# EFFECTS OF VEGETATION ON HUMAN RESPONSE TO SOUND

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Trees and shrubs not only beautify our cities, but also can reduce unwanted sounds of traffic and other sources in residential areas, schools, and workplaces. This is an important benefit because environmental noise has a significant effect on the quality of life, even when the noise is not severe enough to induce medical or psychological symptoms in people exposed to it.

Vegetation affects what city residents see as well as what they hear. Research has shown that the visual and acoustic aspects of urban vegetation may interact to alter the perception and evaluation of sound in urban settings (Mulligan et al. 1982). For example, people sometimes report that noise is reduced by thin planting strips and even hedges that are simply too sparse to have much physical impact on sound transmission. Psychological factors, having to do with how we perceive our environment, must explain why a narrow planting strip or hedge is prized as a screen against noise, when it actually has little or no humanly detectable effect on sound transmission. This paper provides two overviews, first of findings on the physical abatement of noise with vegetation, and second on several studies we recently completed concerning the influence of vegetation on perception and evaluation of noise.

### Physical Aspects of Noise Abatement with Vegetation

Researchers have studied the ways sound transmission is altered by vegetation since World War II.[1] To summarize briefly the results of the studies, it has been demonstrated that cities need wide planting strips near the sound source to effectively abate traffic noise. Abatement is achieved by a combination of forest elements. First, a soft forest floor reduces the intensity of low frequency sound by absorbing its energy (Aylor, 1972). Second, leaves and stems help to reduce noise levels by scattering high frequency sound waves (Aylor, 1971).

Acoustic researchers emphasize, however, that substantially more than a single row of street trees is needed to significantly reduce noise pollution. Trees and shrubs must be planted in dense stands at least 5 meters (16 feet) wide, to affect appreciably the transmission of sound (Cook, 1980). Where there is too little land area for a wide planting strip, constructed barriers, perhaps beautified with trees and shrubs, can provide noise relief.

Constructed barriers are combined with vegetation to produce visually attractive, acoustically effective noise abatement. Vegetation relieves the harsh and monotonous effect of constructed noise barriers along traffic corridors, while the barriers themselves provide relief from traffic noise for residents adjacent to the corridor. In a few cases constructed barriers have actually made problems worse, by increasing the noise levels they were supposed to reduce (Allen and Dickinson, 1977). Trees at the crest of an earthen barrier may scatter high frequency sounds down into the protected area behind the barrier (Lyon et al., 1977). The solution may be to plant deciduous trees on the source side of the barrier, and short-leafed conifers on the top.

There is much to learn about the physics of sound transmission through vegetation and the best ways to combine vegetation and other materials to alleviate noise pollution. While some researchers continue to study the effects of trees and shrubs on sound transmission, others have addressed the effects of vegetation on human response to sound. The psychology of noise abatement is fundamental to the study of noise pollution, because it is people who decide what sound levels and types constitute noise.

[1] Gordon Heisler summarized the practical implications of much of this work for J. Arboric. 3: 201-207 in 1977.

## Psychological Aspects of Noise Abatement with Vegetation

The interplay between visual and acoustic characteristics of vegetation in the urban setting may be important in determining human response to noise in cities. Aylor and Marks (1976) showed that if a sound source was completely screened from view, its noise was described as *louder* than when the source was either partially or completely visible. The noise was described as even louder if the observer was blindfolded, although the sound intensity at the observer's ears was the same in all cases.

An explanation of this paradox lies in the fact that people's past experience and expectations affect their perception of current information. People learn that the intensity of a sound is reduced by obstacles, and by distance away from the sound source. When a screen blocks the observer's view of the sound source, the observer expects the sound to be of lower intensity. This expected drop in intensity could be due to a possible increase in distance of the source behind the screen, or to the obstacle of the screen itself. What happens if the screened source is just as loud as the unscreened source? The observer may then report that the screened source is *louder*, as it would have to be if the source were further away or if the screens involved were truly effective in reducing noise levels.

Sometimes people experience noise "reduction" from vegetative screens that have little detectable influence on actual sound intensity. Here the listeners may be responding to their expectation that the screen is effective, and so attribute noise reduction to the screen when it is really due only to distance. Physical intensity of sound falls off rapidly with distance, decreasing fastest nearest the source. Traffic noise intensity on the inside of a hedge, compared to the street side, may be noticeably reduced, but the difference is due to the observer's moving further from the traffic, not to any noise absorption or refraction by the hedge. Thin planting strips and hedges provide other real advantages when placed between street and yard, of course, but their acoustic influence is minimal.

## Some Experiments on the Psychology of Sounds Outdoors

**Loudness.** In studies conducted since 1978, we found additional evidence that visual and acoustic characteristics of settings interact to influence people's responses to noise. We were trying experimentally to determine whether noxious effects of noise on people might be somewhat relieved by the visual improvement vegetation brings to cities. If stress is reduced in pleasant, landscaped settings, compared to harsh or ugly settings, then perhaps people will find noise less obnoxious in the more desirable settings.

Our studies to demonstrate this phenomenon did not succeed — in fact, we found that the perceived loudness of sounds tended to *increase* as the amount of vegetation visible in the sites increased. Briefly, our investigations tested the perceived intensity or loudness of pure tones at different locations around Athens, Georgia. The locations ranged from a completely wooded area (Figure 1) to a downtown street devoid of vegetation (Figure 2). Intermediate sites contained mixtures of vegetation and man-made structures, generally representing outdoor plazas, landscaped gardens, and urban parks. We presented pure tones through headphones to 100 college students, all with good hearing. The tones varied in amplitude identically at each location. At first the tones were presented against only the background sounds normally heard at each of the five sites. Later, we broadcast a tape of the sounds heard at the noisiest of the five sites, the downtown street, to equalize the intensity of the backround noise levels at all five places. The results indicated that the observers experienced the tones as louder at the more vegetated sites than another sample of students tested in our lab, or at the unvegetated downtown street site. Results were similar regardless of background sound levels at the sites.

Like the visual screen effect, the visual influence of vegetation on loudness also may be due to experience. People learn to expect reduced sound levels in more vegetated setttings, at least compared to highly developed urban settings. The expectation that a city street will be noisy leads people to use a lower standard to

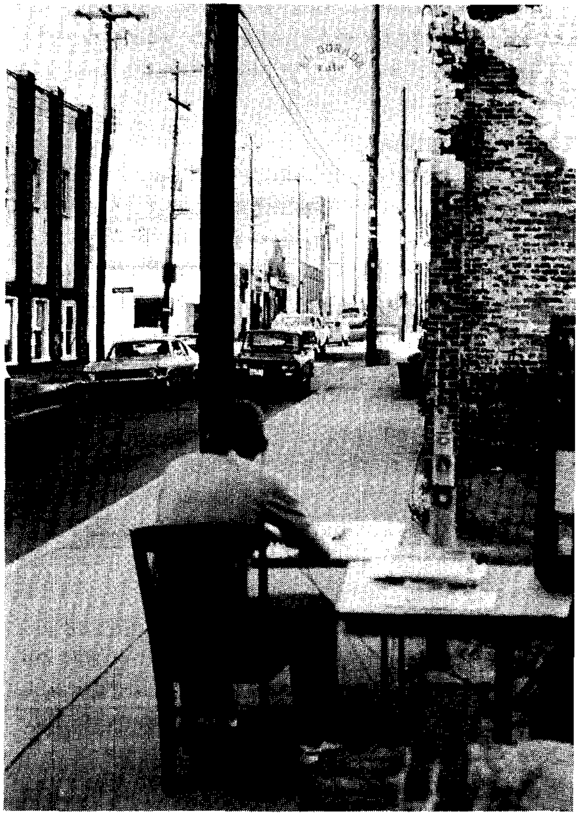

**Figure 1. A student participates in the sound evaluation study at the downtown street location. Downtown sites are not enhanced by natural sounds, but mechanical and traffic sounds don't detract much from them either. The presence or absence of street trees has little influence on people's response to sound downtown, despite their strong impact on the visual quality of the street.**

**Figure 2. The participant's view at the completely wooded testing site. In such sites traffic and other mechanical sounds have strong detrimental impacts, while natural sounds are enhancing. Similar results obtained for residential and urban park settings, where sounds of children and pets are more tolerated as well.**

judge sounds heard there, and so the sounds are not found to be as loud. Conversely, the expectation that wooded areas will be quiet leads people to use more stringent criteria to evaluate sounds heard there, and the same sounds are judged louder.

**Environmental Quality.** Does this mean that planting trees on a noisy urban street will make people's experience in that setting worse than if the trees were not planted at all? The answer lies in the fact that trees have many effects on people besides influencing their perception of loudness. We looked at some of these issues in subsequent studies. We asked our student participants about the influence of different kinds of sounds on the overall quality of the different Athens locations. The results of the second phase indicated that the *acoustic* quality of a city street is not much affected by trees; however, the students indicated that the *visual* quality of the site was improved significantly by the presence of trees.

In this second phase, we asked observers at the five Athens locations how some common sounds affected the locations' overall quality. The sounds were selected from sound effects recordings, and were played to the student observers at each site through headphones. As expected, natural sounds, such as those of birds, insects, and wind, enhanced the wooded setting, while mechanical sounds detracted strongly from it. The sounds of children and pets also detracted somewhat from the completely wooded setting.

At the downtown site most sounds were rated neutrally: the natural sounds did not enhance nor did the mechanical and engine sounds detract to a great extent. In fact, most of the students rated traffic sounds at the downtown location as somewhat enhancing.

When we tested some additional settings, we found that responses to the 18 sounds on a tree-lined downtown street were similar to those for the treeless downtown scene used in the first study. Apparently noise is tolerated as part of the downtown setting, and the presence of trees does not make any existing noise problems worse. In this study we also asked about the visual quality of the sites, and here the downtown trees had a strong enhancing effect. For residential settings we found the evaluations to be similar to those for the completely wooded site, except that children and pets were better tolerated in the neighborhood scenes than in the woods (Anderson et al., 1983).

These results further implicate expectations about the different environments. Traffic is more common on a city street; birds and insects are not often heard there. People expect quiet in a forest, not jets, traffic, construction, children, and pets. Children and pets are characteristic of human habitations, and sounds made by them were better tolerated at sites like residential areas. With the exception of children and pets, we found that responses to sounds in urban residential areas and parks closely resembled the responses to the sounds at the forest site.

While the traffic sounds used in these studies were found to be slightly enhancing to the downtown environment, they were not the sounds of a large number of vehicles, nor was their volume high. Other studies of urban acoustics (such as Southworth, 1969) indicate that some sounds, including traffic, may be enhancing if heard from a distance or at low intensity. However, intense downtown traffic is widely regarded as a severe source of noise pollution for urban residents.

There are other effects that different settings may have on how people respond to noise. Social science researchers are beginning to examine how setting characteristics such as landscaping might affect some of the bodily symptoms of stress (Ulrich, 1981).

**Summary**

Vegetation influences both the physical properties of sounds and the ways in which people perceive, evaluate, and respond to sound in different urban settings. Vegetation significantly affects people's expectations about the acoustic quality of the environment — they expect lower levels of sound in vegetated settings, whether these are natural areas or city neighborhoods. People's evaluations of particular sources of noise pollution, such as traffic, are also modified by what they expect to hear in a given setting. Greater tolerance of noise is shown when the sounds are expected. Finally, our studies indicate that vegetation makes a considerable difference in people's evaluation of an urban setting, by substantially improving perceived visual quality, and in many settings, expected acoustic quality as well.

**Recommendations**

Municipal budgets for urban forestry programs are never so large that effort can be wasted. Where there is sufficient land area for an effective vegetative noise barrier — that is, a strip at least 16 feet wide — the urban forester and the planting designer should follow the recommendations from physical abatement research, such as those outlined in Heisler (1977) and in Cook and van Haverbeke (1971, reprinted in Grey and Deneke, 1979) to obtain the most relief. As in most forestry applications, noise reduction benefits may not be fully realized until the planting matures. The urban forester may find it helpful to adivse his clients in advance of this delay in benefits. Also in common with other urban forestry applications, the preservation of existing vegetation which can be incorporated into a screen will provide benefits sooner than replacing existing trees with new stock.

In many urban settings there is neither enough spare land for a wide planting strip, nor enough money for a constructed noise barrier, with or without vegetative adornment. While a vegetative screen cannot be recommended for noise control in such instances, the other benefits, including visual quality improvement, screening of undesired views, enhancement of privacy and wind control, may make the screen a worthwhile investment. Other characteristics of the setting will determine whether these additional benefits compensate for inadequate noise buffering — is the site a residential or commercial area? is it used for recreation or for work activities? are people in the area for any length of time or only for a few moments on their way between buildings? is the area already attractively landscaped, or would some plantings really enhance its appearance? is wind a problem during part of the year? This research indicates that the visual attributes of a setting are more important than its characteristic acoustic quality in determining a person's overall evaluation of the site. Thus the visual benefit of a vegetative screen can in many cases compensate for its inadequacy as a noise barrier.

## Literature Cited


Allen, W., and P. Dickinson. 1977. The tree lined barrier. **In:** International Conference on Noise Control Engineering: Inter-noise 77, 1977 March. Zurich, Switzerland, Swiss Federal Institute of Technology, B587-B592.

Anderson, L.M., B.E. Mulligan, L.S. Goodman, and H.Z. Regen. 1983. *Effects of sounds on preferences for outdoor settings.* Environment and Behavior, 15: 539-566.

Aylor, D.E. 1971. *How plants and soil muffle noise.* Frontiers of Plant Science, May: 6-7.

Aylor, D.E. 1972. *Noise reduction by vegetation and ground.* J. Acoustical Society of America 51: 197-205.

Aylor, D.E., and L.E. Marks. 1976. *Perception of noise transmitted through barriers.* J. Acoustical Society of America 59: 397-400.

Cook, D.I. 1980. Trees, solid barriers, and combinations: Alternatives for noise control. **In:** Proceedings, National Urban Forestry Conference, November 13-16, 1978, Washington DC. Syracuse, NY: State University of New York, College of Environmental Science and Forestry, ESF Publication 80-003; pp. 330-339.

Cook, D.I., and D.F. van Haverbeke. 1971. Trees and shrubs for noise abatement, University of Nebraska Agricultural Experiment Station Research Bulletin No. 246, 77 pp.

Grey, G.W., and F.J. Deneke. 1978. Urban Forestry. New York: John Wiley, 279 pp.

Heisler, G.M. 1977. *Trees modify metropolitan climate and noise.* J. Arboric. 3: 201-207.

Lyon, R.H., C.N. Blair, and R.G. DeJong. 1977. Evaluating effects of vegetation on the acoustical environment by physical scale modeling. **In:** Proceedings of the Conference on Metropolitan Physical Environment; 1975 August 25-29. USDA Forest Service Northeastern Forest Experiment Station, General Technical Report NE-25, Upper Darby, PA, pp. 218-225.

Mulligan, B.E., L.S. Goodman, M. Faupel, S. Lewis, and L.M. Anderson. 1982. Interactive effects of outdoor noise and visible aspects of vegetation on behaviour. **In:** Proceedings, Southeastern Recreation Researchers Conference, February 18-19, 1981, Asheville, NC, pp. 265-279.

Southworth, M. 1969. *The sonic environment in cities.* Environment and Behavior 1: 49-70.

Ulrich, R.S. 1981. *Natural versus urban scenes: Some psychophysiological effects.* Environment and Behavior 13: 523-556.



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## ABSTRACT


POTTER, D.A. and G.M. TIMMONS. 1983. **Knowledge of clearwing borer cycles promotes diagnosis and treatment.** Am. Nurseryman 157(4): 57-63.

Clearwing borers are common destructive pests of woody plants. Borer larvae tunnel and feed in living wood, destroying vascular tissues and causing loss of vigor, structural weakness, branch dieback, or complete girdling and death. Infestation sites may provide entry points for disease pathogens. Trees in the urban landscape, which may be under stress already, are especially prone to borer attack. Because borer-infested plants may not be sold legally, it pays to control them as soon as possible. The following clearwing borers are particularly damaging to woody ornamental plants. Flight periods and optimal treatment dates apply to the lilac borer, dogwood borer, peach tree and lesser peach tree borers, oak borer, and banded ash borer.