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# Modelling Acoustics in Ancient Maya Cities: Moving Towards a Synesthetic Experience Using GIS & 3D Simulation

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## Abstract

Archaeological analyses have successfully employed 2D and 3D tools to measure vision and movement within cityscapes; however, built environments are often designed to invoke synesthetic experiences. GIS and Virtual Reality (VR) now enable archaeologists to also measure the acoustics of ancient spaces. To move toward an understanding of synesthetic experience in ancient Maya cities, we employ GIS and 3D modelling to measure sound propagation and reverberation using the main civic-ceremonial complex in ancient Copán as a case study. For the ancient Maya, sight and sound worked in concert to create ritually-charged atmospheres and architecture served to shape these experiences. Together with archaeological, iconographic, and epigraphic data, acoustic measures help us to (1) examine potential locations of ritual performance and (2) determine spatial placement and capacity of participants in these events. We use an immersive VR headset (Oculus Rift) to integrate vision with spatial sound and sight to facilitate an embodied experience.

**Keywords:** acoustics, GIS, ancient Maya, 3D modelling, immersive virtual reality (VR)

## Introduction

The acquisition of large and comprehensive data sets using, for example, airborne LiDAR is changing our perceptions of ancient landscapes, and importantly encouraging fresh lines of enquiry (e.g. Chase et al. 2014; Prufer, Thompson, and Kennett 2015; von Schwerin et al. 2016). Diverse methodologies employing space syntax, Geographic Information Systems (GIS), and network analysis are used to carry out investigations of ancient cities (e.g. Brughmans 2013; Landau 2015; Parmington 2011). Several archaeological analyses have successfully employed 2D and 3D tools to develop computational methods to measure visibility and movement to enrich our understanding of ancient landscapes (e.g. Dell' Unto et al. 2016; Llobera 2007; Paliou 2014; Richards-Rissetto and Landau 2014; Richards-Rissetto 2012, 2017a, 2017b; Sullivan 2017).

Archaeoacoustics—the study of sound in archaeological contexts—is now becoming more commonplace, particularly to complement phenomenological approaches (e.g. Cross and Watson 2006; Feld and Basso 1996; Helmer and Chicoine 2013; Mlekuz 2004; Rainio et al. 2017; Tilley 1994).

To contribute to this growing body of knowledge, we investigate the question: What roles did sound potentially play in the urban dynamics of ancient Maya cities? As a case study, we employ GIS, 3D modelling, and Virtual Reality (VR) to model acoustics in the main civic-ceremonial complex at the ancient Maya city of Copán in Honduras. Our approach seeks to take advantage of both computational and embodiment methods. The computational component provides quantitative data on sound propagation and reverberation time and the experiential component uses these data to create spatial audio in VR. The two-prong approach involves three components:

1. The Spread-GIS toolbox for ArcGIS to calculate noise propagation in Copán's city center.

2. The 3D modelling software SketchUp Pro to calculate building capacity and reverberation time for interior spaces.

3. The gaming engine Unity3D and the Dear-VR plugin to create a VR prototype environment with appropriate spatial sound.

To investigate the potential role sound played in urban dynamics at Copán, we situate the resultant GIS and 3D modelling data within a framework of proxemics—a concept examining the impact of space and distance on human interaction. In regard to sound, different distances between speakers and audience are associated with different methods of communication that provide information on cultural uses of space (Hall 1969; Moore 1996). For example, among the ancient Maya, data on acoustics can inform on the position(s) of a ruler during ritual events in relation to different audience members offering insight into the role Maya ritual practices played in establishing, maintaining, and transforming social relations (Sanchez 2007; Schele and Miller 1997). In our case study, we perform preliminary comparisons of acoustics between two locations in Copán's main civic-ceremonial complex—the accessible, public Great Plaza and the restricted, private East Court—two important spaces transformed by Ruler 13 in the early eighth century (Figure 1).

## Ancient Maya Synesthesia—Vision and Sound

The senses were particularly important in ancient Mesoamerica. The ancient Maya regarded the senses as invisible phenomena that invested life and meaning to spaces. Synesthesia, which is the release of one sensation through another, was integral to the ancient Maya. Visual imagery could lead to sensations associated with hearing. Maya art and architecture was a means of sensory communication as was writing. Evidence suggests scripts were meant to be read aloud, and that writing was a device for vocal readings or performance—thus intricately linking the senses of sight and sound (Houston et al. 2006).

Sensory organs like eyes were believed to possess a form of agency; sight, illustrated by iconography of projective eyeballs, served a projective role in ancient Maya society—what you saw affected what you did (Houston et al. 2006). Visibility studies have been done on regional and city-scale levels in the Maya region, illustrating that visibility served as a cultural mechanism to send messages to targeted audiences, establish boundaries, foster social cohesion, and send messages of power (Anaya Hernandez 2006; Doyle et al. 2012; Hammond and Tourtellot 1999; Richards-Rissetto 2010, 2017a, 2017b). While these studies add to our knowledge of experience and interaction among the ancient Maya, they leave out another important sense—sound.

Speech and song scrolls depicted in ancient Maya artwork communicate the importance and properties of sound. Sound was perceived as something concrete and the whiplash motion in the scrolls may represent the changing volume of speech. Music aroused deities, guided a dancer's rhythm, induced trance through repetition, mimicked animal calls, and enhanced the sensory experience (Houston et al. 2006). Sound and music were essential components of ritual—songs represented beauty, marked spaces as divine, and communicated information (King and Santiago 2011; Moore 2005; Sanchez 2007). Hieroglyphs often associate deities with music; for example, the storm god Chaak (associated with thunder and wind) is linked to song and music. Moreover, echoes or vibrations of sound have been artistically depicted in glyphs, showing an understanding of sensory stimuli (Houston et al. 2006).

Paintings, such as the Bonampak murals, depict trumpeters, drummers, and other musicians taking part in processions. Similar depictions are found on a mural fragment from the site of Las Higueras. These murals depict rattlers and flautists closer to their audience and drummers and trumpeters positioned further away, reflecting a sophisticated understand-

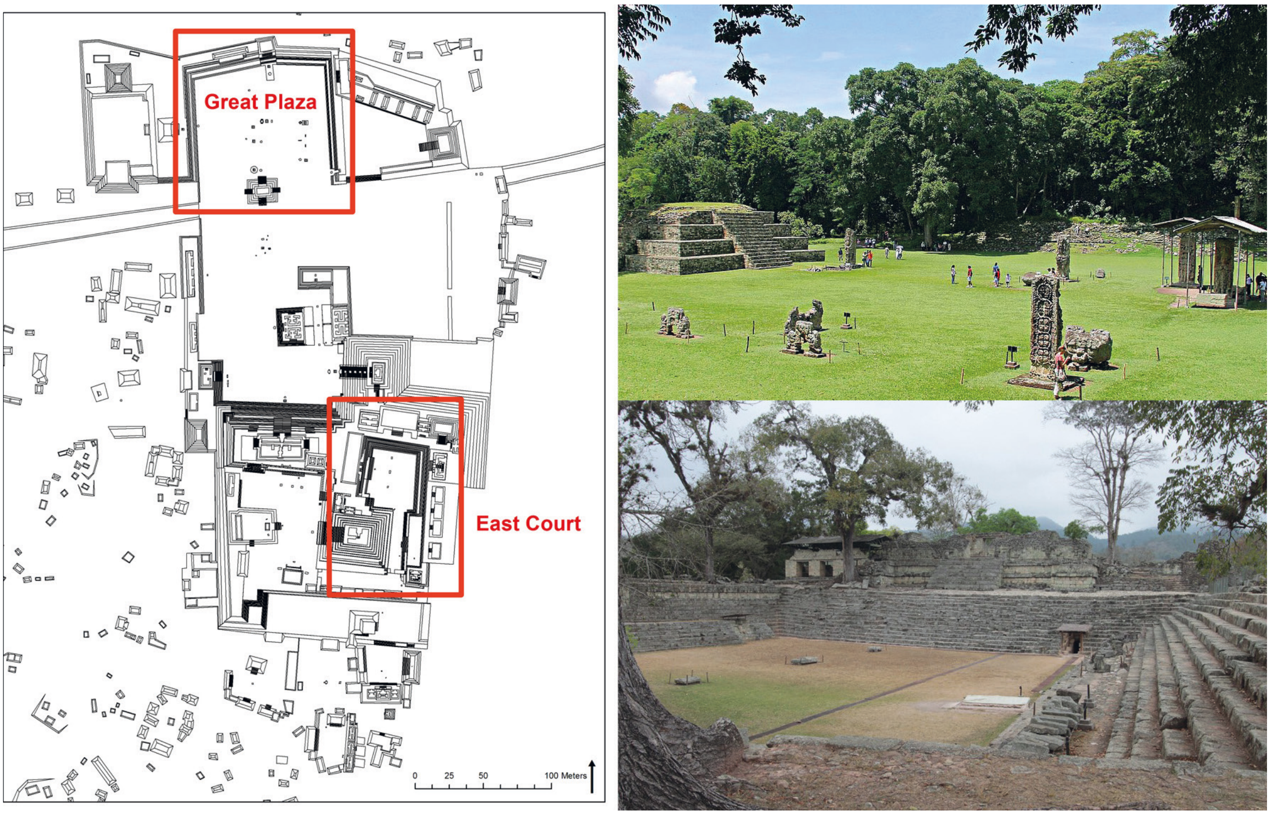


**Figure 1.** Main civic-ceremonial complex at Copán, Honduras (Great Plaza (top right); East Court (bottom right)).

ing of musicology where instruments with higher treble should be closer to the audience, while drums and other instruments with higher bass should be placed in the back (Houston et al. 2006). Additional archaeological evidence exists in the form of musical instruments, including shell trumpets, ceramic whistles, and wooden drums.

While musical instruments at the site of Aguateca are primarily found in elite contexts, instruments are also found in non-elite houses, suggesting music was not limited to a single social class (Stockli 2007).

The sonorous qualities of raw materials were also important in Mesoamerica. Clays, metals, and precious stones were selected for specific sound and color producing qualities in Postclassic Oaxaca. Moreover, clothing was often embellished with sound producing beads, pendants, and bells (King and Santiago 2011). Together, these lines of evidence indicate that sound was an essential component of ancient Maya life, but how did sound work in conjunction with different places, architecture, and material culture to differentially affect audiences, their experiences, and the messages they received?

## Case Study—Ancient Maya City of Copán, Honduras

The case study is the ancient Maya city of Copán. Today, Copán is a UNESCO World Heritage Site, but from the 5th to 9th centuries CE it was the center of a kingdom that at its peak covered about 250 square kilometers. Located at the southeast periphery of the ancient Maya world, it was an important cultural and commercial crossroad (Bell et al. 2004; Fash 2001). To begin to explore this question of "What roles did sound play in the urban dynamics of the ancient Maya?", we focus on the reign of Ruler 13, Uaxaclajuun Ub'aah K'awiil, who ruled the Copán kingdom from 695CE until he was decapitated by a nearby vassal state in 738CE.

Ruler 13 is known for introducing high-relief stelae and sculpture to the city. Scholars hypothesize that he commissioned the overhaul of Copán's Great Plaza, erecting several stelae within this open, public plaza to form a ritual circuit that he traversed in public performances (Newsome 2001). He also commissioned one of the city's most impressive temples, Temple 22, which he placed in the enclosed, private space of the Acropolis (von Schwerin 2011).

Presumably, the differential placement of this architecture held significance and differentially shaped the experiences of ancient Maya people in the eighth century. But, what were these experiences, how did experience differ based on audience, and more specifically can we use acoustics to enrich our understanding of ancient Maya ritual performance and architectural design and ultimately its impact on urban dynamics?

## Methods—Computational and Experimental

To begin to address these questions, we have designed a two-prong methodological approach that is computational and experiential. The computational part uses GIS and 3D modelling to derive quantitative data for acoustical analysis. The experiential part employs immersive virtual reality to offer a sense of past experience that involves vision, sound, and bodily movement.

### Computational

**GIS for Sound Propagation Calculations |** Spread-GIS is an open source ArcGIS toolbox (a series of five Python scripts) for modelling propagation of anthropogenic noise in wilderness settings (Reed et al. 2012). While the toolbox is primarily used for modelling the effects of noise pollution in ecosystems (Lorig 2016), a few archaeological applications exist. Researchers successfully applied Spread-GIS to calculate sound propagation in Levantine rock art sites in Spain (Díaz-Andreu and Mattioli 2015). In the U.S. Southwest, Primeau and Witt (2017) modified the scripts to create a new Soundshed Analysis tool, which they employed to model the propagation of sound at 33 sites within the Chacoan landscape (New Mexico). However, our approach differs from previous applications in two important ways: (1) we apply Spread-GIS in an urban landscape and (2) we incorporate 3D modelling data of architecture.

The ancient Maya are often viewed as practicing urban agrarianism (Isendahl and Smith 2013)—thus, to calculate noise propagation requires a modelling approach that incorporates both ecosystem and urban data, making a modified version of Spread-GIS appropriate. We made minor changes to the Python script to improve output resolution from 100m to 1m (to account for architectural features such as platforms, stairs, etc.), and adjust for syntax and other changes from ArcGIS 9.3 to ArcGIS 10.4.1.

Several environmental variables are required to run Spread-GIS. They include: temperature, humidity, wind speed, wind direction, and time of day. We use weather forecasts from Copán Ruinas, Honduras to fill these parameters, because they adequately represent past climatic conditions. Terrain (Digital Terrain Model-DTM) and land cover data (as raster) are also required. The MayaArch3D Project provided a 1m resolution Digital Terrain Model (bare earth) generated from airborne LiDAR (von Schwerin et al. 2016), but the analysis requires an Urban DEM comprising bare earth and archaeological structures. The MayaCityBuilder Project provided a 1m resolution Urban DEM (Richards-Rissetto 2017a) representing Copán's archaeological surface during the reign of its final dynastic ruler, Ruler 16, circa 800CE. However, our analysis requires an Urban DEM from the reign of Ruler 13, approximately 50 years earlier circa 750CE. To create this second Urban DEM, we modified the heights of structures from Copán's main civic-ceremonial complex—removing structures that did not exist (e.g., 10L-18, 10L-22A) and reducing heights of other buildings that existed but were not as tall (e.g., 10L-11, 10L-16)(Figure 2). We generated land cover data by combining geological, hydrological, and ecological data into vector data (shapefile) and converting to raster data with the attributes required to run Spread-GIS (Baudez et al. 1983; Fash and Long 1983).

Sound is produced when an object or substance vibrates and energy is transferred in a wave that alternatively expands and contracts, a cycle that repeats until the energy of the wave has dispersed (Moore 2005). This sound energy is measured by pressure and frequency using decibels and hertz. Decibels measure sound pressure (volume) and hertz measure sound frequency (pitch), or how many times per second the energy wave goes up and down. Objects with less air pressure have lower volume, and objects with a lower hertz (low-pitched sounds) have waves that go up and down slower and take longer to dissipate. The decibels and hertz of the sound source must also be set in Spread-GIS because, for example, drums

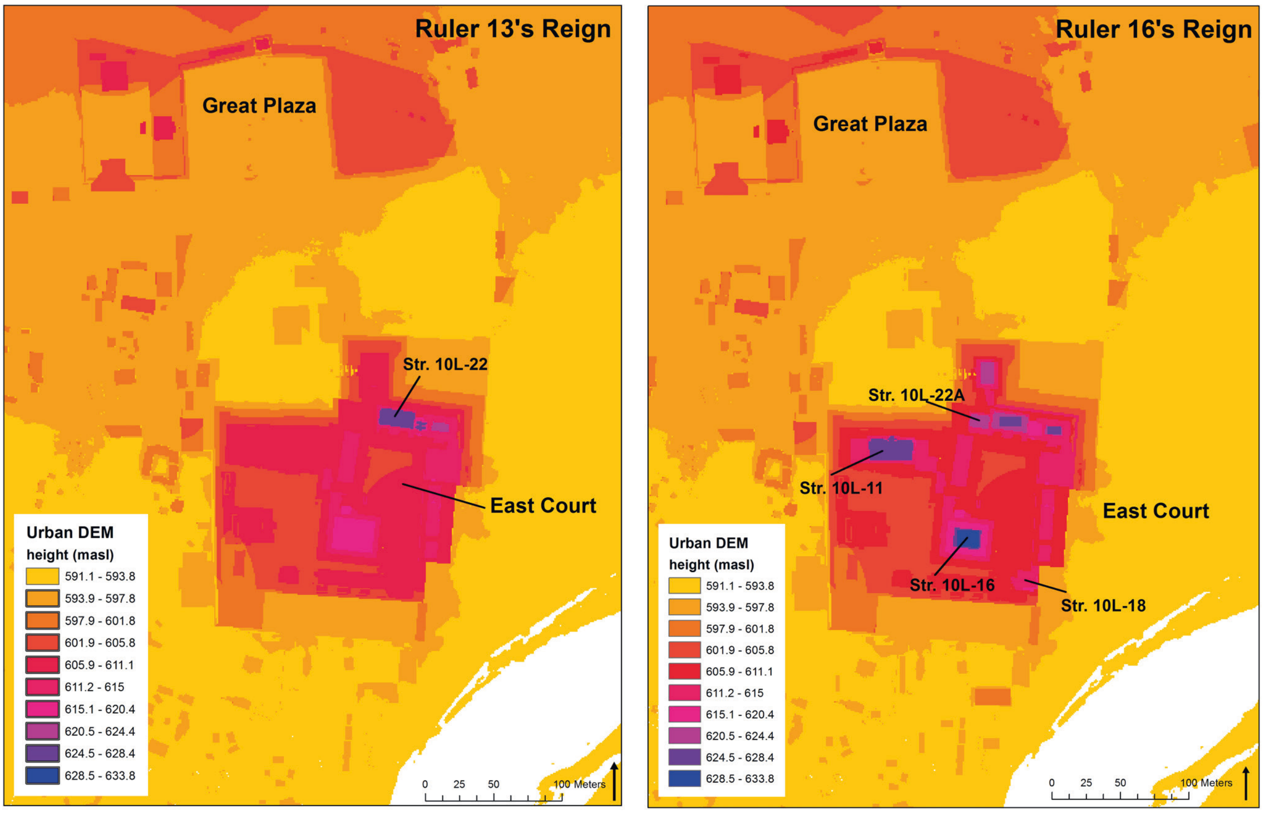


**Figure 2.** Urban DEM of Copán's main civic-ceremonial complex; East Court structures with heights for Ruler 13's reign; (left) East Court structures w/heights for Ruler 16's reign (right).

versus a human voice have different sound energy that affects sound propagation.

Spread-GIS has five modules—each module introduces a factor influencing sound propagation and requires data derived in a previous module. A shapefile (point) representing the location(s) of sound sources along with the Urban DEM and Land Cover data are required to run Module 1. Module 1: *spherical spreading loss*—the decline in sound level based on distance from the sound source. Module 2: *atmospheric absorption loss*—the decline in sound level due to air temperature, humidity, and elevation. Module 3: *foliage and ground cover loss*—the decline in sound level due to vegetation and terrain. Module 4: *downwind and upwind loss*— directional changes in sound level due to wind direction, speed, and seasonal conditions. Module 5: *terrain effects*—decline in sound level due to barrier effects from hills or ridge lines. The final output is a floating-point raster dataset that provides data on sound propagation in a landscape setting.

**3D Modelling for Sound Reverberation Calculations |** Trimble SketchUp is a user-friendly 3D modelling software that allows users to easily calculate surface area and volume—two measurements essential for calculating reverberation time and building capacity (i.e., number of potential occupants). The first step is to calculate reverberation time. Reverberation time is the time it takes for an echo to fade in a space. It is important for the clarity of speech and music. Too much reverberation and words become muddled, too little reverberation and a person's voice or music will not carry as far (McBride 2014). In ritual contexts, reverberations induce sensation among performers and observers (Hume 2007). Reverberation can aid in detection of otherwise inaudible sounds and help amplify sounds across space (Bruchez 2005). Architectural design directly impacts reverberation because sound is affected by the amount a surface reflects or absorbs sound and the dimension, shape, and properties of the space in which any given sound is produced (Mills 2014). The calculation requires three parameters: (1) surface area, (2) volume of a space, and (3) absorption coefficients of building materials (how much sound particular materials absorb). The equation is:

**Reverberation Time (seconds)** = Constant (0.049 for feet, 0.16 for meters)*Room Volume/Area Total [a]

[a] *Area Total = Surface Area x Absorption Coefficient*

**Equation 1.** Calculation for total reverberation time for architecture using 3D models.

For absorption coefficients, we used modern equivalents for stone and plaster to represent ancient building materials (McBride 2014). However, absorption coefficients do not remain constant; rather they vary by sound frequency, i.e., sound source. Furthermore, because sound is a wave of energy that oscillates, it is affected by the medium it passes through. Wind, temperature, background noise, reflection, refraction, and diffraction of sound all play a role in how far a sound travels. Hertz (or frequency) refers to how many times per second a sound wave moves up and down. A sound with a lower Hertz travels slower, dissipates slower, and tends to travel farther. Decibels (dB) measure the intensity of a sound. A sound with higher decibels is perceived as louder. Frequency of the human voice is typically between 80-500 Hertz (Hz). For this reason we chose to calculate frequency results for 125, 500, and 2000 Hz to cover the range of the human voice and also instruments. And, following Jerry Moore's (2005) we measure intensity using four categories: inaudible (0-10 dB), faint (10-40 dB), moderate (40-70 dB), and loud (70-100 dB) (Table 1).

The second step to calculate reverberation time is estimating the number of people that can fit in a space. The number of people affects reverberation time by increasing the number of potential sound sources, and surfaces for sound to reflect off. The relationship between acoustics and audience size is important because a tightly packed space can hold more people, but leaves less room for dynamic performances such as dancing or processions. Based on Takeshi Inomata's (2006) study of performance and capacity within Maya plazas, we test the impact of number of people on reverberation time for 0.46 m, 1.0 m, and 3.6 m per person.

### Experiential

The main objective of the experiential component is to begin to move beyond simply a visual experience in VR. Knowledge of the world relies on senses, and localization of a person within their environment is enhanced by interactions between auditory and visual sensations (Bruchez 2005; King and Santiago 2011). Spatial audio simulates the spaciousness of sound creating more immersive VR experiences by better situating users within 3D environments. Data from the MayaArch3D and MayaCityBuilder projects are being employed to create a VR landscape for ancient Copán (late eighth century) within the gaming engine Unity3D (Day and Richards-Rissetto 2016). Using the Unity 3D platform and Dear-VR, a Unity plug in that simulates human spatial hearing via head-tracking in VR headsets—we make use of the Oculus Rift headset to explore the potential of a synesthetic experience to induce a greater sense of embodiment by combining vision, sound, and movement (Fernández-Palacios et al. 2017; Forte and Siliotti 1997).

## Results

This section presents and compares the GIS sound propagation results for the open, public Great Plaza and the enclosed, private East Court to explore the potential role acoustics played during ritual performances. For the East Court, we also present the 3D

| Subjective Experience | Modern Examples | Map Color and dB Level |
|---|---|---|
| Inaudible | 10 dB Breathing | White (0-10 dB) |
| Faint | 20 dB Whisper | Yellow (10-40 dB) |
| Moderate | 50 dB Background conversation | Blue (40-70 dB) |
| Loud | 90 dB Jackhammer | Pink (70-100 db) |

**Table 1.** Intensity measures for acoustic analysis of subjective experience (based on Moore 2005).

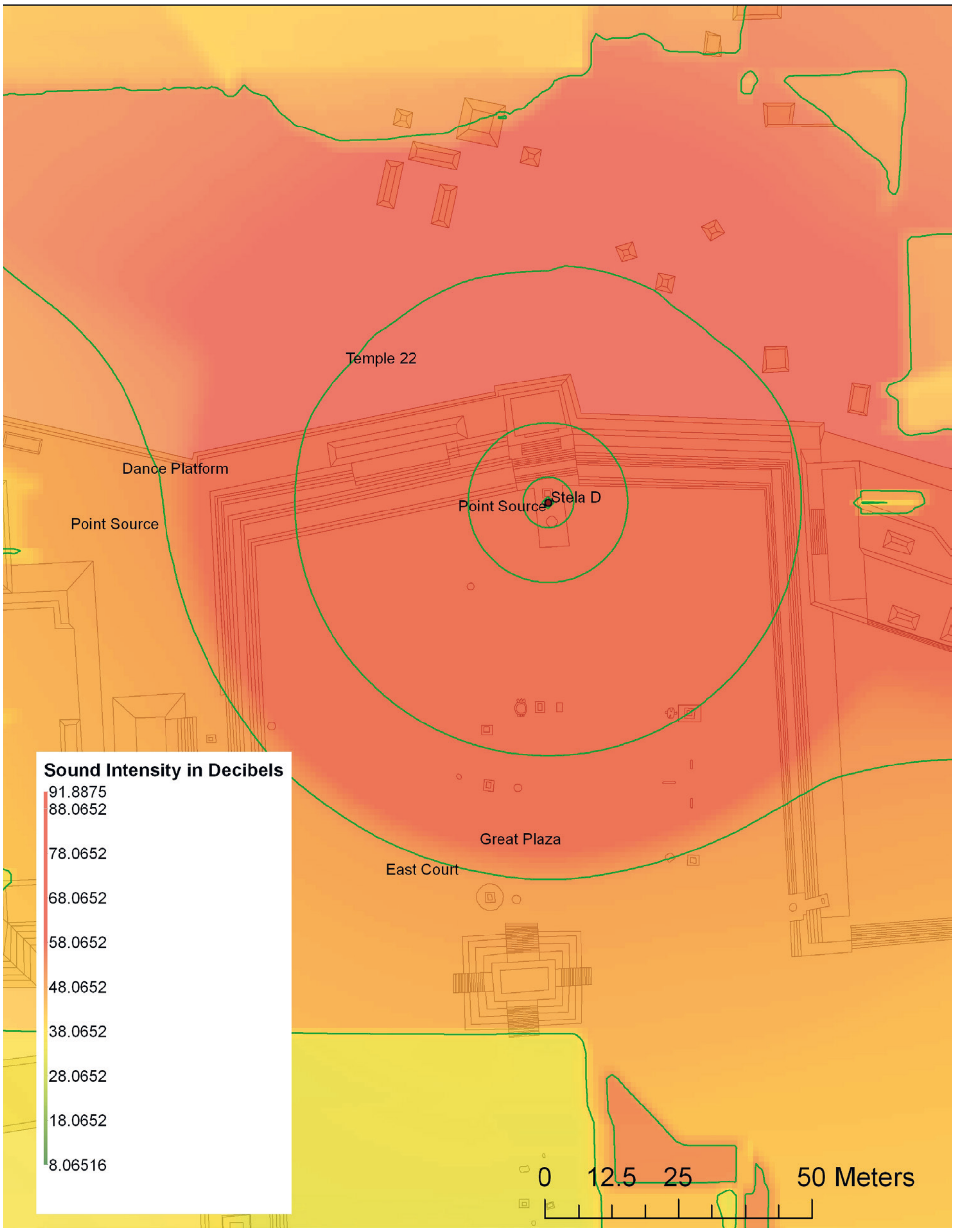


**Figure 3.** Sound propagation from Stela D, Great Plaza, Copán.

modelling reverberation results to further investigate the potential role of acoustics in ritual performance within "enclosed" spaces. Before continuing it is important to define what we mean by audible, and intelligible. We define audible as words being heard but not necessarily understood, while intelligible is defined as the words being understood. The parameters entered into Spread-GIS were:

**Parameters of Sound Source:**

- Frequency (Hz): 250
- Sound Level (dB): 75
- Measurement distance (ft): 50

**Environmental Parameters:**

- 79 Degrees Fahrenheit
- Humidity: 90%
- Average Wind Speed: 3 MPH
- Direction at 25
- Calm, Cloudy Day

## GIS Propagation Results

**Great Plaza |** Current interpretations suggest that Ruler 13 began his ritual circuit atop Structure 10L-4—a stepped pyramid that served as a dance platform evidenced by dancing Maize God iconography,

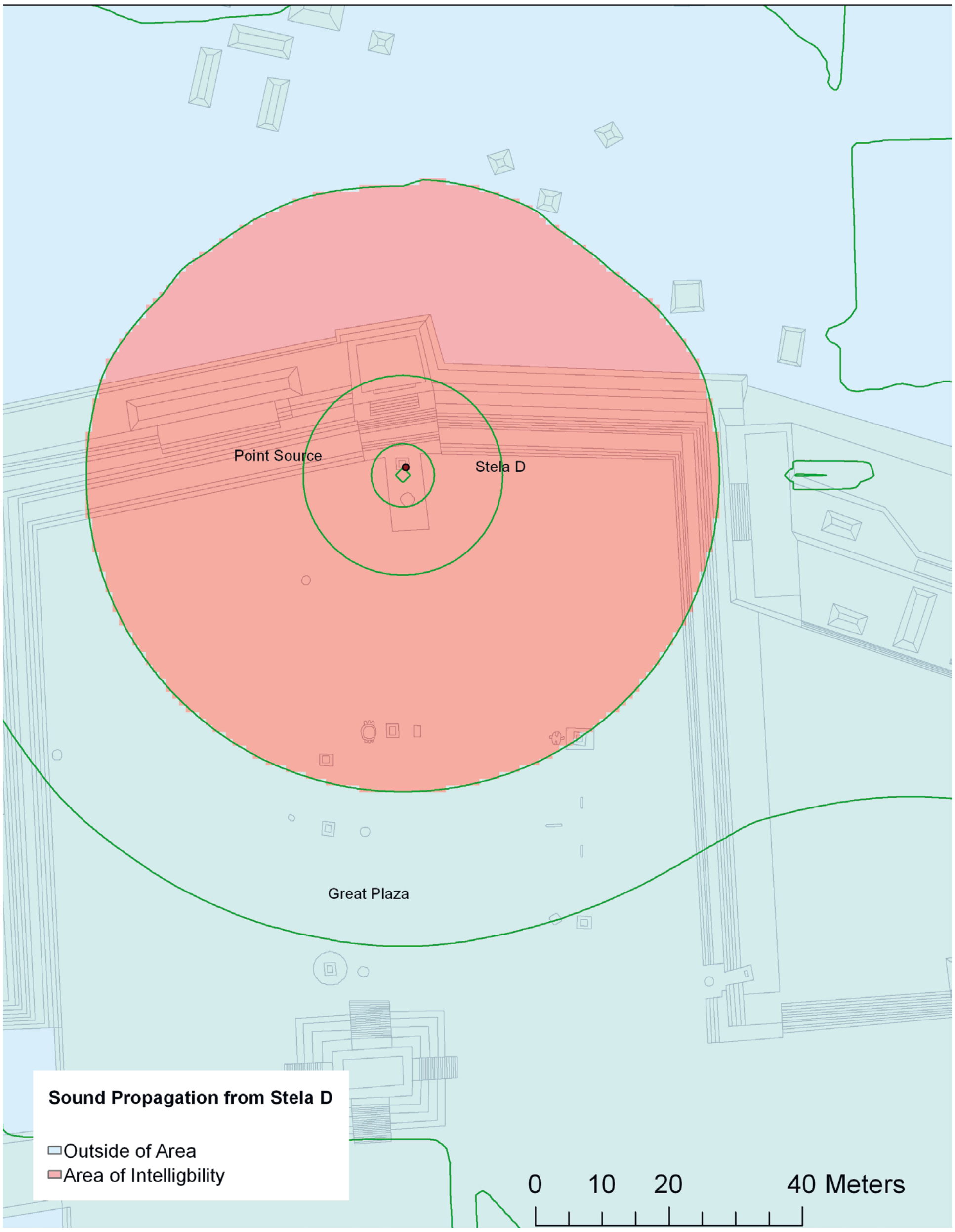


**Figure 4.** Map highlighting space in Great Plaza where speech would be intelligible from Stela D.

and proceeded down the step to process through the Great Plaza's seven stelae (Newsome 2001). We selected a source point placed at Stela D to represent a location where Ruler 13 might have stood during a ritual procession. Figure 3 shows a raster surface of sound propagation from Stela D. The results indicate that someone speaking at this location would be audible to people sitting on the steps surrounding the Great Plaza Stelae, supporting the hypothesis that these steps served as bleachers for an audience (Inomata 2006); but were the speaker's words intelligible, and if so, from what locations?

Figure 4 illustrates that area of intelligibility from Stela D (based on 60dB or higher). Table 2 compares total audience capacity to number of people able to hear and comprehend a speaker at Stela D. The results suggest that 0.46m per person is ideal spacing to maximize the number of people to directly hear a speaker's words in the Great Plaza; however, regardless of audience size approximately 9% of attendees could decipher a speaker's words. However, this does not mean that Stela D did not serve as an "oration" space for all participants. While the stela served as a visual focal point it would have also been an auditory attraction forming part of complex ritual performances that spoke to the Maya emphasis on synesthetic experience (Looper 2009). As humans we communicate beyond our voices; visual cues re-

| Meters per person | Capacity (# people) Great Plaza | # of People Intelligible Speech | % audience (intelligible) |
|---|---|---|---|
| 0.46m | 27,711 | 2504 | 9% |
| 1.0m | 12,747 | 1152 | 9% |
| 3.0m | 3,541 | 384 | 9% |
| Loud | 90 dB Jackhammer | Pink (70-100 db) | |

**Table 2.** Comparison of audience capacity to persons able to hear and comprehend speaker from Stela D.

inforce spoken messages. Moreover, a comparison of visual to auditory results can provide information on audience members and their social standing within ancient Maya society—individuals seated within areas of intelligibility may reflect acoustical targeting.

**East Court |** We used the same sound and environmental parameters in Spread-GIS to investigate sound propagation from the steps of Temple 22 in the East Court (Figure 4). The Spread-GIS propagation results indicate that a speaker from the steps of Temple 22 could be heard throughout most of the East Court but would likely have to rely on a raised voice, instruments, or visual signals (such as a headdress) in order to send a desired message to the entirety of the East Court (Figure 5). The acoustic results support hypotheses that Temple 22, dedicated by Ruler 13 in 715CE, served as a focal point for performance and that the East Court was an exclusive performance space for the elite (Inomata 2006; von Schwerin 2004, 2011). However, because sound, albeit unintelligible, was able to also be heard outside the East Court, the results suggest that others (non-elite) were meant to hear the performance, yet simultaneously be excluded; similar to seeing the highly visible Temple 22 and yet not able to directly access it (Richards- Rissetto 2010, 2017a).

Figure 6 reveals further analysis of East Court acoustics. Propagation results from the elevated Jaguar Dance platform 10L-1 (Looper 2008) suggest that it was an effective platform for vocal performance in the East Court with a larger soundscape than the Temple 22 stairway. While only some audience members within the East Court could see a performance situated on 10L-1, all audience members in the East Court and many beyond could hear the performance. These results also reinforce differential access to ancient Maya performances—only a small percentage of Copán's inhabitants could see a performance in the East Court, yet many elite and non-elite could hear it. Together, vision and sound were complementary. For some within the East Court they offered a synesthetic experience, but for others their experience was limited to one sense, i.e. sound, creating differential experiences and sending different messages to "audience" members.

The results indicate that 1-2 seconds reverberation time is ideal for clarity of speech and music; in contrast, at 3-4 seconds there is loss of articulation and difficulty understanding speech (Nave 2017). When the number of people in the East Court is between 0.46 and 1.0 meters per person, sounds at 500Hz, or 2000Hz have reverberation times between 1.287 and 2.54 seconds. It is reasonable to suggest Maya rulers would desire vocal clarity when addressing large crowds and Maya musicians would desire instrumental clarity when performing; thus, the results indicate that an audience size between 4,435-9,641 persons (based on Inomata 2006) is ideal for ritual performances involving speech as well as musical instruments in the East Court.

## 3D Modelling Reverberation

To further understand the acoustics of the East Court and its potential role in ritual performance, we calculated reverberation time from the East Court. Surface area, construction materials, and number of people in a space affect reverberation time; we used previously estimated capacities for the East Court (Inomata 2006). Figure 7 shows the 3D model in SketchUp used to calculate reverberation times using Equation 1 and Table 3 lists calculated reverberation times of the East Court.

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| # of People | Meters per person | Reverberation Time (secs)—125Hz | Reverberation Time (secs)— 500 Hz | Reverberation Time (secs)—2000Hz |
|---|---|---|---|---|
| # of People | person | 125Hz | 500Hz | 2000Hz |
| 9,641 | 0.46m | Apr-97 | Jan-37 | 1.287 |
| 4,435 | 1.0m | Aug-42 | Feb-54 | Feb-17 |
| 1,232 | 3.0m | Nov-23 | Apr-75 | Mar-84 |
| Empty | N/A | Dec-51 | Jul-51 | May-48 |

**Table 3.** Reverberation time in the East Court for a sound at 125Hz, 500Hz, and 2000Hz.

500Hz, or 2000Hz have reverberation times between 1.287 and 2.54 seconds. It is reasonable to suggest Maya rulers would desire vocal clarity when addressing large crowds and Maya musicians would desire instrumental clarity when performing; thus, the results indicate that an audience size between 4,435-9,641 persons (based on Inomata 2006) is ideal for ritual performances involving speech as well as musical instruments in the East Court.

## Conclusions

Archaeologists increasingly use GIS and 3D modelling to examine vision and movement within landscapes; however, few researchers have investigated the potential role of sound across ancient landscapes. Using a case study from the ancient Maya city of Copán, we have employed Spread-GIS, 3D modelling, and VR to begin to explore the role of acoustics in ritual performance and differential audience experience.

Proxemics, a term coined by Edwin Hall (1969) referring to how people use space in communication, categorizes interactions into four separate spatial distances: intimate, personal, social, and public. Researchers hypothesize that the open Great Plaza at Copán served as a performance space for large audiences comprising both elite and non-elite attendees. While the GIS results support this interpretation indicating that a speaker could be heard throughout the Great Plaza, the integration of GIS and 3D modelling provides additional information of differential audience experience. Initial calculations show that regardless of audience size, only about 9% of attendees could actually decipher the words of a speaker at Stela D, a hypothesized performance location along a ritual circuit in the Great Plaza (Newsome 2001). However, the placement of the Great Plaza's seven stelae suggests that movement combined with sound was integral to performance. Six of the seven stelae are located within 14 to 42 meters of the "bleachers"—this public spatial distance (far phase) is ideal for communicating with a large group; only Stela C is not within this public distance. Thus, as a performer (presumably Ruler 13) processed through the Great Plaza, the majority of audience members would be "incorporated" within the ceremony. Future work will compare soundsheds to viewsheds to determine if overlap and/or complementarity exist between vision and sound at each of the Great Plaza's stelae.

As for the restricted and enclosed East Court, researchers contend it was an exclusive performance space for the elite with Temple 22 and Structure 10L-1 serving as focal points for performance (Inomata 2006; von Schwerin 2004). The distance from the top of the Temple 22 stairs to the plaza floor below is 5.5 meters. In proxemics this distance fits within the public distance, close phase (3.6-7.6 meters) suggesting someone speaking from the stairs would be at an ideal distance for addressing a group gathered at the base of the steps; however, the enclosed courtyard comprising stairs (possibly serving as bleachers) allows a voice to reverberate across the space extending the impact of a speaker's voice. 3D modelling results reveal that when audience spacing is between 0.46 and 1.0 meters per person sound propagation is ideal.

However, performances atop the Jaguar Platform (Str. 10L-1) on the west side of the East Court could address larger audiences via sound propagation and reverberation. Based on population estimates, approximately 5-10% of Copán's population could participate in a ritual event held in the East Court supporting interpretations of it as a performance space for the elite. And yet, interestingly, the GIS sound propagation results indicate that people outside of the East Court could hear voices and instruments suggesting that these secluded events, while visually restricted, were still meant to be heard. The fact that they could be heard but not seen would have created an air of mystic enhancing elite power.

Theatrical events and politics are closely linked in Classic Maya Society, and dynastic rulers benefited from the creation of memory through public ritual (Inomata 2006). While physical distance is a major factor in the regulation of human interaction and experience, urban design and elements of the built environment also influence social experiences. The placement of temples, plazas, freestanding monuments, stairs, and other built forms regulate interaction by insulating some individuals for small, private affairs and welcoming large crowds for other large, public events (Moore 2005). Among the ancient Maya, synesthetic experiences incorporating multiple senses were integral to daily life and ritual performance (Houston et al. 2006). The spatial organization of cityscapes differentially affected human experiences—they were not the same for everyone. Large, open spaces accommodated more people, inviting them to participate in events through sight and sound. In contrast, small, enclosed spaces restricted audience size allowing only a relative few to see a performance and yet through sound others, outside of the performance space, could still participate—simultaneously sending messages of inclusion and exclusion to Copán's non-elite inhabitants; thus, promoting social cohesion alongside messages of elite power and authority.

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