctuation) and others, overall and versus frequency, generally represent subjective auditory evaluations better than conventional level-based measurements.

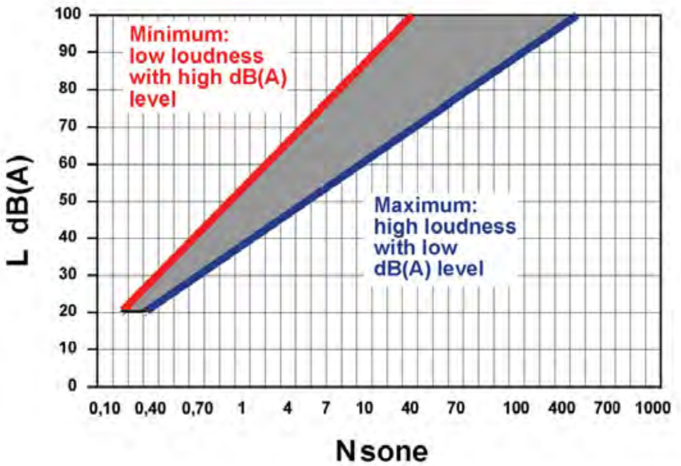

Fig. 1. Possible relationships linking sound pressure level (vertical, dB(A)) to psychoacoustic loudness (horizontal, the linear measure Sone) depend on spectral shape (there is no single rule). The inner ear, assigning frequencies to locations of hair-cell excitation along a physical structure (much different than the way a microphone works), responds as loudness to the total area being excited. For example, tonal centers close together have merged excitation areas and generate lower loudness than tonal centers more separated in frequency, for the same sound pressure level. Another major factor in loudness sensation: for constant sound pressure level vs. frequency, loudness is much higher (approximately double)—around 4 kHz due to a strong acoustic resonance of the outer ear near the ear canal entrance.

Perceptual measurements

The key to understanding, and ultimately to applying these physical measurements, is an evaluation of the perceptual effects induced by the various magnitudes of those specific physical and psychoacoustic parameters.[8] Since soundscapes have to be considered as two-component environments, comprising certain sound sources as well as the way people feel about those sounds contributing to the identity of those residential areas, these essential "human weighting" effects may be analyzed through the use of scientifically-developed interviews, questionnaires and other means to determine the frank and honest appraisal by community members of their sound environment.[4] Only through the accurate evaluation of this cause-and-effect relationship may successful strategies be developed and implemented. It is important to recognize that among varying soundscape types the relationship between physical and perceptual parameters will have similarities, but the relationship will also have unique properties tied to each specific community and living context, related to socio-economic background and specific lifestyle.

For example, the contextual conditions are important when people are evaluating noise annoyance. The combination of methods with different sensibilities for subjects' work during a process of perceiving, describing and/or evaluating noise in such an environment is necessary for a reliable and valid analysis and interpretation of data.

Another aspect is that the annoyance of exposed individuals rises with increasing traffic density. In a situation with low traffic density, single noise events stand out. This results in a high level of annoyance although the L_{eq} is low. These parameters must be adequately considered in measurements. The broad approach using acoustical diaries and both indoor and outdoor measurements guarantees the identification of the relevant indicators that have an essential impact on the perception and evaluation of environmental noise.[9,10]

"Soundscaping"—Combined soundscape analysis technique

"Acoustic coloration" from the environmental sound sources carries information that may either block or stimulate human activities, thoughts, and feelings. Therefore, soundscape evaluation will include acoustical as well as other sensory, aesthetic, geographic, social, psychological, and cultural modalities in the context of human activity. The aim is to get access to the social, psychological, and cultural conditions that are important to determine a particular individual's and/or collective behavior, attitudes, and emotions relative to the given noise under scrutiny.

In daily life, parameters and phenomena enter into interrelation and interaction that can be investigated with regard to their acoustic-ecological, psycho-acoustic, socio-acoustic ascription. Detailed analysis of the typology, morphology, and topology of potential test sites must include, criteria like land use and function, urban fabric and its state or condition, qualities of private, semi-private and public zones, analysis of neighborhoods in terms of architectural shape and scale, specific issues of any existing site development strategies, and specific features related to the site, i.e. differentiating patterns and situations.

Soundscapes are defined with respect to their scope. This can be done by sound walks that are participatory sound and listening walks with respect to the acoustical, visual, aesthetic, geographic, social, and cultural modalities.

Data collection—Short term

A brief demonstration of the combined soundscape analysis technique ("Soundscaping") was given at the 151st Meeting of the Acoustical Society of America, in Providence, Rhode Island, June 2006.[11] During a walk in the urban area near the meeting hotel, physical sound measurements and perceptual interviews were conducted at two downtown locations. Both of these locations were close to office and shopping destinations.

One location is known as the "Riverwalk." This riverside area is popular with residents of the city and the surrounding communities for its attractive setting and for its famous Saturday night event "Waterfire," which is held throughout the summer months. In this event, fires are built and displayed in a series of metal stanchions placed in the river and the surrounding plazas are alive with music, food and other entertainment.

Measurement and interviews

For this soundscaping demonstration, measurements and interviews were conducted during an afternoon of fair weather, while the Riverwalk Plaza was busy with lunch hour pedestrian traffic (see Fig. 2). Although the sound level in dB (A) was consistently in the mid 60's, with higher excursions due to nearby construction activity, the reaction of pedestrians to the sound was universally positive. This was primarily due to their positive personal associations for the area with the enjoyable "Waterfire" activities.

The soundscape analysis of the second location, the large lawn between the Rhode Island State House and the Train Station, yielded similar results (see Figs. 3-7). Again, despite the relatively high incursions of noise from passing vehicles, particularly city buses, the area was well-liked by community members for its attractive expanses of greenery and dignified buildings.

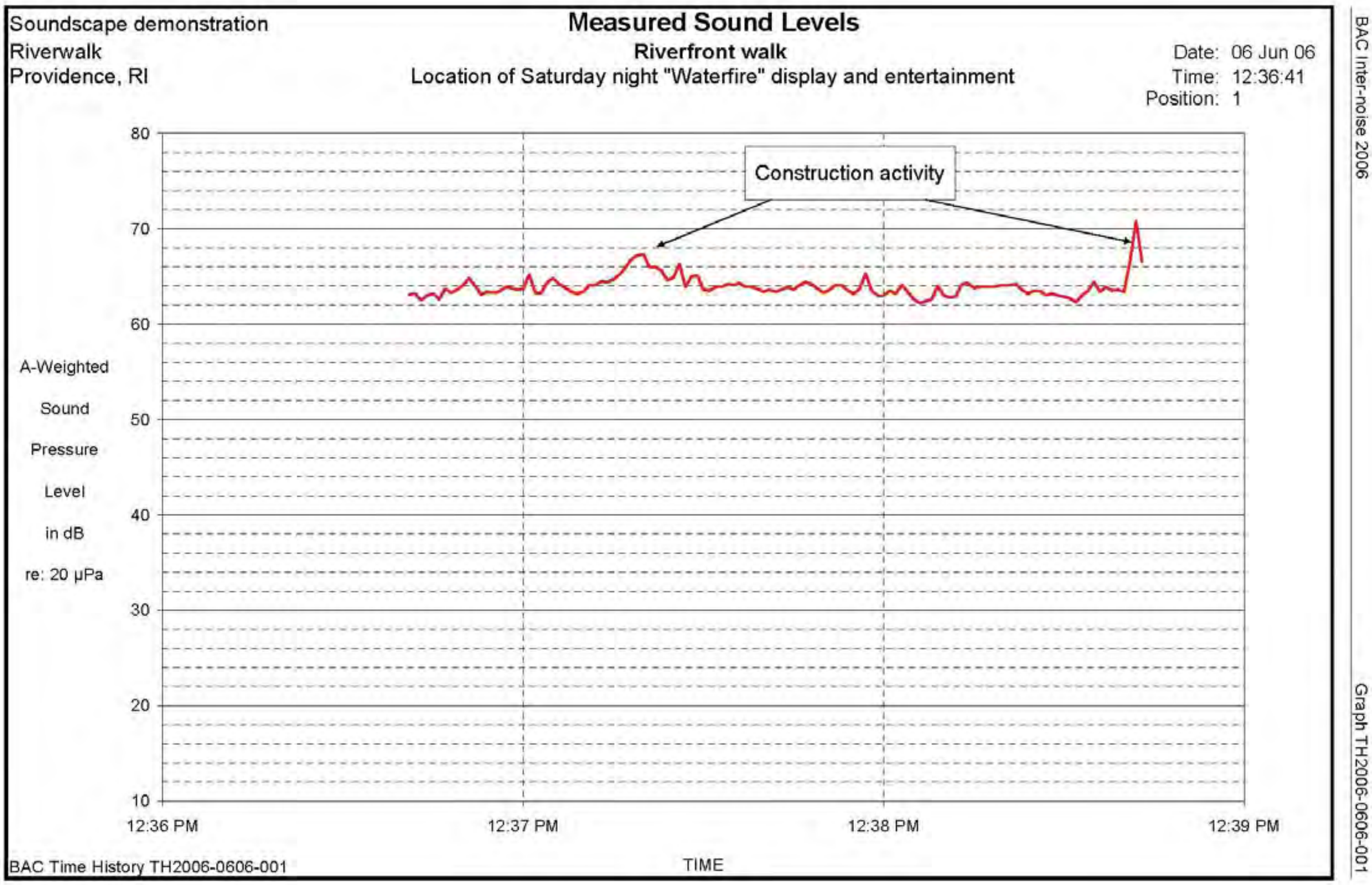

Fig. 2. Riverfront walk

Photos: Riverfront walk

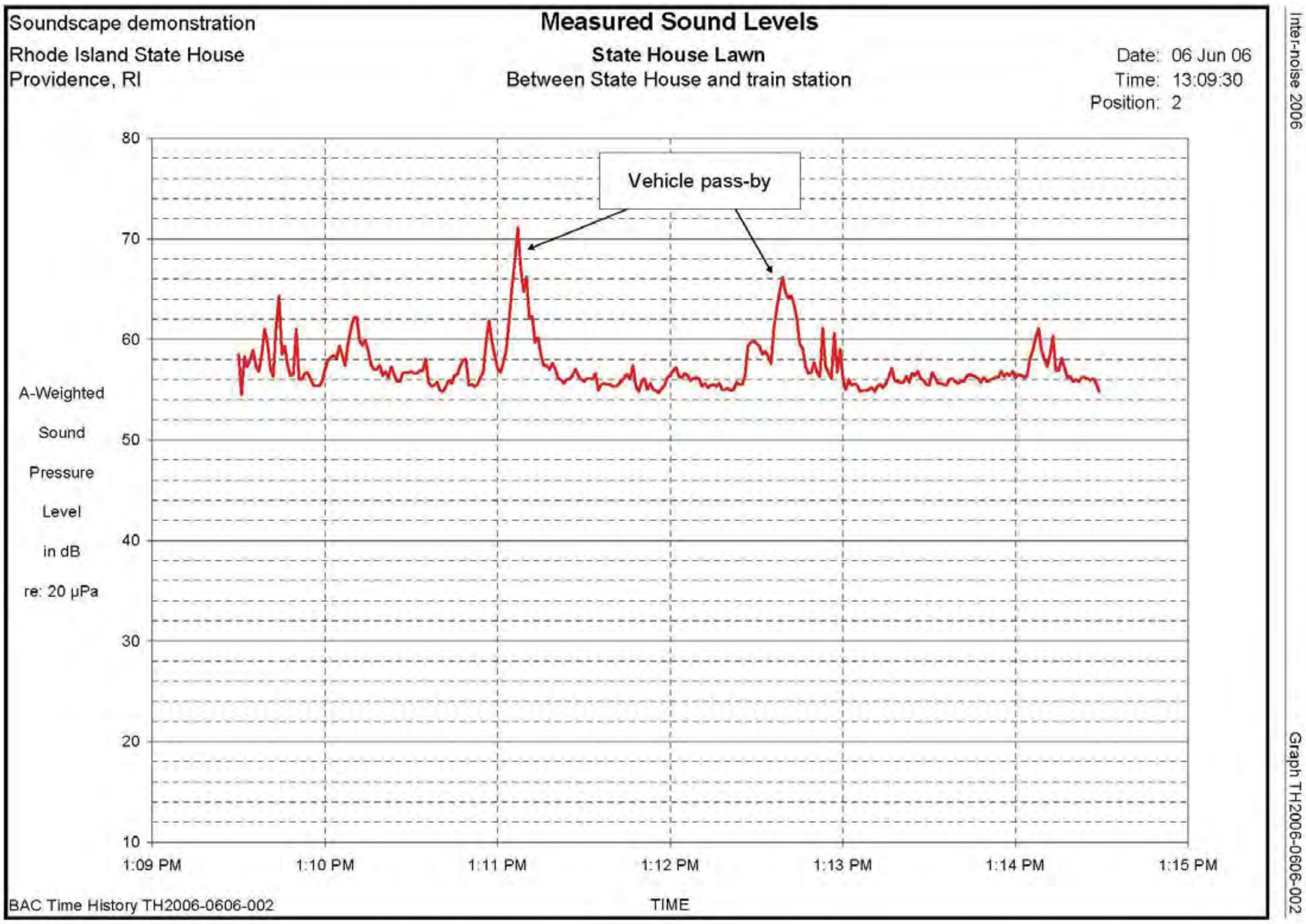

Figure 3: State House lawn and Train Station

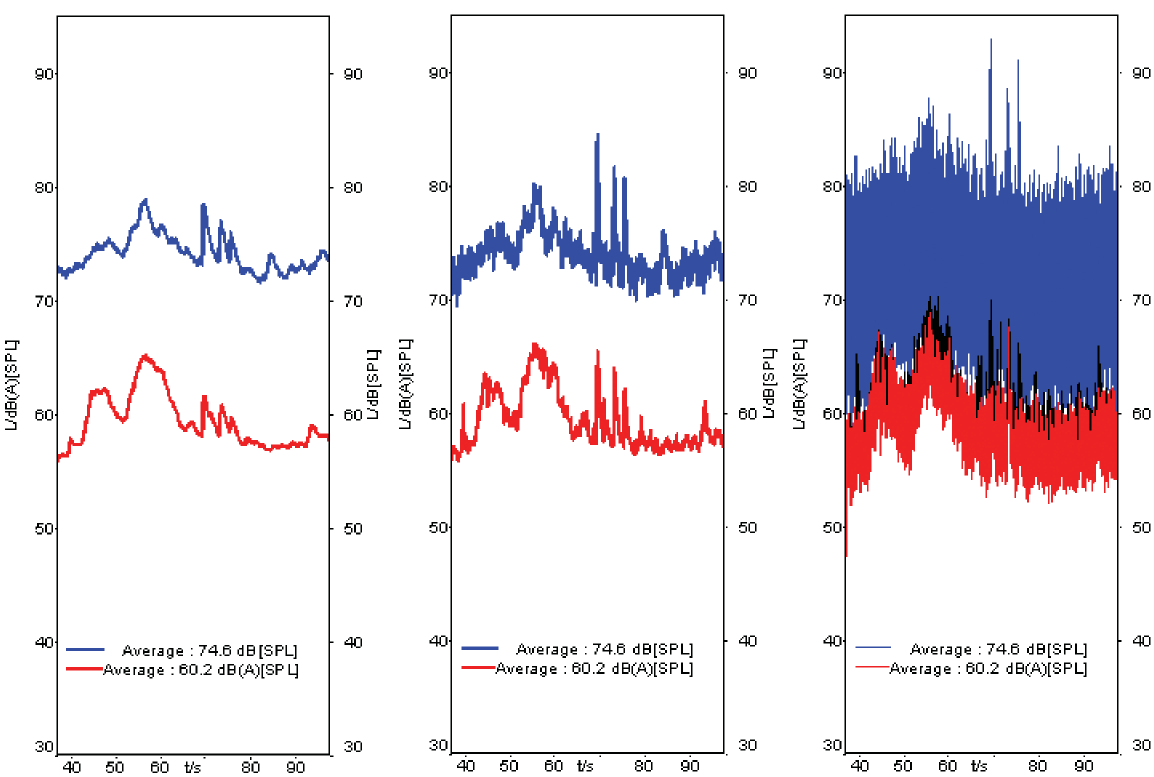

Fig. 4. Halfway up the State House lawn, "looking" toward the Train Station, a bus pass event between approximately 1:12 p.m. and 1:13 p.m. Level vs. time over about 65 seconds, left ear of artificial head, unweighted (blue) and A-weighted (red). The time resolution of measurements can be important. Left: Slow time weighting (1-second integration). Middle: Fast weighting (125 ms). Right: 2 ms, similar to human auditory integration time for short-duration events. The average values are also given. The three peaks to the right of the bus event are due to a pile driver several blocks away.

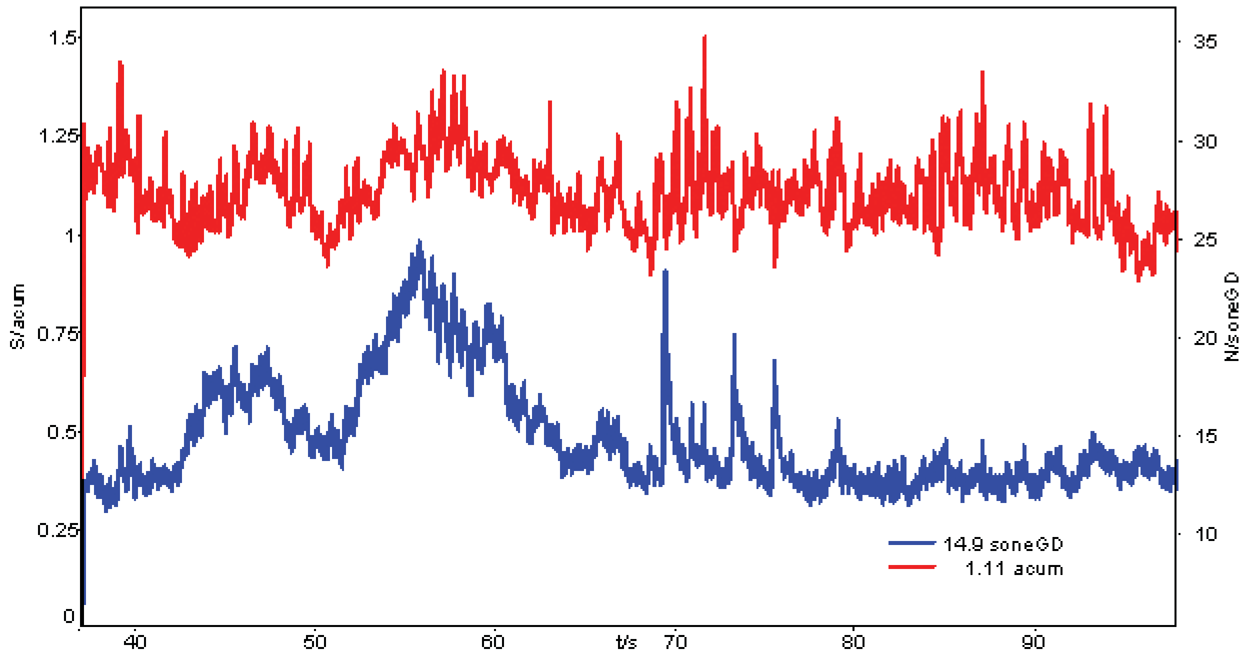

Fig. 5. Same data, psychoacoustic measures: overall loudness vs. time in the unit Sone (blue, right scale) and sharpness vs. time in acum (red, left scale). As the bus passed, its engine fan noise was rapidly masked and unmasked by parked cars and the spaces between them, producing a rhythmic whooshing sound.

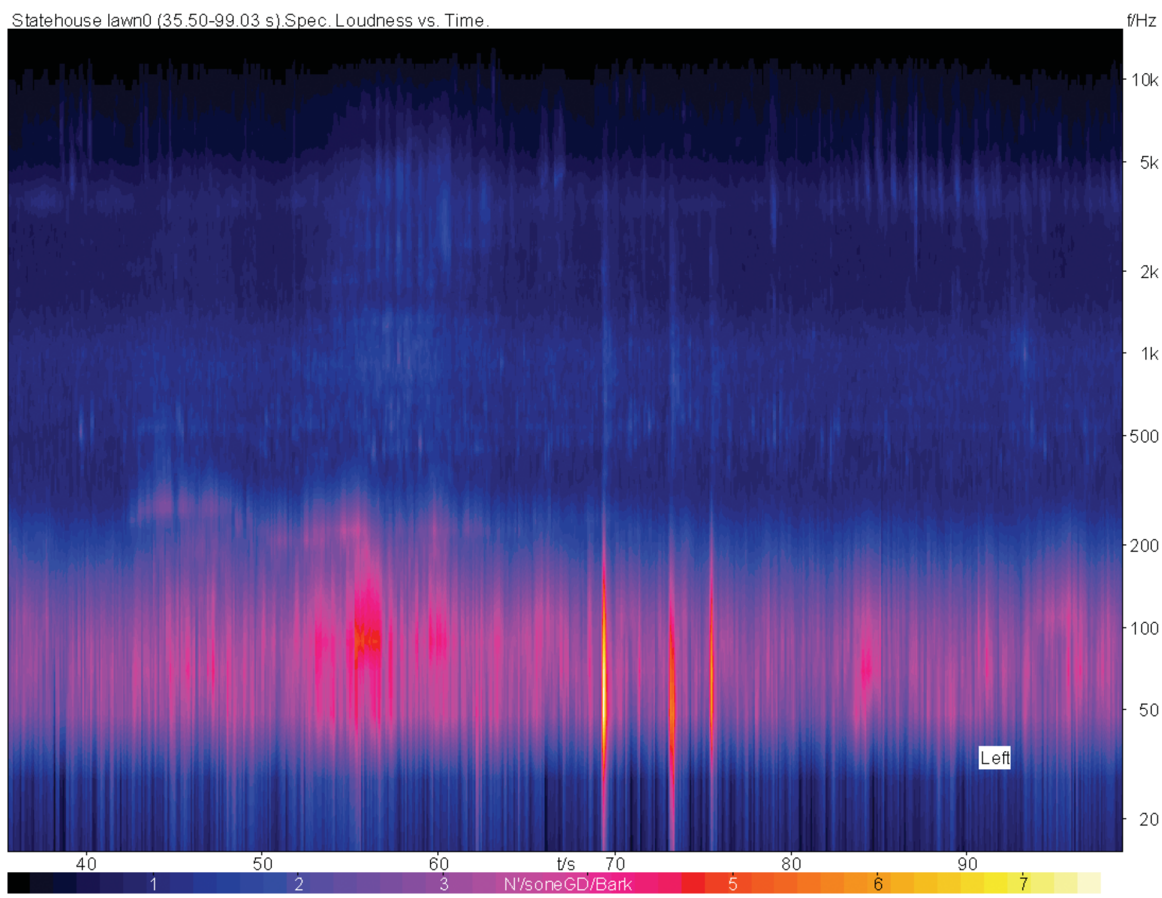

Fig. 6. Specific loudness (spectrum of loudness) vs. time. The vertical axis represents frequency and the color scale represents loudness. Note that the highest loudness occurred roughly between 30 and 300 Hz, and that the region around 4 kHz has a higher loudness than at nearby frequencies. The ear discriminates by frequency and can often detect simultaneously a relatively low-loudness event at a different frequency than a higher-loudness event. Specific loudness vs. time can show this, in cases where overall loudness measurement masks the effect.

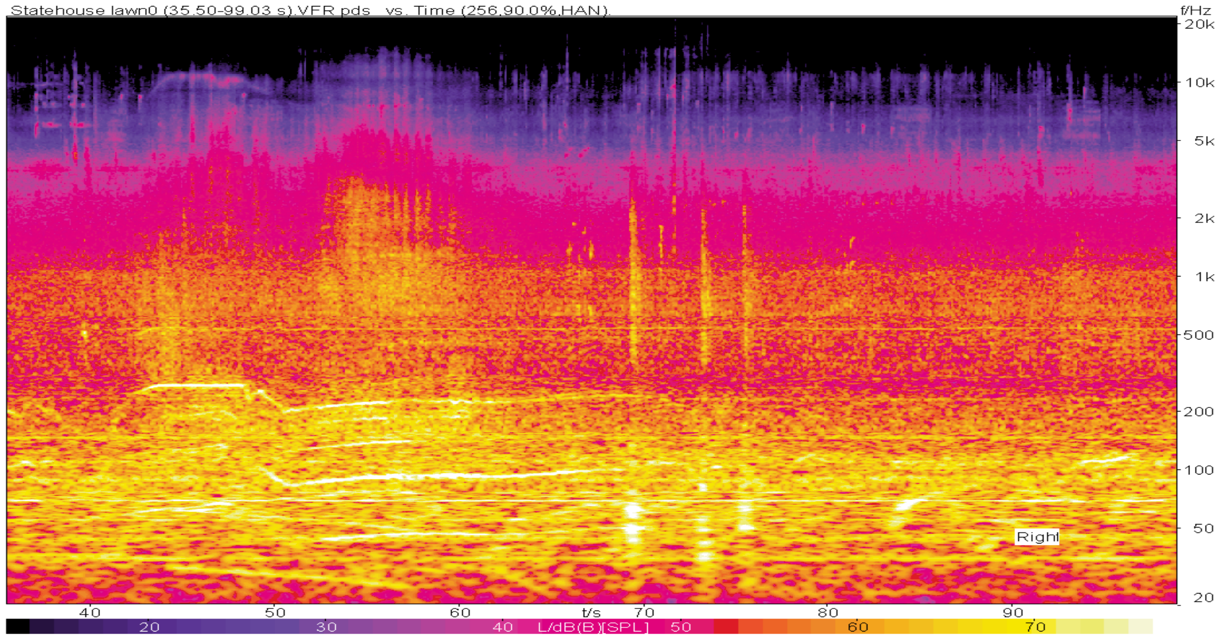

Fig. 7. Human hearing discriminates low-frequency tones, such as the engine orders of the passing bus. In addition to the psychoacoustic and level-based measures, a spectrum vs. time measurement with good frequency resolution at low frequencies, such as this variable-frequency-resolution (VFR) analysis, proves useful. The vertical axis is frequency and the color axis represents sound pressure level in B-weighted dB.

Data collection—Long term

Soundscaping may be undertaken as a complete study with long-term, detailed measurements of physical acoustical parameters, and comprehensive attitudinal surveys. Brief preliminary results may be obtained through the use of local police or other public workers, who are assigned to obtain short sound level samples and activity observations, along with personal assessments, during their normal daily rounds in the community.[3,6] A typical form for this type of preliminary survey is shown below.

The "Soundscape Approach," understood as a qualitative-quantitative methodology, has been applied recently in several field studies. Empirically, the perception of sounds and their evaluation were explored under the premise of combining human judgment and physical factors. In those field studies, the environmental noise perception and evaluation in a defined urban area were investigated in detail. For that reason, open, narrative, but issue-centred interviews with residents were carried out, and those interviews allowed the interviewed persons to set their own focus on certain aspects. The interviews are the basis for the subject-centered categorization.[2–6,9]

The qualitative data analysis shows that the sound evaluations depend on the social and cultural structures in which the individual is embedded. Therefore, the socio-cultural frame of reference, which the sound-exposed per-

Jamestown Police Department **Sound Pressure Level Survey**

A Location	B Date	C Time	D Base - SPL	E Description - Sound Event	F Event - SPL	G General weather conditions/ Other Special Conditions	H Officer's Initials
BEAVER TAIL POINT	3/15	0558	39.5	NONE –	—	CLOUDY, COLD, SLIGHT WIND	WD
CLARKES VILLAGE	"	0607	39.1	FLOCK OF SEAGULLS	51.5	"	"
BEAVER TAIL @ HULL COVE FARM RD	"	0612	39.5	COMM. AIRLINER FLYING OVERHEAD	55.3	"	"
BONNET VIEW DRIVE	"	0618	39.3	NONE	—	"	"
B'TAIL @ FORT GETTY RD	"	0622	38.8	"	—	"	"
FT GETTY CAMPGROUND	"	0626	38.5	"	—	"	"
HAMILTON @ SOUTHWEST AVE	"	0632	41.7	SOUND OF WAVES @ MACKEREL COVE	67.9 PICKUP TRUCK	"	"
HAMILTON @ HOWLAND AVE	"	0636	40.6	CROWS / BIRDS	50.6	"	"

son uses automatically as a criterion for orientation and evaluation, must be explored in detail. Especially, a collective feeling of identity has a major impact on the expectancies and claims people have concerning their sound environment.[3–10]

Summary

The combination of physical and psycho-acoustical measurements with scientific evaluation of perceptual responses to environmental noise, known as Soundscaping, is an essential method for assessing and actualizing environments. Determining the properties of the soundscape which lead to specific human emotions (e.g. calmness, annoyance, discontentment, anxiety, etc., besides the pathogenic effects) will go far beyond measuring the sound pressure alone. For those reasons, different types of data (qualitative and quantitative) must be compared and combined. Interviews with exposed people will highlight the data acquisition to consider all the objective and subjective dimensions that are relevant in the context of soundscapes.

Therefore, diverse boundary conditions have to be taken into account to reflect adequately the circumstances of everyday life. By means of the newly-defined parameters, it will be possible to propose a range of measures and solutions that can be integrated in models for improving urban soundscapes and urban planning concepts.

One more remark

During the past 10 years in "Soundscape and Community Noise" there has been much research done and knowledge gained about sonic environments related to daily life and lifestyle. But, as Mike Stinson pointed out in his recent overview on noise in *Acoustics Today*, Vol. 2, July 2006: "We're not done yet!"

As we seek to develop and refine the methods of Soundscaping further the following actions are needed:

- Cataloging correlations between physical parameters and perceptual responses
- Standardizing a terminology lexicon of soundscape descriptors
- Standardizing measurement procedures
- Listing recommendations for perceptual evaluation and analysis
- Setting up an international working group on Soundscapes **AT**

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