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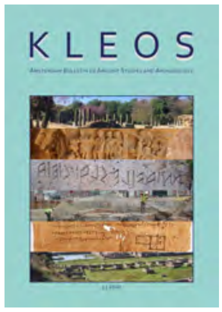

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Sound Experience in Archaeology and Field Investigations:

An Approach to Mapping Past Activities through Sound at Mount Lykaion's Sanctuary of Zeus

ARTICLE

Pamela Jordan

ABSTRACT

The recent increase of sensory archaeology investigations has broadened the theory and field practices employed when examining ancient site experience. Sound and acoustics have played a recurring theme in many studies, from retracing past acoustic designs to investigating the impacts of an ancient everyday soundscape. The development of sense-based archaeological explorations in the early 21st century coincided with similar phenomenologically related inquiries across the built environment fields, from contemporary architectural theory and city planning to intangible and values-based heritage practices.

In this discussion, an initial overview of the current discourse of sensory archaeology, archaeoacoustics, and ancient sound studies highlights discursive and applied overlaps from architectural and soundscape theory. The review focuses in particular on the field of psychoacoustics and recent advances in predicting the human response to differing sonic conditions. It also sets the multidisciplinary stage for current fieldwork at the Hellenic sanctuary of Zeus on Mount Lykaion, Greece. Few written accounts of this site remain from antiquity, and the architectural remnants are limited and fragmented; thus the rituals and athletic competition practices of antiquity remain largely unknown. One must look to other informative sources to gain insights into the past. Sonic relationships observed at the site enable startling communicative ability between certain distant locations, often linking landscape features and building footprints. Could such synchronicities point to possible acoustic awareness in the ancient siting of structures? It remains a logical possibility considering the public and performative nature of Zeus' cult practices at other contemporaneous sites. Binaural recording technology, psychoacoustic analyses, and site-mapping techniques are presented as tools for detecting whether and where such determinative patterns exist between the site and surrounding mountainous terrain. The methodologies that bridge these

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▶ *Profile page*

technologies with theoretical approaches from multiple disciplines will be described in detail along with the first findings and their possible significance.

Introduction

When few material traces remain of a place, how can the interpretation of non-material artefacts be made meaningful? What information can a present-day soundscape express about the ancient past? Experiential archaeology and archaeoacoustics offer perspectives that focus on non-physical remnants of former times, which can include acoustic designs or sonic qualities. However, for examining current conditions, adjacent investigative fields offer additional methods: soundscape study investigates the holistic sonic environment in its overlapping physical and cultural contexts, while the field of psychoacoustics studies how humans perceive and process sound. The combination of these perspectives has proven beneficial in investigations at the Hellenic sanctuary of Zeus on Mount Lykaion in Arcadia, Greece, where limited and fragmentary ruins remain above ground-surface level. Despite this limited physical presence, surprising sonic connections exist throughout the sanctuary. Distant points of the architectural remains become sonically linked with the surrounding landscape so that spoken conversations can be conducted across 75 m or more between certain locations. Investigations at the site focus on these connections to determine where they occur, what features they connect, and what types of activities they could promote. The sonic features are mapped via a series of test sounds (both abstracted tones and based on the human voice) that are played and recorded in the field. The behavior of these sounds in a controlled environment is known; by comparing control and field-gathered measurements, unusual accentuation or dampening within the sanctuary can be identified. Such characteristics would assist or hinder sound transmission, for instance, and alignments of these characteristics with architectural features and landform positions are noted. By cross-referencing such observations with typical ancient practices – public processions, private bathing, musical performance, spectating and supporting 'back-of-house' services – the investigation can offer evidence as to whether the architecture and landscape were designed in tandem to support specific ancient practices that would have benefited from sonic accentuation or isolation. Such a finding would suggest that Hellenic builders could have applied their sophisticated understanding of acoustics beyond amphitheaters to other places of public spectacle such as sanctuary landscapes.

The Mount Lykaion case study reverses the typical focal division between architecture and surroundings, where the target of study is on the architecture and the context is considered secondarily. Here, the landscape can offer rich information about the architecture that the buildings no longer can communicate. Further, the work demonstrates how tools and techniques from multiple sound-based fields can be applied towards the archaeological investigation of an historic landscape. The landscape and sonic features therein offer a connection with the past experiential reality of the site that the ruined buildings alone cannot. They can be approached as both setting and architectural construct – as both the context for architectural insertions, and as the architectural structure itself – manifesting a relationship between visitor and place through sound that is at least partially illustrative of ancient experience.

A review of sound-focused studies of the archaeological environment

Current considerations of sound in the built environment spring from several fields. In the Western scientific tradition, acoustics as it is applied in the fields of architecture and engineering has been present since at least the turn of the 20th century, when W. Sabine attempted to correct the acoustics of a lecture hall at Harvard University.[1] After steady examination through an engineering lens, the consideration of sound in the built environment experienced something of a flashpoint starting in the early 1990s. Four important texts set in motion a sonic consideration of place-based experience in their respective fields: H. Fastl and E. Zwicker's 1990 expansion of acoustics into psychoacoustics, or the study of the human perception of sound; C. Tilley's 1994 approach to both phenomenology in the landscape and landscape archaeology; the republication of R. M. Schafer's seminal work on soundscape study in the same year; and J. Pallasmaa's call for a reconsideration of architecture and the city through all of the senses in 1996.[2] Further archaeological branches of inquiry solidified in the next few years, first with the formal establishment of the International Study Group on Musical Archaeology (ISGMA) in 1998, followed by the formalisation of archaeoacoustics as a disciplinary perspective in a workshop held at Cambridge University in 2003.[3]

The paths introduced in these first fruitful ten years have since diversified in form and methodology while maintaining an interest in the human experience of sound, both individually and collectively. Extremely sensitive psychoacoustic recording

1 Katz/Wetherill 2006.

2 Fastl/Zwicker 1990; Pallasmaa 2005; Schafer 1994; Tilley 1994.

3 Scarre/Lawson 2006.

technologies can be paired with ethnographic survey, for instance, while musical archaeology studies may use digital reconstruction to simulate musical instruments.[4] The work started at the 2010 conference *Making Senses of the Past* (Center for Archaeological Investigations, Southern Illinois University, Carbondale) and has culminated in a recently published survey of sensory archaeology as a field, which provides an excellent summary of theoretical debates and applications across cultural contexts and time periods.[5] The historic built environment has emerged as its own subfield, from psychoacoustics and soundscape studies, to building acoustics and architectural/cultural heritage.[6] Archaeoacoustic investigations have been carried out on a variety of scales, locations and historic periods.[7] Attention to a sonic past has also been a driver of recent archaeological revaluations.[8] Inquiries within historic landscapes as well as larger archaeological assemblages have aimed to understand the primary role sound likely played in the construction and use of ancient built spaces.[9]

More recently, studies of archaeological sites and their surroundings have begun to incorporate some of the testing technologies employed in building acoustics and soundscape study, such as binaural recordings for psychoacoustic analysis or digital reconstructions.[10] Such disciplinary cross-overs prove instructive for the case study on Mount Lykaion, where despite the 2400 intervening years, two factors have remained stable since antiquity: the landscape of the Lower Sanctuary and human hearing.

The initial human response to sound is based on physiological factors to the human ear-brain connection. Such factors produce both heightened or dulled sensitivities to certain frequency ranges as well as consistent responses to certain characteristics such as a sound’s ‘sharpness’ or its pattern through time. The physiology that creates this initial 'signal processing' of sound is consistent across cultures and is the focus of psychoacoustic research. This processing system has remained constant since ancient times – someone today will likely be especially sensitive to the same frequency bands of sound as someone in ancient Greece (a baby crying, for example). What is different, of course, is how these

4 Bellia 2019; ISO 2018; Koumartzis et al. 2015.

5 Skeates/Day 2019.

6 Brambilla et al. 2008; Hedfors/Berg 2003; Huang/Kang 2015; Mills 2014; O’Connor 2011; Suárez et al. 2016.

7 Díaz-Andreu/García Benito 2012; McMahon 2013; Rainio et al. 2018; Till 2014; Williams 2013.

8 Berardi et al. 2016; Butler/Nooter 2019; Day 2013; Hamilakis 2015; Hurcombe 2007, 539.

9 Díaz-Andreu/Mattioli 2015; Hamilton et al. 2006; Kolar et al. 2018; Lubman 2013; Till 2017.

10 Alonso et al. 2018; Berardi et al. 2016; Chapman/Wilson 2010; Kolar 2017; May 2014; Tronchin/Knight 2016; Tsilfidis et al. 2013; Vassilantonopoulos/Mourjopoulos 2001.

Figure 1
Typical landscape and ruins in the Lower Sanctuary. The researcher stands in the Stoa, with the mountain peak altar in the background (photograph by G. Davis).

sounds are then *interpreted* by the listener, a process which can vary widely depending on personal experience, cultural conditioning, training, and contextual surroundings. It is the initial perception of sound that is the focus of acoustic study on Mount Lykaion.

The multidisciplinary approach at Mount Lykaion

The study of Mount Lykaion integrates signal processing as a key component to its greater historical queries. The Lower Sanctuary today sits near the peak of Mount Lykaion, isolated from extensive human development and dotted with the ruins of Hellenic structures (see figures 1-2). The landscape also hosts moments of sonic connection (soundlines) within the Lower Sanctuary, where a sound emitted at one position can be heard clearly from another point in the landscape. These connections can be surprising – the distances over which a sound can clearly be heard can vary widely between soundlines, and a soundline does not necessarily require a clear sightline. Rather than simply being a product of distance, the soundlines often appear to line up with an ancient building ruin or a prominent landscape feature at one or both ends. The investigation thus employs psychoacoustic measurements to comparatively examine whether such alignments indeed exist and what characteristics they have. Determining if a sound is heard consistently from certain positions could reveal if, for instance, buildings were located to take advantage of the landscape's natural acoustic properties to foster clear communication or conversely, to sonically isolate more private areas and activities from public ones. Approaching the site initially through sound instead of sight requires a sensitivity to landscape experience initiated by Tilley. His work presented ancient landscapes and people in a dynamic relationship through time, the value of which stems from social memory and meaning-creation rather than

Figure 2
Map of Greece with Mount Lykaion's location highlighted (created by author, base map courtesy of Google Earth).

objective qualities such as coordinates or weather patterns. This approach was continued by later archaeoacousticians in various forms. But proposals of ancient design intentionality also rely on the findings derived from the ongoing Mt. Lykaion Excavation and Survey Project as well as the extremely limited descriptions remaining in the written record.[11]

Methodology and approach

The basic framework of the sonic study of the Lower Sanctuary rests on comparing how current site acoustics are experienced by average human hearing. When investigating the sonic environment of the distant past, field research can only test present-day conditions. This need not be perceived as a limitation, just as the fragmentary evidence of buildings provides an opportunity rather than a constraint for investigation. Furthermore, the physical environs of Mount Lykaion today — with exposed limestone beds, natural springs, and limited architectural fragments — present landscape conditions that may have defined the Lower Sanctuary for its initial phase of use without monumental architecture, from at least 500-360 BC (see the *Site History* section that follows below). Then as now, the surrounding

11 The most complete description of the site was provided in a brief passage by Pausanias, when the Lower Sanctuary was already in ruins (Pausanias, *Description of Greece* 8.38.5).

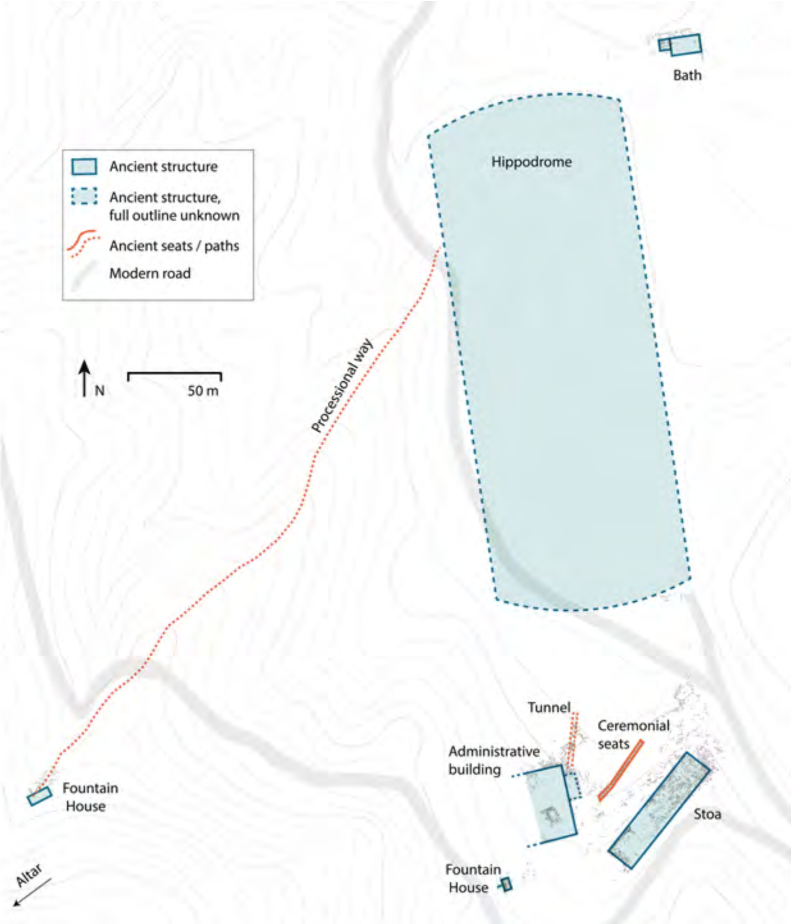

Figure 3
Map of the Lower Sanctuary with known ancient structures as of 2017 outlined (1 m topographic lines) (created by author, base-data courtesy of the Mt. Lykaion Excavation and Survey Project (MLESP)).

hillsides provide ample viewing and listening positions of the hippodrome and structures. The exposed flysch and limestone beds provide ample reflective surfaces as well, and likely were key players in how the ancient public could have engaged with the site and its activities.[12] Indeed, the landscape as a physical entity is likely similar to its condition in antiquity.[13] Approaching the landscape as representative of the architectural/built conditions prior to monumental building construction, one can also consider the soundlines as representative of the embodied experiences of ancient visitors and, critically, ancient site planners looking for favourable ways to organize activities and building placements.

The study first measures and records existing sonic conditions at locations where exceptional acoustic connections at Mount Lykaion have already been observed. One example is a soundline connecting the front edge of the Stoa and a possible processional path on an adjacent ridgeline (figure 3). These two points are about 250 m from each other, seemingly too far for sound to travel clearly between them. However, human-made sound has been experienced between these locations several times over the years

12 Davis 2017.
13 Ibid.; Davis 2018.

by the author as well as other researchers, leading to its selection as a soundline of interest. Is sound consistently accentuated between these locations? Could such an effect have been a design intent when siting the Stoa in antiquity?

A number of factors could contribute to this phenomenon beyond architectural design, including favourable weather conditions, the frequencies of sound being projected, the location of sound source and sound receiver, and the texture and composition of the surrounding landscape. So, the first research objective must be to collect a representative sample of sound travelling between these two points in tandem with meteorological data. To determine the characteristics of soundlines such as this one, a series of control sounds are played that include different features for cross-comparison. For instance, a logarithmic sine sweep is played, which is a smooth tone progressing from 20 Hz to 20 kHz (the human hearing range) that is used frequently in standard interior acoustics tests called impulse response tests. Playing this sound provides information about all audible frequencies and whether any range might be accentuated or dampened over others. A series of pure tones in random order are played as a distilled approximation of musical notes, and a recording of human speech is also played; later analysis can determine elements such as clarity, pattern recognition, perceived loudness, and other psychoacoustic elements to sonic perception.

The speaker that projects the control sounds is positioned in one research location and faces each recording position; the microphones are worn in a headset by a researcher who stands at each position of interest and faces the speaker – in the above case, the speaker was first placed on the edge of the Stoa while the microphones were worn by a researcher standing in the center of the possible processional way. The binaural microphones capture a 360-degree recording of the sonic environment, enabling later analysis of directionality of reverberations and measured decibel levels (dB or dBA) along with psychoacoustics metrics such as perceived loudness, roughness, and tonality of the recording.[14] Values from the measured results are compared to identify unusual characteristics that are not normally present in field recordings made in open field environments. These might include the accentuation of certain frequency ranges or the sonic isolation of a position that is physically unobstructed from the speaker position. These data are then mapped onto a site plan of the Lower Sanctuary and analyzed for any coincidence between

14 Bray 2004; Fastl/Zwicker 1990; Genuit/Fiebig 2017.

sonic anomaly and architectural/landscape feature.

Case study: the sanctuary to Zeus on Mount Lykaion, Greece

Site history

Mount Lykaion is located in the Peloponnesian Mountains on mainland Greece, situated on the border between Arcadia and Messinia (figure 2). As one of the tallest mountains in the area, the peak is visible throughout the region, including the nearby Temple to Apollo at Bassae (erected between 450 and 400 BC) and the city of Megalopolis in the valley (founded between 371 and 368 BC). The mountain peak's visual prominence in the region belies its isolation – it remains a long and steep journey to reach the peak, with little development and few paved roads to this day.

In addition to the continued sonic isolation of the site, one reason that the sanctuary of Zeus on Mount Lykaion presents an appropriate study scenario is the unusual origin of its design. The entire sanctuary was a prominent destination for worship in antiquity, known as the birthplace of Zeus.[15] Its initial structure was simply an ash altar and sacred *temenos* at the mountain's southern peak (1382 m above sea level), known today as the Upper Sanctuary. Recent findings suggest ritual activity may have predated the worship of Zeus, with evidence from at least 1600 BC.[16] The smoke from the sacrifice and burning of animals at the altar was likely visible throughout the region and accompanied by processions and ritualised song or chanting.[17]

Ritual activity eventually expanded on the eastern slope of the mountain, where freshwater springs are still present to this day. The remains of a complex of ancient buildings and a hippodrome, known today as the Lower Sanctuary, are still visible (figure 3). Archaeological findings have traced activity here from the late seventh century BC, with the construction of the hippodrome appearing in the third to second century BC.[18] The monumental limestone buildings were added afterwards.

The limestone buildings that surrounded the hippodrome included a Stoa, ceremonial seating with statues, an administrative and/or banquet building, a tunneled entrance that opened towards the hippodrome, a bathhouse, and multiple fountain-houses or water sources. A processional way, a sacred grove, and a temple to the local cult of Pan may have been present

15 Pausanias, *Description of Greece* 8.36.3.

16 Romano/Voyatzis 2014; Starkovich et al. 2013; Urbanus 2018.

17 Pedley 2005, 118; Romano/Voyatzis 2010.

18 Romano/Voyatzis 2015.

as well.[19] The known building remnants appear similar to many standard architectural typologies at other sanctuaries to Zeus such as at Olympia and Dodona.[20] However they bear the unusual characteristic of sharing a single construction period rather than being gradually added or expanded through time. The construction likely took place around 368-362 BC.[21] However, Lykaion was a well-known destination for athletes by around 466 BC, therefore suggesting that this isolated sanctuary was already a prominent destination a century before the stone buildings were introduced to serve the competitions.[22]

The history of use at the Lower Sanctuary can be divided into two major phases: pre- and post-building construction. This distinction is vital: ritual competitive practices initially developed in the mountainous landscape without stone structures – it is possible that the landscape *was* the architecture for at least 140 years. The buildings then featured as part of athletic competitions for the next 145 years until the games were moved to the valley in 215 BC.[23] The site had fallen out of use by the second century AD with limited ritual activity sustained at the altar when the Roman historian Pausanias visited the site.[24]

SITE AND RITUAL CONTEXT

Much remains unknown about the sanctuary, from ritual activities to the rationale behind the positioning of structures in antiquity – no detailed observational accounts survive from ancient competitions or ceremonies. However, information about practices in similar sanctuaries, as well as knowledge available to ancient Greeks concerning sound, can provide some hints. Ritual practices often included sound at formal and informal levels, from strict religious rites (processions, singing, hymns, offerings, washing, competitions) to aspects of public attendance (crowds, pilgrimages to the site, shepherding and corralling animals for sacrifice, training of athletes prior to the contests, banqueting, and general spectacle).[25] Archaeological investigations have confirmed the likely purposes of visible buildings in the Lower Sanctuary including the Stoa, bathhouse, fountain houses, and tunneled athlete

19 Such dual deity worship was present at other sanctuaries as well, including Megalopolis, the nearest city in the valley (Emerson 2007, 6; Pausanias, *Description of Greece*, 8.30.2, 8.30.3; Pedley 2005, 12; Polignac 1995); Pausanias, *Description of Greece* 8.38.5.

20 Pedley 2005, 119; Dieterle 2007.

21 This aligns approximately with the establishment of the city of Megalopolis in the valley around 370 BC (Romano/Voyatzis 2015).

22 Pindar, *Nemean Odes* 10.45; id., *Olympian Odes* 7.80, 9.95, 13.105-111.

23 Romano/Voyatzis 2015.

24 Pausanias, *Description of Greece* 8.38.6.

25 Pedley 2005.

entrance. The full purpose and roles of other structures in ritual practices remain elusive.[26]

Concepts of architectural acoustics were already advanced throughout Greece by the time the Lykaion competitions were anchored by stone structures. This is evident in both indoor and outdoor applications. Open-air theaters boasted acoustical designs that could reach thousands of spectators without amplification, such as the sanctuary of Epidaurus, built in 340 BC for up to 13,000 spectators. A *therselion* or *bouleutêrion*, buildings constructed for political deliberative oratory, may also have been designed with specific acoustic properties (such as controlled reverberation times through material choices and spatial geometries) to aid orators in conveying their arguments effectively.[27] In Megalopolis, significant examples can be found of both an open-air theater (for 20,000 people) and a political assembly hall built around 370 BC.[28]

It is important to keep in mind A. Barker's warning that distinguishing a branch of inquiry called 'acoustics' is a modern construct without meaning for ancient Greeks.[29] Nevertheless, the control and application of 'acoustics'-based design strategies in architectural space was advancing nearby Mount Lykaion while the construction of the Lower Sanctuary buildings was taking place. It is compelling to consider that the same builders could have constructed the buildings both in the valley and on the mountain while applying their 'acoustic' understanding to both.

The spiritual space of Zeus and Pan worship in ancient Greece also featured prominent sonic components beyond song and chanting practices. Zeus was associated directly with the sound of thunder and divination of his messages at the sanctuary of Dodona were read through the sound of sacred groves.[30] The mythologies surrounding Pan carried direct sonic associations as well, from his eponymous flute to the creation of the echo from his pursuit of a nymph by the same name. Depending on the context, sound could be a divine signifier of a deity or an element of spiritual practice. This aural dimension was a defining component to religious, political, and cultural practices throughout ancient Greece. Such weighty associations would not have been suspended when traveling to Mount Lykaion and were perhaps even heightened in the arduous ascent of the slopes to the sacred

26 The archaeologist K. Kourouniotis noted observing a hemicycle building in the late 1800s (Romano/Voyatzis 2015), uncovered again during 2019 archaeological digging and the subject of upcoming sound-based fieldwork.

27 Johnstone 1996, 105–109; Johnstone et al. 2018.

28 Benson 1892.

29 Barker 2019.

30 Nicol 1958.

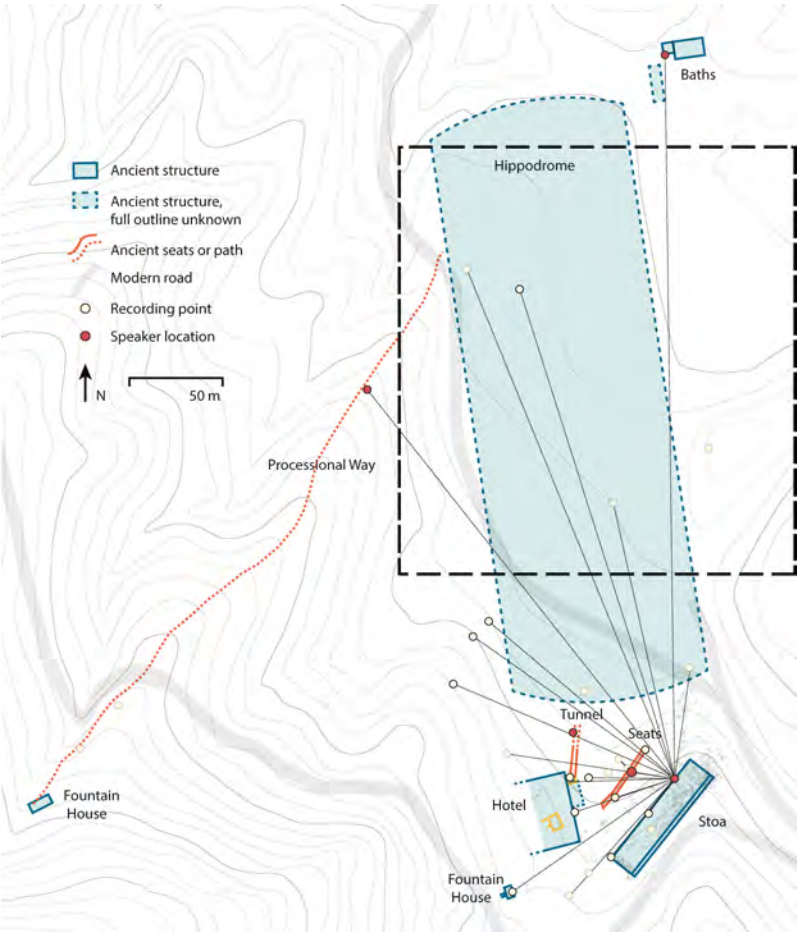

Figure 4
Map of recordings made from control sounds played in the Stoa; study area depicted in figure 6 within dashed lines (created by author, base file information courtesy of the MLESP (as of 2017)).

grounds of the sanctuary, with its refreshing springs and bustle of activity.

Sample findings

Sonic data collection on Mount Lykaion is a multi-season effort and the analysis is in the beginning stages. Around 500 binaural sound recordings have been made during two seasons so far, bringing the total to around 1000 recordings (figure 4). These files include a substantial amount of embedded metadata that requires processing away from the field, including information used for psychoacoustic analysis and GPS coordinates of recording locations. Co-recorded meteorological data such as wind velocity, air temperature, and humidity levels are also noted and linked to the audio data.

The audio recordings provide an unprecedented quality of playback when away from the field (utilizing binaural headphones). Researchers are able to re-hear the original conditions with very high fidelity along with the precise orientation and directionality of sounds. Having this ability is key to researching the acoustic environment – the human sonic experience is equally important for comparison as the data points that can be generated from digital recordings. The files are also

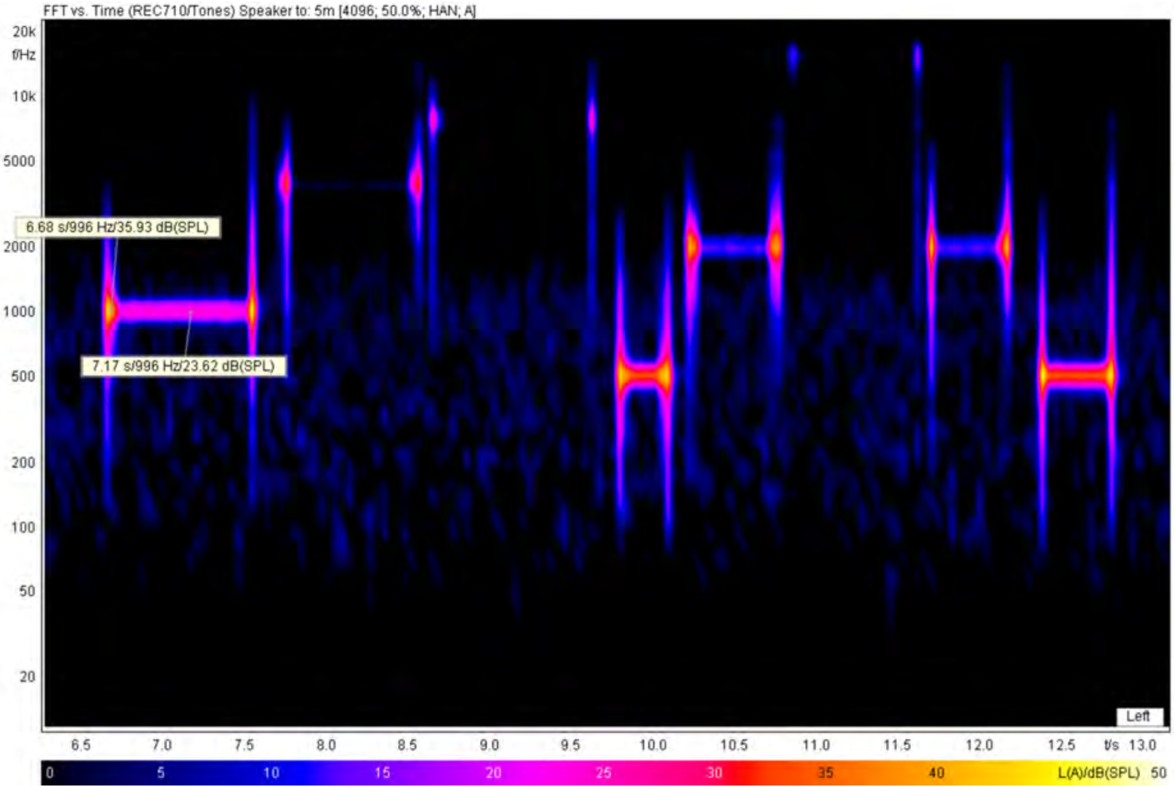

Figure 5

Spectrogram of the FFT vs. Time analysis of the tones-based control file, recorded in an anechoic chamber at 5 m between source and receiver. The separate tones of the test file can be read as the horizontal colored bars between two bright points at either end of the individual tones. Sample spot measurements are depicted in the yellow bars to the left, drawn from the beginning and middle position of tone number 1. There are eight tones total in this spectrogram (created with ArtemiS Suite©, HEAD acoustics, GmbH).

used for psychoacoustic analyses, which can produce average values or time-based graphic depictions of the acoustic data analysis. One of the visual outputs that proves most helpful is the spectrogram, where certain attributes of the recorded sound are represented over time. These images render the sound file into color-coded data that can be quickly sifted through and compared. Once the visual pattern of each test file is known, the field recording spectrograms can be compared for anomalies. Spot measurements can be extracted at specific timepoints and frequencies to ensure an exact comparison between recordings as well (figure 5 depicts a sample).

For an example of the psychoacoustic analysis procedure, it is helpful to consider the loudness of reciprocal recordings made between two points, depicted in figure 6: the position of the original footrace starting blocks in the hippodrome (position SB), and a small, natural outcrop in the landscape 142 m away next to the hippodrome (position LH). Both positions can be seen throughout the majority of the Lower Sanctuary and are located on bedrock – the physical foundation and context of each position thus appears to have changed very little since antiquity. Given the prominence and centrality of the hill, the visual connection between the two positions, and the important role that footraces played in antiquity, the hypothesis is that the hill could have been used as a location for spectating or for communicating throughout the Lower Sanctuary. The goal of analysis is to compare the perception of sound from and to each location and determine

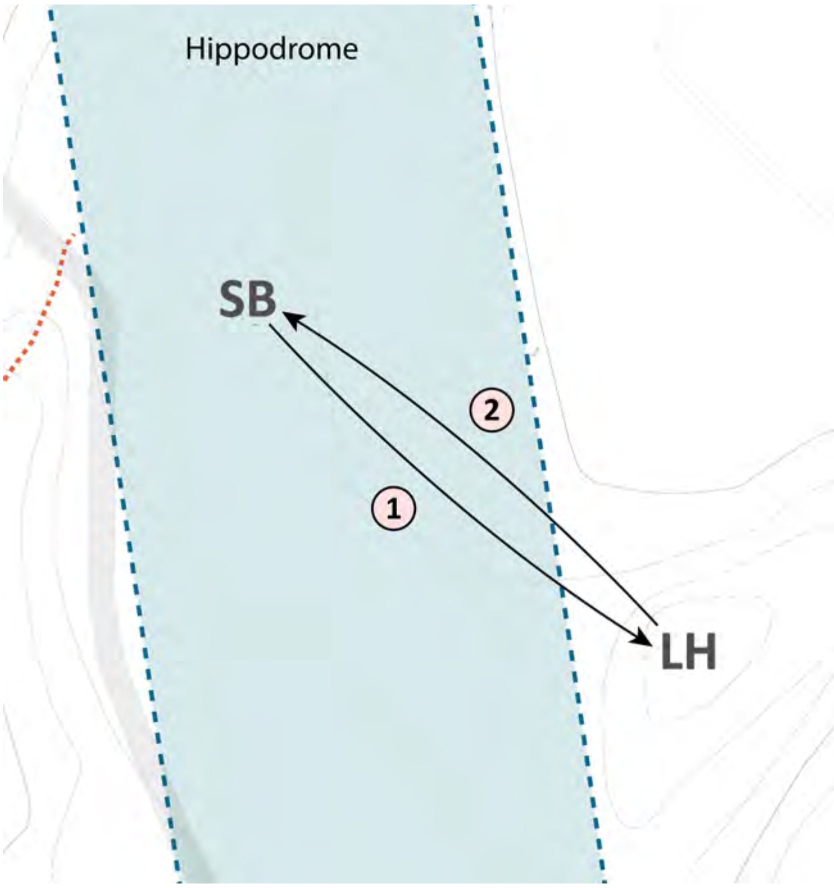

Figure 6
Map detail of recordings made between SB and LH points of interest at 143 m; arrows point in the direction of sound projection (arrowhead points from the speaker to the microphones for each number) (created by author, base file information courtesy of the MLESP (as of 2017)).

whether and how well sound travels between the two points. Given the stability of physical conditions, the results can be understood to represent conditions from antiquity.

The reciprocal recordings are made by first placing the speaker on the outcrop and the microphones on the starting blocks while facing each other. After the recordings are made, the speaker and microphone positions are reversed, the speaker is placed on the starting blocks and the microphones on the outcrop so that the devices are facing each other again, and new recordings are made. These two positions sit in very similar contextual environments, essentially an open field condition with low plant growth and some exposed bedrock. The reciprocal recordings of all the control sounds were made at human height using a tripod to elevate the speaker (the microphones were worn on the head by a researcher). Despite a slight elevational difference (approximately 2.5 m), sounds played from either position are expected to be perceived very similarly.

Once the recordings of each test sound were made, they were analysed using ArtemiS Suite©. This discussion focuses only on the test sound composed of a series of pure tones, which provides simple spectrograms for straightforward visual comparison (also depicted in figure 5). In order to answer the research questions posed earlier concerning the possible connection between the starting blocks and the nearby hill, two different spectrograms

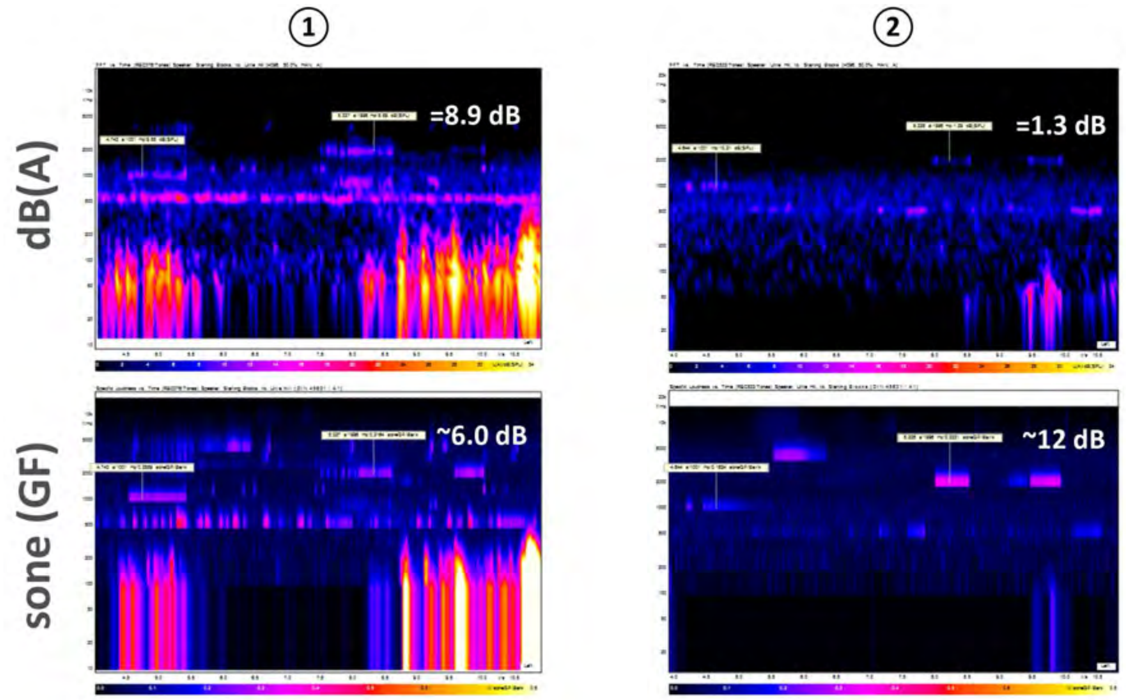

Figure 7
Spectrograms of recordings made between SB and LH points from figure 6; dB measurements are in the top row, sone measurements in the bottom row. Position 1 is what can be heard on the small hill; position 2 is what can be heard from the starting blocks. The dB levels or rough equivalences are highlighted in the top right of each spectrogram (created with ArtemiS Suite©, HEAD acoustics, GmbH).

were produced of each recording and shown in figure 7: sound power in dB(A) and perceived loudness in *sone*. The top row shows the measured dB(A): the objective, physical energy of the original sound that is received by the listener (essentially, how loud a sound actually is). This row helps to substantiate field observations, where it was observed that the tones can indeed be heard from both locations. However, observations also suggested that sound from one direction was perceived to be louder than from the other direction. The dB(A) measurements alone cannot prove this observation, even though the equivalent dB values differ (8.9 dB versus 1.3 dB). One reason for the observed difference is likely to be different meteorological conditions in each. Recording number 1 was made while much stronger winds were blowing, observed by the bright pink, yellow, and white disturbances in the lower Hz ranges in row 1. Wind can act to mask or, as is possibly true for recording 1, it can accentuate sound propagation.

In order to ascertain whether perception is different between the two recording directions, the psychoacoustic metric *perceived* loudness was calculated using *sone* and depicted in row 2 of figure 7. Perceived loudness is a metric that factors in human sensitivities to particular frequencies, to competing sounds or interference, and filtering mechanisms that enable the prioritization of certain sounds over others in one's composite perception of loudness. *Sone* can be converted roughly to dB(A) with an accuracy of about 2 dB, thus enabling a basic comparison of the physical reality of sound and the human perception of that same sound.[31] With these measurements, it is possible to compare the physical reality of an environment to the human perception of the same space: is the volume at which I am hearing this file expected, based on sound energy transmission in normal circumstances? Or is the volume of the file somehow unusual, more or less intense than I would expect?

The perceived loudness spectrogram results in row 2 of figure 7 show that the tones file is perceived differently in each direction. The separate tones of the test file are particularly clear in the sone analysis for recording number 2 (lower right spectrogram). The objective and subjective results were similar for recording number 1, where the sound power was 8.9 dBA versus a perceived loudness of approximately 6 dBA. However, there was a significant difference in recording number 2, where the actual sound power of 1.3 dBA was perceived to be approximately 12 dBA – in this case, perception was twice as loud as physical reality![32] Thus, someone standing on the starting blocks would hear a sound from the hill significantly louder than the other way around. This finding substantiates anecdotal observations: the hill is a convenient position to speak to someone positioned at the starting blocks, but it is not a useful position from which to hear activity taking place at the starting blocks. From these recordings, the sonic relationship between these points appears to be rather one-sided; it suggests that, if sounds at the starting blocks were important to ancient spectators, this small hill would not be a very useful position from which to watch and hear races. However, it could have been a convenient position from which to announce something to race participants.

The above example demonstrates one method for analyzing the collected data, which focuses on how loud a sound seems *in-situ*. The recordings being compared are singular conditions – they could be affected by meteorological situations or competing sounds, and the recordings require repetition to ensure that average conditions are compared rather than single events. Other analyses are also possible: locating and measuring circumstances of sound dampening (isolation from the site); assessing perceived speech clarity between positions; locating positions within the Lower Sanctuary that are sonically connected to every public building or major outcrop (through higher perceived loudness measurements, for instance); or determining the best locations for both seeing and hearing activity on the Hippodrome. Many options remain on the table going forward and only point to the

31 dB(A) = 33.2 Log10 (*sone*)+28; dB(A) levels are 'weighted' to accommodate human sensitivities to certain frequencies over others.

32 The dB scale is logarithmic; an increase of 10dB is a doubling of sound power.

fruitful potential of activating the soundscape for research purposes.

Conclusion

Returning to the opening question of this discussion, the hippodrome sample demonstrates that a present-day soundscape indeed can convey information about the ancient past. The loudness comparison explored a potential relationship between the starting blocks and a nearby hilly outcropping. Both locations have clear visibility throughout the Lower Sanctuary and between each other – they are each a prominent feature. The hypothesis that the hill could have been used as a position for spectating or for communicating throughout the Lower Sanctuary derived from its clear lines of visibility and centralized location. The test was used to ascertain whether the role of sound could match visibility; that is to say, whether a clear line of sight denoted a clear soundline in this case as well. The results were complex. First, the analyses provided concrete and comparable metrics to the sonic experiences between these two points. They proved in these recordings that there is a significant difference in experienced loudness between the study points for human listeners that is not prescribed by the physics of sound alone. Secondly, the results problematize the idea that the hill could have functioned as a point from which to take in the full-sensory experience of a footrace, given that the sounds coming from the starting blocks would not be conveyed with much power. Instead, the hill seems more suited towards conveying sonic information towards the starting blocks and possibly other positions in the Lower Sanctuary. It is a goal of the study to locate such sonic connections in order to determine whether the ancient builders may have taken advantage of the inherent sonic environment. Similar reciprocal tests are being conducted between the hill and sanctuary buildings to hear if any structures are tied strongly via soundline to the small hill.

The data generated from this acoustic research does not provide ready-made answers. Rather, it helps to reposition sonic experience as a driver in archaeological work. At Mount Lykaion, it produces a new way of moving through the site, of reading meaning into sound that may have been consequential for the experience of ancient users. Synchronicities between soundlines and architecture would suggest a simple economy of means: that ancient builders capitalized on acoustic singularities in the landscape in their site designs and building placements. From an architectural standpoint, then, the acoustic anomalies that are present today begin to take on the role of historic fragments, traces of what activities and connections could have been possible in antiquity and requiring contextual research and informed interpretation. The sonic remnants on Mount Lykaion enable a reconstruction of sounded experiences at the sanctuary that architectural study alone would miss.

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