**ABSTRACT**

In the context of cultural heritage, soundscape analysis offers an untapped tool for identifying and assessing historic elements in built environments. A growing number of soundscape studies have begun to outline the additional level of interrelations present specifically in historic settings, exposing the experiential implications of current preservation work. But previous studies have not considered the soundscape itself as an element of history or historic value. Can a previous soundscape be identified as extant, partially or in full? Must physical heritage or intangible practice be intact for an historic soundscape to exist? What’s more, can a soundscape without any living witnesses be identified? A case study in rural Greece, the ancient complex for Zeus worship on Mt. Lykaion, is presented in effort to both address these themes and contextualize such investigations within broader design and soundscape-based inquiry. Though the site stands in ruins, acoustic anomalies at Mt. Lykaion point to the potential persistence of an ancient designed soundscape, one that may have assisted direct communication between far removed buildings and locations during ancient ritual use. Strategies developed for soundscape identification and measuring at the site are presented alongside preliminary conclusions from the gathered data.

Keywords: Historic soundscape, measurement, perception

1-INCE Classification of Subjects Number(s): 72

1. **INTRODUCTION**

The use of the Soundscape Approach is currently undergoing a powerful shift in perspective, from purely investigative to playing an active role in site design, creation, and maintenance (1), (2), (3). One application that has received sporadic attention so far is the soundscape of historic places. Part of the challenge of such spaces, which embody a complex set of value assessments in addition to those of all soundscapes, is that their analysis is best conducted from a number of separate fields – heritage studies, architecture, archaeology, anthropology, history, city planning, landscape design, engineering, and so on. A number of these fields have begun to incorporate ideas of soundscape into their own research methodologies, resulting a collection of beginnings that do not necessarily inform each other. For instance, archaeoacoustics combines acoustical study within archaeological investigative frameworks, looking at acoustic properties of places or objects, such as musical instruments (4). In heritage studies, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) has developed a framework of intangible heritage to include aspects of heritage that have no physical presence, such as ritual practices or handcraft traditions, which often include an aural dimension (5).

A number of acoustics studies have investigated the soundscapes in historic places, particularly of historic city centers (6), (7), (8). There have also been more general inquiries into the concepts of soundscape heritage, as collected in (9). The focus of these various projects, however, has tended to be the present; the soundscape in these discussions is conceived and analyzed as a rare yet relatively static condition, something that affects certain user groups (residents, visitors) and which might present certain aspects that are rare and worth maintaining in their present state. General recommendations for such conditions rely on the creation of an archival recording as the best form of
maintenance or preservation.

In contrast, the position of this paper is that soundscapes are not simply present tense. As current acoustic qualities can be assessed and identified, so too can past versions in that same location. Changes can be identified, whether they are variations in contributing sounds through time or the shifting reactions of people to the same sound. Identifying any soundscape requires both physical and perceptive data – this is no less true for past conditions as well. Depending on the timeframe under consideration, past soundscapes can be reassembled through interviews with living witnesses, archival recordings and documents, or reconstructions based on available physical data. Few attempts have been made to access the full sonic character of the past; the best example may be the study conducted by historian Alain Corbin on 19th century rural France (10).

If a past soundscape can be identified through certain changes over time, it follows that it is also possible to identify certain elements of a present soundscape as having roots in an historic past. Both buildings and soundscapes can have historic foundations that are only partially accessible. Much like a historic building, then, one can consider the soundscape itself as having historic value, as being an historic soundscape. The historic value of a site is no longer limited to physical objects, but rather is embodied in the sonic experience of the place as well. The assessment of such contributions requires the development of historic soundscape analysis techniques with the focus shifted away from expressions of contemporary preference or comfort and towards historic function and meaning instead. Tools such as binaural measurements and analysis, soundwalks, and interviews with living witnesses are all valuable contributions in addition to archival research and other multidisciplinary techniques.

But what should the procedure be when approaching a site of the distant past, when no living witnesses and almost no archival material concerning its original use remains? In the following case study of Mt. Lykaion, the historic soundscape concept serves as the starting point for fundamental questions about how the site may have functioned in antiquity. Sound characteristics can be conceived as material evidence, which can be revealed as partially or fully intact and traceable to original uses. Could the past soundscape be reactivated, so that one could experience the site as it performed 2400 years ago? Could it be used as a tool of investigation alongside historical research, archaeological analysis, and geomorphology?

2. METHODOLOGY

2.1 The study site – Mt. Lykaion, Greece

Mt. Lykaion is one of the tallest of the Arcadian mountains, located in the Greek Peloponnese. At the southern peak (elev. 1,382 m) sits an ancient ash altar where offerings were made to Zeus for many hundreds of years—enough to create a mound of ash that can still be seen today. Worship activity may have even extended far before Zeus, as evidence of ancient religious activity has been found from the 7th through 1st century B.C.E. (11). But it was for Zeus that athletic games similar to those conducted at nearby Olympia were held in the lower sanctuary, approximately 200m below, from ca. 400-100 B.C.E. For this purpose, a series of limestone buildings were constructed in the lower sanctuary around the 4th century B.C.E. (see Figures 1 and 2). Use of the lower sanctuary has also been traced to the early-to-late Byzantine periods with some isolated building and religious activity unearthed (12).
Today, discernible remains of a stoa, administrative building, bath complex, ceremonial seats, a walled corridor, and springhouses are assembled around a hippodrome, though the building remains are generally greatly deteriorated (13), (14). There may have been a small temple to Pan in antiquity as well (15), though it has yet to resurface. A prominent destination during its heyday, it was and remains an isolated and rural setting, set between steep inclines of undulating limestone layers and scrub oak at the far end of dirt roads.

The primary period of significance for this site is the four hundred years in which the lower sanctuary was constructed and used. The building ruins offer only a few clues about how individuals may have interacted in antiquity, owing mainly to the standard function of building types (e.g. bath, stoa) during that time. The written record offers only a few other glimpses with very little about cult practices (16). Ultimately, few reliable details are known about the historic functions of the site; the ancient soundscape, how individuals experienced the place and activities conducted there, has been thoroughly obscured with the passage of time.
Figure 2: Map of lower sanctuary

Figure 3: Mt. Lykaion today – lower sanctuary (lower center) and ash altar at peak (upper right)
2.2 Preliminary observations

Despite the damaged conditions of the building remains, a number of acoustic singularities were noted throughout the site while working with the Mt. Lykaion Excavation and Survey Project (2005-08). For instance, speech clarity appeared to be maintained unusually well between distant site features (e.g. between the bath and stoa ruins, which are separated by approximately 384 m). This clarity is not uniform throughout the site and perceptively degraded even 20 m closer to the Stoa. But the regularity with which such intelligibility seemed to align between ruins or particular landscape features suggested the possibility of intentional ancient design—and the need for precise measurements to confirm or deny the possibility. It is not unreasonable to think that amplification of sound may have been played a role when the site was in use; sound was a critical element to ancient ritual practice, both for Pan (16) and Zeus (17,18) worship, not to mention for public athletic contests. Further, the theater at Epidaurus, built in 340 B.C.E. only 97km away, demonstrates how precisely ancient builders understood and employed acoustic design during the same time period.

2.3 Study aims

The study was designed as an exploratory trial focused on possible acoustic relationships between sanctuary buildings. Because so little is known about ancient functions at the site, this work aimed at identifying locations for more precise future measurements and developing a working methodology for conducting those measurements.

2.4 General site approach

When first approaching the search for acoustic relationships at any site, especially one with an extensive and distant history such as Mt. Lykaion, it is essential to recognize the degree to which the site has changed or remained the same since its ancient use; and the degree to which one can be certain either way. The sanctuary continues to be used for various purposes; residents from the neighboring village Ano Karyes have used it for farming and animal grazing as long as the village has existed, and walnut trees and retaining walls currently stand in the lower sanctuary. The ancient sanctuary buildings have succumbed to intentional deconstruction (ancient blocks have been found in modern retaining walls) as well as earthquakes, sedimentation, and weathering. The area has not been maintained for religious practice dedicated to Zeus (not expressly; a small chapel to St. Elias currently sits near the summit and ash altar of the mountain, a saint bearing some historic associations with Zeus (19), pg 11). However, it has hosted an incarnation of the ancient games since the inception of the Modern Lykaion Games in 1973. This local festival has motivated nearby road grading and resurfacing a portion of the hippodrome along with revived versions of ceremonial and celebratory practices.

Aside from the known structural changes to the site, the field grasses and other plant growth present today are unlikely to be identical to what was present in antiquity. Different landscaping, ground surface treatments, and proportions of exposed bedrock, not to mention original building dimensions and materials, all would have an effect on the acoustics of the area. With so many variables, the focus for the first round of study was on how the site acoustically functions today and identifying any organizational patterns for further analysis.

A number of studies in other historic locations have suggested techniques for measuring and analyzing the acoustics of a space, be they interior rooms (20) or exterior conditions (21). For many such studies, much more is known about the original use of the location under investigation—certainly whether it was designed for acoustic properties in some sense—and thus these studies are able to target certain aspects of the acoustic properties for study, such as reverberation times or resonance frequencies. Without the benefit of such information, the investigations approached the lower sanctuary similarly to a room or open field condition, using a basic impulse response test to seek out singularities.

2.5 Recording points – identification and selection

To begin, locations of research interest were explored according to possible historic function. Locations were chosen that could have been relevant to the public functions of the sanctuary, a place of gathering and spectating, procession, athlete competition, and ceremony. Any known or speculated building entrances, exceptional built features, possible ceremonial paths, and viewpoints from which the entire lower sanctuary could be viewed were included. This process targeted areas where sound could have played an obvious role as direct communication between locations or as an
important contextual condition. Once a location was identified, the speaker played a selected sound file continuously from that location (see detailed description below). All other identified locations were then visited in order to witness the quality of playback and how it changed throughout the site. Along the way and at each destination, general ear-based impressions were noted on aspects such as perceived loudness, clarity, reverberation, and any frequency anomalies (e.g. whether higher/lower frequencies were inaudible). This practice was repeated for all predetermined locations. Reviewing this data resulted in the selection of approximately 17 primary locations for further study. These locations are noted in Figure 4 and are as follows:

- Stoa (three points along northeast wall)
- Administrative building (southern entry; eastern collapsed face near Byzantine burial; in between building and Seats))
- Walled corridor at base of administrative building
- Seats (at eastern side; in the center of a built-in indentation; next to a prominent statue base on the western side)
- Fountain house near administrative building
- Hillside overlooking hippodrome (three points at various elevations)
- Hippodrome starting blocks
- Possible Procession Way (located approximately at same elevation as Stoa floor)
- Bathhouse (possible entryway)
- Miscellaneous points

![Figure 4: Lower sanctuary with ruins and recording points highlighted](image-url)
2.6 Binaural recording

Once the points were selected for study, binaural recordings were set up to measure the existing conditions with a custom impulse response test. A four-second source file (the readily available Samsung ringtone, “hangouts_video_call.ogg”, distinguished by five distinct tones played in sequence) was loaded on a Samsung Galaxy S5 mini, relayed through Bluetooth to a portable, rechargeable speaker (a Harman 2015 JBL GO portable Bluetooth speaker) placed with its face pointing up so as to simulate a uni-directional point source, and played with both devices set to maximum volume output. A recording of the source file was then made at every other recording point using a HEAD acoustics, GmbH, SQuadriga® recorder with headset/microphone unit. The sound file was recorded as it played four times in a row (the total duration thus lasting 16 seconds); the extended durations were designed to provide at least one full recording of the source file with as little interference from wind or wildlife as possible. All recordings were made in the morning on sunny or partially cloudy days. The source signal was calibrated in the anechoic chamber of the Technische Universität Berlin upon return from fieldwork.

Figure 5: Spectral representation of the source file played in an anechoic chamber (FFT/Time) during calibration; recording made a 6 m from the speaker. The five individual tones are clearly visible in each set.

3. RESULTS

3.1 Perceptual findings

Final binaural recordings were made in sets that revolved around a single speaker placement, much like the initial tests were conducted. At the seats, the speaker was placed at an prominent indentation built into the rear row; recordings were then taken at all other pre-selected points in the lower sanctuary.
The speaker was then moved to another pre-selected point, and the process was repeated. As the recordings were made and impressions noted, a number of intriguing patterns emerged, many of which were found more from focused attention than the aid of measurements and later analysis. Unexpected clarity between certain locations was indeed apparent, particularly between the stoa and processional way, as well as between the stoa, seats, and administrative building. The region between the seats and administrative building (highlighted in Figure 6) also seemed to amplify the more percussive sounds in the source file, an effect noticed nowhere else in the lower sanctuary.

Figure 6: Diagrams showing the recording locations when the speaker was placed on the Seats; unique effects are highlighted along with recording locations analyzed in detail (see Figures 8 & 9)
It was discovered that, when playing the sound file from almost any point in the lower sanctuary, the sound could be heard with remarkable clarity on the hill to the northwest of the administrative building (highlighted in Figure 6). This effect was particularly apparent when the sound was played in the stoa, seats, and hippodrome. The springhouses, on the other hand, proved to be almost entirely acoustically isolated from the rest of lower sanctuary. General observation reinforced that echoes were not a prominent feature throughout the site except in a particular area west of the stoa (highlighted in Figure 6), where a perceptible echo was present.

3.2 Binaural recording analysis

The data gathered through the SQuadriga device was examined away from the field using ArtemiS Suite from HEAD acoustics, GmbH. A first pass was conducted to look at the perceived loudness of the control sound across the lower sanctuary. Looking again at recordings made at the seats, the right microphone readings were compared for five different recording points.

Figure 8: Comparison of perceived loudness vs. time (soneGF) at five recording spots when the speaker was placed on the Seats (see Figure 6)
The measurements suggest that perceived loudness roughly aligns with expectations for increased distance in a free field condition. Spectral analyses from the seats recordings demonstrate the loss of detail from the control sound as the distance between source and recorder increases (see Figure 9). Point #4 stands out, however, as maintaining quite a bit of the sound source’s original profile and intensity.

Repeating this analysis with the other recording sets confirmed a number of anomalies. First, as mentioned, the hillside highlighted in Figure 6 enjoys a particular perceived clarity from almost every recording point, especially the stoa, seats, bath and hippodrome. A further test with a number of individuals confirmed the ability to have a spoken conversation between the middle of the hippodrome and recording point #4 highlighted in Figure 6 (approximately 100 m away). This relationship allows spectators not only to hear activities on the hippodrome, but activities proceeding at the stoa or seats, or possibly louder activities at the bath complex as well. Additionally, the results reinforce the possibility of the processional way having played a role in antiquity, such as connecting the bath complex to the upper springhouse; sound played from this area could be heard throughout the lower sanctuary to various degrees.

4. DISCUSSION

While this first investigation offers no firm conclusions concerning the ancient design intent behind the acoustics at Mt. Lykaion’s sanctuary to Zeus, the findings demonstrate the rich potential in using a historic soundscape approach to investigate acoustic characteristics and their origins, even when very little is known concerning the original acoustic design. A future iteration of the study will be necessary to confirm the hypotheses presented above and hone in on which analyses are the most effective. Precision is key; a Global Positioning System (GPS) or total station for recording point locations should be utilized to calculate exactly how measured effects are related to physical distances between sound and receiver. An impulse tone and perceptual sine sweep should be employed as control sounds, and these should be played on a high quality speaker. It would also be beneficial to use human speech and/or sounds employed at similar contemporaneous sites as control sounds (such as those in the ancient athletic contests and Zeus worship at nearby Olympia), as they would represent more accurately the acoustic elements that would have been present in the ancient
There are a few specific points that must be followed up with care. The masking effect of wind and wildlife (birds and insects in particular) on perception should be assessed, as this is a constant influence on the current soundscape. Further investigation is necessary to ascertain whether the percussive effect between seats and administrative building might be a ‘flutter echo’. The possibility is intriguing, as it occurs where both the seats and administrative building ruins are at their most complete. A more precise investigation of this effect could suggest in what proportions it derives from the built structures (and possible ancient design) and the topography. Similarly, the clarity maintained between the stoa and possible processional way requires additional study, particularly to determine if there are other influential factors besides the unobstructed area between the two recording points at similar elevations.

The binaural recordings proved to be very useful tools for supplementing and supporting perceived impressions in the field; the next round of examination should explore the untapped potential of this technology further. Beyond sound pressure levels, analysis should focus on aspects such as clarity, enhancement or damping of particular frequency ranges, and reverberation. Results will produce more robust information by using standard impulse tones and perceptual sine sweep files for recording.

5. FINAL REMARKS

The acoustic properties observed at Mt. Lykaion indicate a complex web of relationships that, whether designed or pre-existing, could allow spectators, athletes, and religious figures even today to interact in very specific and intimate ways when nonetheless visually distant from each other. Given the ruined state of the ancient structures, the acoustic properties could be derived in great part from the landscape; however, their alignment with ruins makes a powerful case for these structures having been placed to take advantage of—or perhaps even to enhance—such properties. The historic soundscape at Mt. Lykaion may be partially intact, allowing visitors today to interact with the site much as ancient Greeks could have 2,400 years ago. The first step to confirming the condition of the historic soundscape is a detailed follow-up study using the lessons from this initial experiment. A thorough investigation of the historic soundscape ultimately may offer insights as an archaeological tool and a technique for site interpretation. And as the methodology is refined, the soundscape could prove to be the most intact element left of this ancient site.

ACKNOWLEDGEMENTS

Funding for this research was provided by the Alexander von Humboldt Foundation through a German Chancellor’s Research Fellowship in 2015. The author wishes to thank the Mt. Lykaion Excavation and Survey Project, and Dr. David Gilman Romano in particular, for their interest and support of the research as well. The base map data used to construct the plans and diagrams is courtesy of the Mt. Lykaion Excavation and Survey Project, http://lykaionexcavation.org.
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