GIS APPLIED TO BIOARCHAEOLOGY: AN EXAMPLE FROM THE RÍO TALGUA CAVES IN NORTHEAST HONDURAS

NICHOLAS HERRMANN
Department of Anthropology, The University of Tennessee, Knoxville, TN 37996 USA

The presence of human skeletal remains in caves is a common phenomenon throughout the world. In an effort to preserve these remains, researchers often document the material in situ*. The application of a geographic information system (GIS) in combination with a flexible recording system provides an efficient means of recording the context of the burial or ossuary. Two caves, La Cueva del Río Talgua and Cueva de las Arañas, in eastern Honduras, provide a case study for the application of a GIS to human skeletal remains from cave environments. A GIS-based investigation offers the ability to visualize the relationships and context of the ossuary. It also provides a means to estimate specific population parameters, such as the minimum number of individuals and the Lincoln Index.*

When confronted with osteological remains in cave environments, archaeologists must realize the significance of the skeletal material and appreciate the context of these remains. In Binford's (1971) essay on mortuary practices, he assumes that a "burial" with all its associated attributes reflects the individual's social persona and expresses the communal "debt" owed the deceased. Deep cave interments may result from a complex social context, or may simply document the fate of an unlucky adventurer, as in the case of prehistoric miners in Mammoth Cave (Meloy 1971). The deposition of bodies within vertical shafts or sinks may be the most convenient mode of interment for a local community, or this process may be a symbolic ritual (e.g., for returning the body of the deceased to the underworld). In either situation, the archaeologist must evaluate the remains from both cultural and biological frameworks within the context of the burial environment. Cave archaeologists and skeletal biologists should work together to devise logical, reliable, and efficient methods of data collection for the documentation of these unique archaeological resources. One useful system of recording karst mortuary facilities is within a geographic information system (GIS) framework enabling bioarchaeologists to reconstruct and examine the burial context outside the cave. This paper reviews Honduran cave mortuary practices, describe obstacles and confounding factors involved in cave bioarchaeology, and details the application of a GIS in the analysis of osteological remains from La Cueva del Río Talgua and Cueva de las Arañas in eastern Honduras. Finally, it summarizes the osteological data derived from Cueva de las Arañas.

LA CUEVA DEL RÍO TALGUA AND CUEVA DE LAS ARAÑAS

Human osteological remains were discovered in 1994 in a cave above the eastern bank of the Talgua River, 7 km from Catacamas in the Olancho Valley of northeastern Honduras (Brady 1994; Fig. 1). With permission of the Instituto Hondureño de Anthropología e Historia and under the direction of James Brady as part of a joint archaeological field school of George Washington and Western Kentucky Universities, basic skeletal data were collected during a three-week period in June 1996. The ossuary in Cueva del Río Talgua, or "The Cave of the Glowing Skulls", was the primary focus of the osteological fieldwork. Hereafter, this cave is referred to as Talgua. Prior to the arrival of the osteological research team, a second mortuary cave with human skeletal remains was discovered. Recent explorers had not disturbed the ossuaries within this cave, and only limited prehistoric disturbance had occurred. The survey team named the cave "Cueva de las Arañas" (or "Cave of the Spiders") for the arachnids prominently present throughout it. This cave is referred to as Arañas.

Mortuary activities in both caves date to the Formative Period, also referred to as the Preclassic period (Brady *et al.* 1995a; 1995b; 2001). Five uncalibrated radiocarbon dates derived from bone and charcoal samples from both caves cluster within a 600 year period between 3110 BP and 2510 BP (Brady *et al.* 2001), but the calibrated two-sigma ranges of these dates span a 1000-year window. The Arañas assay (Beta-95367 2790±100 BP: Brady *et al.* 2001) falls nicely among four Talgua dates, which strongly suggests that the caves are contemporaneous and may represent the mortuary program of one population. A sixth radiocarbon date from Talgua (WG286 1385±75 BP: Brady *et al.* 2001) suggests that later populations in the region may also have used the cave. Additional mortuary caves have been found in this area, but the bioarchaeological significance and temporal placement of these sites have not been determined. Two of the radiocarbon dates are Accelerator Mass Spectrometry (AMS) determinations on human bone from the cave. As a result of AMS dating, basic carbon ratios ($^{13}C/^{12}C$) were calculated, which provide valuable evidence for dietary inferences (Buikstra 1992). The $\delta^{13}C$ indicate that the Río Talgua populations were not consuming substantial quantities of maize (corn). This determination is important because diets of later Mayan populations in western

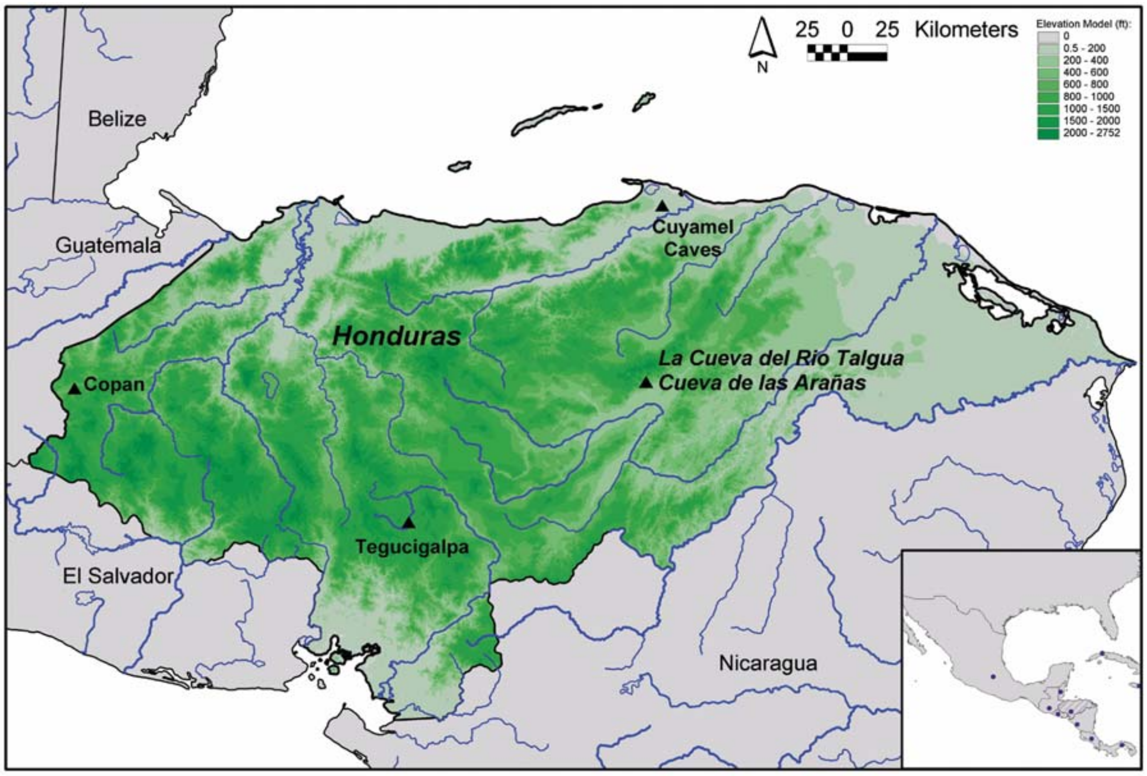

Figure 1. General elevation model of Honduras with the locations of the Río Talgua Caves, Copan, and the Cuyamel Caves.

Honduras (Copan), Guatemala, and Mexico relied heavily on maize. Subsistence in the Talgua population may have been based on a variety of non-domesticated plants, tubers, and fauna. Manioc is a likely candidate for a primary staple of these groups, similar to a pattern documented in many Central American populations (Piperno & Holst 1998).

Mortuary program

Human interment within cave environments is a common approach to the disposal of the dead. Throughout the world, caves have been used as burial facilities. In North and Central America, cave passages and vertical shaft pits have been exploited (Robbins 1974; Walthall & DeJarnette 1974; Willey & Crothers 1986; Turpin 1988; Haskins 1990; Bement 1994). For example, the Woodland Period Copena mortuary complex of northern Alabama exhibits a diverse burial tradition, including extended inhumations and cremations in cave passages and shaft pit interments (Webb & Wilder 1951; Walthall 1974; Walthall & DeJarnette 1974). These mortuary caves often include numerous grave offerings and elaborately prepared burial facilities. The Archaic Period cave mortuary program of central Texas, on the other hand, differs significantly from the Copena example. In central Texas, Bement (1994) documents a mortuary pattern that entailed the interment of partially or completely defleshed individuals into vertical pit shafts and sinks, such as Seminole Sink (Turpin 1988). In the case of the Talgua caves, it appears that the indigenous population transported the skeletonized remains of numerous individuals into the back passages of these caverns. Individuals of all ages were either disarticulated or allowed to decompose away from the caves. These remains were then bundled into some type of container, into which copious amounts of red ocher/hematite were added. The bundles were carried into the caves to fairly inaccessible areas and stacked in small piles in niches, within flowstone pools, and on shelves (Fig. 2). Multiple individuals and, in many cases, multiple ages are represented at all loci. Burial offerings were included with some, but not all, of the bundles. Offerings include ceramic vessels, jade pendants and beads, and shell beads. Talgua contained a number of these mortuary items, but burial goods were noticeably absent from Arañas, where only four beads were recorded.

The full mortuary program of Preclassic peoples in northeastern Honduras is not well understood because few Preclassic open-air sites in this region have been investigated. However, the archaeological context and ceramic evidence appears similar to those recorded by Healy (1974) from the Cuyamel caves in the Department of Colon in northeastern Honduras (Fig. 1). Healy's (1974, 1984) work indicates that the mortuary program of the Cuyamel caves was quite similar to that of the Río Talgua region. No formal skeletal analysis or basic bone inventory has ever been conducted on the remains in these former caves, however. Gordons Cave #3 is a well-reported ossuary cave near Copan in northern Honduras (Fig. 1). Most research (Gordon 1898; Rue *et al*. 1989) has suggested that the large ossuary in the back room (Chamber #3) of the cave dates to the Middle Preclassic period of the Copan valley (ca. 900-300 B.C.), but this chronology has come under question by Brady's (1995) excavations in the other two chambers of the cave. The skeletal analysis for this material provides evi-

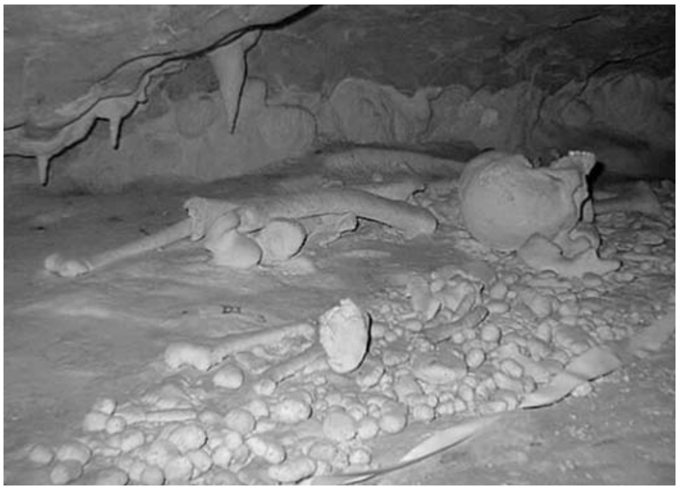

Figure 2. View of Lot III-03 near the back of Arañas.

dence of a select mortuary population comprised primarily of subadults. Brady suggests the biased demographic profile may have resulted from the offering of young children and infants as sacrifices, or as companions for the deceased adults. Brady and colleagues propose a unique Honduran Preclassic cave mortuary program differing significantly from those of the lowland Mayan communities (Brady 1995; Dixon *et al*. 1998; Brady *et al.* 2001). Typically, the lowland Mayan mortuary use of caves focuses on a relatively limited number of individuals that may represent sacrifices (Roberts 1990; Brady 1995). The eastern Honduran examples, specifically the Río Talgua data, differ in that no evidence of the trauma usually associated with sacrifice has been identified. Poor preservation and calcite deposits limit observations of bone surfaces, however.

CAVE BIOARCHAEOLOGY

The basic principle followed here is that cave bioarchaeology is the same as bioarchaeology undertaken anywhere else (compare to Watson 1997). Osteological data collection from caves varies from complete excavation and removal of skeletal material to simple documentation and conservation. Excavations in rock shelters and in some deep caves are no different from excavations of human remains at open-air archaeological sites. With prior legal permission, material is exposed, documented, removed, and analyzed. Thus, a majority of the osteological data is ideally derived in the laboratory outside the cave environment. Dealing with the skeletal materials from Río Talgua did not afforded such a luxury, however. Hence, a well defined, but flexible means of data collection needed to be employed.

The Río Talgua samples are fraught with analytical problems. Because these samples are ossuaries, many of the skeletal elements are fragmented, and all are commingled. Furthermore, the Honduran government requested that all *in situ* material remain in the caves, and that the majority of the analysis be conducted within the caves as well. In most cases, elements were cemented in place by calcite, especially in Arañas. Thus, encrusted remains could not be moved, examined, or assessed for the presence of pathological lesions. In addition, skeletal elements above the old waterlines are typically reduced to bone meal due to taphonomic factors and/or looting activities.

For the Río Talgua ossuaries, a specific data collection strategy for human remains was adapted from the work of Church and Burgett (1996). Burgett (1990) initially developed this information recording and retrieval system to document *in situ* commingled and fragmentary faunal remains. The system offers a quick and efficient format to gather data from the Honduran ossuary caves that minimizes impacts to the *in situ* and disturbed material.

The coding system is an alphanumeric "*integrated identification hierarchy"* within which element, portion, and segment of the bone are identified (Church & Burgett 1996). In addition to the identification hierarchy, Church and Burgett (1996) incorporate basic bone properties and taphonomic attributes. The *properties* fields constitute size, age, sex, fusion/development, and pathological conditions. The *taphonomic* attributes include weathering, gnawing, modification, breakage, burning, and trauma. Based on our initial visits to the caves, an assessment of calcite encrustation was added. This information was entered into the Río Talgua Specimen database within *Paradox*©. These variables can readily be visualized within a GIS platform for examining patterns in the distribution of the various skeletal and taphonomic attributes.

Standard osteological techniques cannot always be applied to cave ossuary samples. Due to commingling and other taphonomic processes, researchers are often restricted to an elemental level analysis, an approach often employed by zooarchaeologists (Grayson 1984; Reitz & Wing 1999). One of the primary objectives of any bioarchaeological research is to inventory and quantify the number of individuals in the skeletal sample. In most burial situations, determining the number of individuals is fairly straightforward. These estimations can be more problematic for cave ossuaries, however. For most commingled human skeletal assemblages, researchers quantify the sample through a Minimum Number of Individuals (MNI) estimate. Skeletal material is sorted according to element, age, and bilateral symmetry, and then counted. The most frequently occurring element provides the MNI estimate.

Research has demonstrated that MNI estimates are generally biased, and dependent upon skeletal recovery rates. Therefore, MNI estimates derived from poorly preserved samples are highly suspect. An alternative to MNI estimates when addressing commingled human remains is the Lincoln Index (LI), also known as the Peterson Index (Grayson 1984). Adams (1996) has demonstrated that the use of the LI for commingled human remains may provide a better estimate of the death assemblage than does an MNI estimate. The LI is calculated from any paired skeletal element, usually long bones because they preserve fairly well. First, the number of observed left and right elements is multiplied, then the product is divided by the

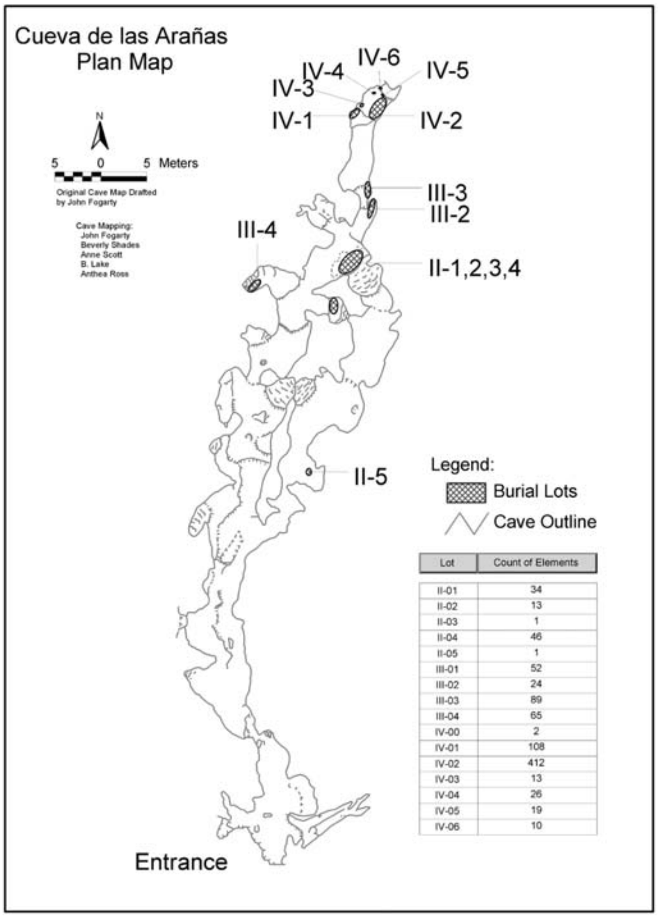

Figure 3. Plan map of Cueva de las Arañas with burial lots marked.

number of matched pairs within the sample. "Matched pairs" refers to the number of left and right elements that were determined to be from the same individual (either through visual assessment or some quantitative method). The LI is also susceptible to error, however. For example, extreme fragmentation can severely bias LI estimates. When dealing with small samples (less than 20 individuals) and relatively high recovery rates, the LI and MNI usually provide similar estimates.

The analysis of the Río Talgua mortuary caves used MNI estimates supplemented in some cases with LI information. A combination of calcite encrustation, severe fragmentation, and degradation of the skeletal material in both caves restricted to pair-matching of elements, thus limiting the use of LI. In some instances, specific individuals could be identified, but skeletal material in Talgua was so disturbed that elements could not be paired. Therefore, MNI estimates were used for Talgua. In Arañas, however, skeletal preservation of several lots was sufficient to use MNI and LI to estimate the burial population. The LI estimates were derived from visually examining ArcView themes and counting the number of paired and unpaired elements.

Mapping and digital imaging

Several unique methods were employed to facilitate rapid data recovery from both caves. This discussion focuses on the work in Arañas because GIS applications were used more extensively there and Talgua was extensively disturbed. During the 1996 season, digital images were taken of all burial lots in Arañas with an Epson *PhotoPC* digital camera. At the time of the field investigations, widespread use of digital imagery was just beginning and the resolution of the images is low (640x480 pixels). Nevertheless, field osteologists used printed copies of the digital images for each lot to aid in the inventory and mapping process. These images enhanced the efficiency of data collection by providing preliminary maps for each location. Notes and specimen numbers could be placed on the printed images during data collection. The digital photographs furnished a quick reference resource and location control. In instances of small bone clusters, the digital image served as the field map, and a line drawing could then be generated within ArcView by digitizing the geo-referenced image. In addition, each lot was closely examined for *in situ* deposits or articulated skeletal material. Intact deposits were mapped on graph paper and tied to a specific datum on the cave map.

Various data sources combined within ArcView reconstructed the cave system and ossuary locations within the cave. John Fogarty, one of the lead cavers working on the project in Honduras, drafted the cave map. During survey and mapping, Fogarty divided the cave into several areas termed *Operations*. These operations were then subdivided into discrete *Lots*. Skeletal data was recorded by the original operation and lot identifications. Areas discussed in this paper are identified by the Operation-Lot designation (e.g. Operation IV, Lot 2 is IV-2).

Original cave mapping data entered into COMPASS (http://www.fountainware.com/compass/) created a three-dimensional plan map of the cave. These data could be imported into ArcView using the Cave Tools extensions (http://www.mindspring.com/~bszukalski/cavetools/cavetools.html). Next, the various individual burial lots were digitized and imported into ArcView, rotating, scaling, and moving each polyline themes into position relative to an associated cave datum. Although the example from Arañas is small, these methods could be employed for larger ossuaries, either subterranean or open-air sites.

ArcView extension Edit Tools (http://www.ianko.com/EditTools/et_main.htm) converted the digitized polylines to polygons. Each polygon was assigned a specific Specimen Number. Next, the polygon theme was linked to the Río Talgua Specimen Database, as described earlier. Once the tables were joined, the ossuary could be queried to examine specific elemental, taphonomic, or demographic patterns in the bone scatters.

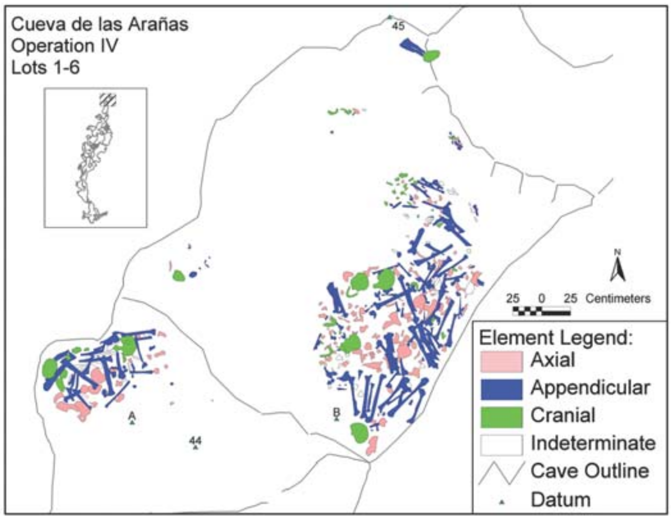

Figure 4. Coded plan map of Lot IV in Arañas. Elements are coded by skeletal divisions (cranial, axial, appendicular, or indeterminate).

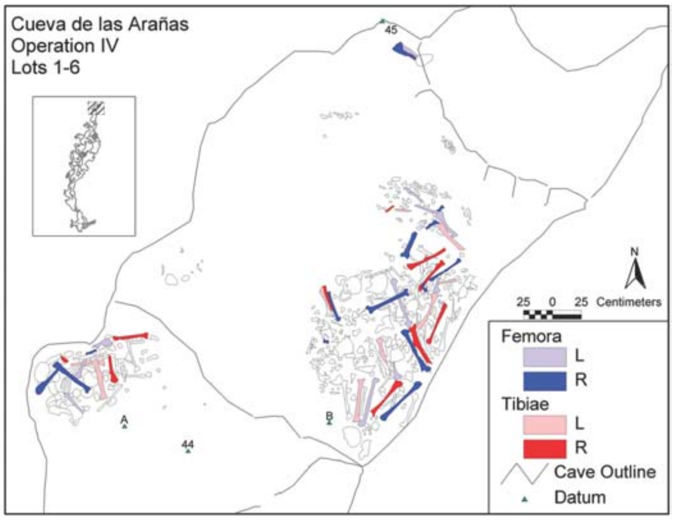

Figure 5. Filtered plan map of Lot IV in Arañas. Femora and Tibiae are identified and coded by side.

RESULTS FOR CUEVA DE LAS ARAÑAS

In Arañas, several discrete burial areas, or lots, were identified. The larger bone scatters were in the back of the cave (Fig. 3). Typically, bones appear to have been placed behind flowstone dams, possibly within pools of water. In the case of Lots IV-1 and IV-2, bone concentrations are quite dense with moderate to heavy calcite encrustation. Other lots were located in niches or along the walls in small passages. Preservation in most locations varied according to the duration of water exposure. In Lot III-3, nearly all elements were located below the old water line. The elements are heavily encased in calcite but some data could be collected, including cranial metrics and dental pathology.

The maps produced for these lots assisted in the determination of the MNI for the cave. In Figure 4, the lots in the back of the cave are plotted by skeletal region (cranial, axial [midline], appendicular [limbs], or indeterminate). This visualization technique aids in interpreting the distribution of elements within the ossuary. Typically, a cranium is surrounded by a series of appendicular elements with the axial elements randomly distributed.

The ossuary theme was then filtered for two specific elements, in this case femora and tibiae. These lower limb bones were then coded by side and plotted. Based on observations from Talgua, it appears that bundles of bones were brought into the cave and placed in the ossuary areas. Typically, the cranium was placed next to or on top of the bundle. Therefore, we expected linear clusters of elements that probably came from the same individual. In Figure 5, the distribution of sided femora and tibiae is depicted. In general, the expected pattern of clustered elements is present. Several distinct clusters of elements, possibly former bundles of bones, are evident. These bone clusters were counted to provide the number of "paired" elements, and this value can be factored into the LI determination. Elements not associated with a specific cluster were considered as unpaired. I use the paired and unpaired values to calculate the LI. Also, each element could be counted by size to estimate the MNI.

Combining observations from skeletal element MNIs, dental remains, and the visualized pair matching using GIS derives a burial population of 22 individuals for Arañas. The LI estimate for femora in Operation IV is 12.2 (with 9 pair matches), whereas the MNI is 11. The slight difference results from "unpaired" elements in Lot IV-2. All the other elements within the Operation IV produce LI and MNI estimates that were lower than the femur values. A combination of elements can be used to estimate the LI (Grayson 1984; White 1996), but the counts per element at Arañas were so low that this approach was deemed unnecessary. If the ossuary sample was larger, a multi-element LI approach would provide a better estimate of the burial population size as compared to a basic MNI.

Three individuals identified at Arañas are subadults (less than 15 years) and the remaining 19 individuals are adults. A similar demographic pattern was observed in the Talgua sample, where a minimum of 73 individuals was identified based on the osteological analysis. A total of 15 subadults were present in this sample. The age distributions of these caves are not significantly different ($X^2 = 0.1721$, df = 1, p-value = 0.68) and support the conclusion that the skeletal samples from these two caves are derived from the same population.

CONCLUSION

The Río Talgua ossuaries represent a rare cultural and archaeological resource. The method detailed here was devised to preserve this resource through documentation and recording of skeletal material *in situ*. By means of GIS applications, we can examine the ossuaries outside the cave. A GIS based analysis provides "quick retrieval and flexible display" of the spatially referenced skeletal data (Green 1990: 3). If skeletal material is extremely fragmented, unidentifiable, or disturbed, as in the case of Talgua, the application of GIS is difficult and unproductive. Elemental mapping and LI estimates are not possible. On the other hand, the undisturbed burial lots found at Arañas do allow the application of a GIS, as illustrated in this paper. High-resolution digital imaging and improved mapping software will permit quicker and more detailed documentation of such cave resources without disturbing the deposit. The example presented from Arañas is small, but it demonstrates the utility of an adaptable data collection system for recording human skeletal material within cave interiors.

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