Ground Truthing of Remotely Identified Fortifications on the Central Coast of Perú

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Abstract
Remote imagery, including freely available satellite images viewed in Google Earth® and historic aerial photographs, was used to identify anomalies in a 25,000 km² macroregion encompassing 13 river valleys along the Peruvian coast. These anomalies, located atop hills and mountains, were hypothesized pre-hispanic fortifications. A sample of remotely identified anomalies was ground truthed in the Huaura and Fortaleza Valleys on the Central Coast of Perú. 140 positive anomalies were documented and assessed using a simple defensibility index. Our results significantly increase the number of fortifications identified in both valleys. We demonstrate the efficacy of this method for locating fortifications in a very large region to facilitate the systematic documentation of these durable indicators of warfare.

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1. Introduction
Episodes of warfare form key points in the plotlines of history. A number of large regional syntheses of archaeological data for North America (Lambert, 2002; LeBlanc, 1999, 2003; Milner, 1999), Mesoamerica (Brown and Stanton, 2003; Hassig, 1992; Webster, 2000), the South-central Andes (Arkush, 2005, 2006, 2008), the Pacific (Allen, 1996; Field, 2008; Field and Lape, 2010) and Europe (Carman and Harding, 1999; Keeley, 1996; Parkinson and Duffy, 2007) demonstrate that ancient warfare was widespread and until recently understudied. This paper presents initial results from a new large regional study of fortified architecture that is aimed at understanding ancient warfare. We focus on two previously surveyed valleys and demonstrate that the material remains of ancient warfare were under represented. The methods we employ provide an inexpensive and efficient means to remedy this situation.

1.1. Description of research project
Fortifications are a relatively durable indicator of past conflict (Field and Lape, 2010: 214; LeBlanc, 1999: 56). Some scholars consider fortified architecture among the largest and most costly constructions built by pre-industrial groups (e.g. Keeley, 1996: 55). These structures form a good starting point from which to examine ancient warfare.

Wars may be widespread, or highly localized. Thus, fortifications may be constructed in the context of local, regional, or global processes. Given that the extent of war may vary spatially, investigating patterns of fortifications to examine warfare at varying scales benefits from studies of large expanses of territory, either regions or macroregions (Kowalewski, 2004: 88; Zhang et al., 2007).

To enable analysis and comparison, macroregional studies require systematic data collection and the compilation of very large datasets into a single database. Project Awqa Pacha (Quechua for “Times of War”) is a multi-year research program to systematically locate and document fortifications along the central and north coasts of Perú. Awqa Pacha is synthesizing existing datasets, and contributing new data, to permit analysis of fortification patterns at multiple scales. This case study focuses on a stretch of the Peruvian coast that incorporates 13 valleys. The macroregion we define is bounded by the Virú Valley in the north, the Chillón Valley in the south, the coastline to the west, and the 2500 m contour line to the east (Fig. 1). The study encompasses an area of roughly 25,458 km².

Pedestrian surveys have been carried out in nine of the 13 valleys that comprise the macroregion (Table 1). Data from these surveys is variable in terms of the field methods used, the reporting of results, and access to the reports. Brown Vega’s recent synthesis (Brown Vega, 2010: Tables 9.2 and 9.3) of published and unpublished data for 11 of the 13 valleys, from Virú to Huaura, indicated there were 73 fortifications attributed to the Early Horizon, and 75 attributed to the Late Intermediate Period (see next paragraph). Fortifications pertaining to other time periods were not enumerated. This synthesis highlighted the lack of basic regional data for
a number of valleys, underscored the issue of data inaccessibility for other valleys that had been surveyed, and identified differential reporting of fort attributes that would be important for regional comparison. Macroregional studies require consistency in sampling density and attribute numeration.

Perú, part of the Central Andes, has yielded evidence of ancient warfare for a number of time periods. In the Andes, warfare is known for the Early Horizon (EH, ca. 900–200 B.C.), the Early Intermediate Period (EIP, ca. 200 B.C. – A.D. 600), the Middle Horizon (MH, ca. A.D. 600–1000), the Late Intermediate Period (LIP, ca. A.D. 1000–1450), and the Late Horizon (LH, ca. A.D. 1450–1532). The Peruvian coast is an ideal place to examine warfare because it has long been at the heart of theoretical debates regarding coercive processes in the development of complexity (Carneiro, 1970, 1988: 508–509; Wilson, 1983: 215, 1988: 357). Based on existing knowledge, the first clear evidence for the construction of fortification in the Central Andes appears in the EH. Warfare and the rise of state-level societies appear to characterize the EIP. Expansionist imperial polities may emerge in the MH, possibly causing turmoil upon their collapse (LIP). War is seen again when two empires, Chimú and Inka, emerge in the LH, the latter ultimately conquering the former.

Conflict during these periods is evidenced by iconographic representations (EH, MH), weaponry (EH, LIP, LH), massacres and sacrifices (EIP, LIP), and ethnohistoric accounts (LH). Yet, systematic studies of fortifications, particularly over large regions of the Andes, are in their infancy. Still lacking are large datasets of the principal evidence for conflict, fortifications, with which to test models of warfare during these various periods. A few recent studies show the potential for assessing regional patterns of prehispanic warfare by examining fortified architecture in multiple valleys (Arkush, 2005, 2006, 2008; Brown Vega, 2010; Chamussy, 2009). Aerial photography in particular has proven effective for remotely identifying highland hilltop fortifications (pukaras) prior to field survey (Arkush, 2005: 202–206).

Surveying in mountainous or steep terrain, where fortifications would be located, can be challenging (Parcak, 2009: 126). We discuss methods and results applied to a remote sensing survey of two valleys, Huaura and Fortaleza, and subsequent ground truthing of a sample of anomalies located in such terrain. The results contribute new data to our macroregional database.

1.2. The case study: Huaura and Fortaleza valleys

The Huaura and Fortaleza Valleys are located in the southern portion of what Awqa Pacha calls the Peruvian coastal macroregion (Fig. 2). These two valleys were chosen to assess our methods because recent full-coverage surveys have been conducted in both drainages (Nelson and Ruiz Rubio, 2005; Perales Munguía, 2007). Comparison of our findings to full-coverage survey results would help evaluate the efficacy of remote survey followed up by ground truthing.

The areas surveyed in these valleys, below 2500 m.a.s.l., pertain primarily to the chala (0–500 m.a.s.l.) and yunga (500–2300 m.a.s.l.) ecological zones (Pulgar Vidal, 1996: 19, 26). The chala, or temperate, humid coastal desert, is usually covered by a year-round fog cap.

### Table 1

Previous pedestrian surveys conducted within the Virú-Chillón coastal macroregion.

<table>
<thead>
<tr>
<th>Valley</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virú</td>
<td>(Willey, 1953)</td>
</tr>
<tr>
<td>Nepeña</td>
<td>(Daggett, 1984; Proulx, 1973, 1968)</td>
</tr>
<tr>
<td>Santa</td>
<td>(Wilson, 1988, 1990)</td>
</tr>
<tr>
<td>Casma</td>
<td>(Wilson, 1995)</td>
</tr>
<tr>
<td>Culebras</td>
<td>(Prazdka and Giersz, 2003)</td>
</tr>
<tr>
<td>Fortaleza</td>
<td>(Perales Munguía, 2007)</td>
</tr>
<tr>
<td>Pativilca</td>
<td>(Perales Munguía, 2006)</td>
</tr>
<tr>
<td>Huaura</td>
<td>(Nelson and Ruiz Rubio, 2005)</td>
</tr>
<tr>
<td>Chillón</td>
<td>(Silva Sifuentes, 1996)</td>
</tr>
</tbody>
</table>

Fig. 1. Map of the survey area. The inland boundary is at 2500 m.a.s.l.

Fig. 2. Detail of Huaura and Fortaleza Valleys. Basemap is Shuttle Radar Topography Mission (SRTM) with 90 m horizontal spatial resolution (Jarvis et al., 2008) available at (http://srtm.csi.cgiar.org).
Remote Imagery

2. Methods

Remote sensing imagery was used to aid in the identification of fortifications in the 13-valley survey region. Schematically, our methods involve an ongoing iterative process of: initially identifying anomalies by means of remote sensing, field checking of those remote anomalies, identification of new field anomalies during remote anomaly visits, re-consideration of visited remote anomalies, followed by further checking of remote anomalies. All positive anomalies are characterized during field visits. The initial phase of remote anomaly identification has been completed for the entire 13-valley macroregional study area. The full iterative process just described has been implemented in the Huaura and Fortaleza valleys.

Remote sensing imagery can afford “direct discovery” (Kvamme, 2006: 32–33) of anomalies that represent site locations. This potential can enable relatively rapid and systematic survey over extensive areas in which full pedestrian survey may be difficult or too time-consuming (Craig and Chagnon, 2006: 56; Hritz, 2010; Thomas et al., 2008: 22; Ur, 2003). Thus, remote imagery can be well suited for operationalizing macroregional research. To implement this technique, the area to be surveyed remotely must be covered by imagery of sufficient spatial resolution to identify targets of interest.

In Perú, fortified architecture is generally made of stone, often spans entire hilltops, and is large and robust. These fortified walls are typically more than a meter thick. Even when collapsed, lineaments of rubble from walls are several meters thick. Fortified sites are generally composed of multiple concentric rings that encircle summits. While other types of defenses may have been built in the past, we focus on these well-known large stone fortifications. Two kinds of remote imagery were used to prospect for fortifications: free satellite imagery viewed in Google Earth®, and freely accessible historic air photos. Both kinds of data are discussed below.

2.1. Remote Imagery

Google Earth®, which allows the public to view satellite imagery, was used in the first phase of remote prospecting (see Ur, 2006 for a detailed explanation of Google Earth®). This freely available computer application has proven useful for visualization and collaboration (Conroy et al., 2008; Myers, 2010: 7–8; Ur, 2006: 36).

Some recent studies demonstrate that Google Earth® is also useful for guiding and designing research in very large regions (Contreras and Brodie, 2010; Thomas et al., 2008).

For the coast of Perú, Google Earth® provides coverage of either medium (15 m) or fine (<1 m) spatial resolution. Roughly 72% (18,323 of 25,458 km²) of the survey area has fine spatial resolution coverage (Fig. 3). The remaining 28% of the area is covered by medium spatial resolution imagery. Thus, for most of the macroregional study area, Google Earth® provides access to satellite imagery with sufficient spatial resolution to detect fortified stone architecture (Table 2).

Imagery covering hilltop areas was carefully examined for the presence of anomalies that likely represent sites with concentric walls, or features that appeared to be concentric. Hilltops are located primarily on the valley edges, but elevated areas or hills in the valley bottoms were also surveyed remotely. Because the focus of survey was on elevated areas, visual inspection of the imagery involved the following of ridgelines rather than the use of linear transects. Anomalies that likely represented walled features formed the minimum unit of identification in the survey area (Fig. 4). These walled units were marked using the Google Earth® “Add Placemark” feature.

Anomalies identified remotely via Google Earth® were termed “Google Earth Anomalies”. These point features were coded as high,
that are not annotated or mapped by GPS. There are hundreds of additional lineaments that correspond to architectural elements the photograph comprising Fig. 5 was taken. Note that in the upper and lower during ground truthing. The lower

Fig. 4. Shows a GeoEye® satellite image of an anomaly in the Huaura Valley. This same image is displayed in Google Earth. Here we use a grayscale version of the original GeoEye® source image. The upper figure illustrates the anomaly with no annotations. The lower figure shows GPS data superimposed on the satellite image. The lower figure Location A illustrates where a major defensive wall meets with a ridgeline next to an outcrop of dark rock. Location A is visible in the upper figure, and is also plotted in Fig. 5. The lower figure Location B illustrates where this same defensive wall crosses over another outcrop of dark rock. Location B is visible on the un-annotated upper figure, and is also plotted in Fig. 5. The lower figure Location C illustrates the position of a baffled entry, one DI criterion, in the large defensive wall. This entry is not visible in upper figure or in Fig. 5 (plotted as Location C). The baffled entry was identified during ground truthing. The lower figure Location D illustrates the spot from where the photograph comprising Fig. 5 was taken. Note that in the upper and lower figures there are hundreds of additional lineaments that correspond to architectural elements that are not annotated or mapped by GPS.

medium, or low probability of being fortified architectural units. Regardless of the level of confidence, all anomalies were treated as requiring ground truth verification or rejection.

After the initial phase of remote prospecting by means of Google Earth®, aerial photographs housed at the Servicio Aerofotográfico Nacional (SAN) in Lima, Perú were reviewed for part of the survey area. Reviewed aerial photographs were limited to medium and large-scale aerial photographs (Lillesand and Kiefer, 2000: 197), ranging from 1:6000 to 1:20,000. For the Huaura Valley, SAN series 1008 from 1945 (scale 1:10,000) was examined. For the Fortaleza Valley, series 170-69-A7 (from 1969, scale 1:17,000) and series 6513-3-1-72-A1 (from 1972, scale 1:20,000) of the Fortaleza and adjacent Pativilca Valleys were viewed.

Photographs were divided into quadrants, and locations of anomalies were assigned by quadrant of the photo. The index for each air photo series reviewed was photographed. Photographs of the indices were stitched together, and the stitched image was roughly georeferenced to make location of anomalies from the photos possible in Google Earth®. This proved to be very coarse, and only general locations were marked in Google Earth® where additional anomalies had been noted in the air photos. These additional targets for field checking were termed “Aerial Photograph Anomalies”.

Throughout the exed work phase of the survey the examination of Google Earth® to search for new anomalies was ongoing. Over time the identification of new Google Earth® Anomalies improved, in part because more fortifications were viewed in the field as existing anomalies were confirmed. The iterative process of anomaly identification, field verification or rejection, and anomaly re-evaluation is an extremely useful calibration that greatly improves visual interpretation of remotely sensed data.

Beyond looking for concentric or perimeter walls, other features running along ridges were recognized during remote prospecting. Dark areas of rock were looked at more closely to determine if the feature was rubble from collapsed walls. When examining the satellite imagery, the field of view was expanded to include ridges or hilltops located close to visible areas of extensive terracing because many fortified areas seem to be associated with terraces (see Fig. 4).

During field checks, additional anomalies were identified by looking at hilltops adjacent to the site being visited, or were seen from the road or valley bottom. People living in the area also mentioned hilltop sites they had seen. Although these locales were not identified as anomalies using remote data, they were incorporated into the database as Field Anomalies. Field Anomalies were also ground truthed.

2.2. Ground truthing

The use of remote sensing in archaeology to prospect for sites is ideally a two-pronged approach that entails image interpretation followed by ground truthing, or in-field verification of anomalies (McCoy and Ladefoed, 2009: 270). Remotely sensed anomalies in the Huaura and Fortaleza valleys were evaluated by targeted field survey. Field survey began in the Huaura Valley first, and then proceeded to the Fortaleza Valley.

Anomalies marked in Google Earth® as Placemarks were exported as a keyhole markup language (.kml) file. This file was converted to a Garmin Mapsource® GPS waypoint file (.gdb), and uploaded to a Garmin eTreX® Global Positioning System (GPS) which was used to navigate to the anomaly. Each anomaly visited was determined to be a positive or negative identification (ID) by the presence of ancient material remains. An ID may be positive in terms of having cultural remains, but may not be defensive in nature. Rather than assuming that all positive IDs were fortified features, they were assessed in light of criteria established prior to initiating the survey (Keeley et al., 2007; Topic and Topic, 1987). All anomalies met one basic criterion:
location in a naturally defensible location (on a hilltop) (Figs. 4 and 5). The Defensibility Index (DI) was developed and used to assess human-made constructions or attributes that enhanced these naturally defensible locations. The presence or absence of perimeter walls, moats or ditches, bastions, parapets, baffled-entries, and slingstones was documented. It is important to note that these small, specific architectural and surface details are not detectable in imagery viewed in Google Earth® (see Fig. 4 lower, Location C). They must be identified on the ground. At each anomaly, these attributes were quickly viewed and a point was tallied for the presence of each. Thus each positive anomaly was rated on a scale of 0—6 for presence of defensive features. This rating is the DI.

GPS and photographic data were collected at all visited anomalies. GPS data of architecture and surface attributes were collected using a 10 cm accuracy Trimble® ProXRT L1/L2 receiver with a Zephyr antenna and Omnistar® real-time differential correction. Mapping focused on major architectural features that were accessible (see Fig. 4 lower). Some in-field digitizing was done for wall sections that were located in extremely dangerous to access locations (cliff faces or steep scree) but could be drawn in in-field observations. In some instances, too much rubble made wall definition difficult on the ground. When viewed remotely, some large features (in this case, walls) are clearer and easier to define (Parssinen et al., 2009: 1087). Selected satellite images and air photos permitted additional mapping of some architectural features that were not documented in the field.

Photographs of temporally diagnostic artifacts, like pottery, were taken at all locales visited. Project members photographed surface collections while carrying a consumer grade GPS, either a Garmin eTrex® or a Garmin Forerunner 405CX®. Both of these receivers have 3—6 m accuracy. Photos were geotagged with GPS track logs using Geosetter®, a free software tool that embeds geographic data in image files (http://www.geosetter.de/en/). Field observations, subsequent analysis of the photographs of these surface assemblages, and characteristics such as architectural building style, permitted a tentative temporal characterization of each locale.

3. Results for two valleys: Huaura and Fortaleza

3.1. Comparison of Google Earth and air photos

The Huaura and Fortaleza Valley case study illustrates some distinct advantages to using Google Earth® over aerial photography. The major difference between the two image sets is that the aerial photographs do not cover as much area as Google Earth®. Prior aerial surveys focused on agricultural zones (i.e. the floodplains and lower terraces of the major river valleys) or areas of interest for construction or development. These image collections often have incomplete coverage of the mountains that border the valleys. Minor river valleys, dry washes, and intervalley areas were often not covered. These marginal areas may appear in series that are 1:50,000 or 1:100,000. However, these scales are too small to permit visual prospecting of fortifications without enlarging the photos (which requires purchase) or using high-powered magnification.

The quality of fine spatial resolution (<1 m) imagery viewed in Google Earth® was also better than some aerial photographs. The 1969 and 1972 aerial photographs for the Fortaleza Valley were often overexposed. This made detection of sites difficult. In the aerial photographs, cloud cover, a common occurrence on the fog-covered coast, also obscured many mountaintop areas. Satellite detectors repeatedly cover the entire earth, and thus a single location is imaged many times. This fact improves the probability of capturing a given location free of occlusion from clouds or other atmospheric moisture. Google Earth® provides views of historical imagery, and there is often more than one scene available for an area. One scene may have cloud cover over a specific area, while others may not.

Another difference involves the degree of processing. If purchased, aerial photographs require scanning and georeferencing to obtain the coordinates of an Aerial Anomaly. Alternatively, Aerial Anomaly locations can be transferred to a map to provide a coarse estimate of their coordinates. We did not purchase photos for the purposes of prospecting; we relied on digital photographs of series indices that were roughly georeferenced. In contrast, anomalies marked in Google Earth are linked to geographic coordinates at the time of creation. Coordinates, as well as any attributes linked to the placemark, can be easily exported for use with GPS and geographic information systems (GIS). This greatly facilitates navigating to an anomaly.

Access is another key variable to consider. A major advantage of using Google Earth® is the ability to continue to peruse imagery when convenient. The limiting factor is access to an internet connection, and how much time one wants to spend prospecting remotely. Although air photographs exist for a number of areas, access can be highly variable. Unless purchased, air photos must be studied where they are housed. For the macroregion we sought to cover, purchasing numerous complete aerial series was not economically feasible. Immediately prior to fieldwork, Brown Vega spent 2 weeks at SAN to examine air photos of the survey area. On the other hand, she spent 9 months perusing Google Earth® before even departing for fieldwork, and remote prospecting using Google Earth™ continued throughout the field verification stage of the project, because the data are easy to access (Parcak, 2009: 43).

4. Results of remote sensing and ground truthing

1798 km² were remotely surveyed for the Huaura Valley, and 1284 km² were remotely surveyed for the Fortaleza Valley. Combined these two valleys have 231 anomalies; 158 were visited in the field.

The total number of combined remotely identified anomalies in the Huaura Valley is 81. 73 of these were identified using Google Earth®. 41 anomalies were identified in aerial photographs (1945 series), but only 8 of these had not already been identified in Google Earth®. An additional 26 anomalies were Field Anomalies. The total number of anomalies in the Huaura Valley database is 117. 68%, or 80 anomalies, were ground truthed (Table 3). Of these, 82.5% were positive IDs, while 17.5% were negative IDs.
In contrast to the Huaura Valley, for the Fortaleza Valley no additional anomalies were identified in the historic aerial photographs that were not already identified initially in Google Earth®. Only 6 anomalies were identified in the Fortaleza Valley using aerial photographs. One fort was viewed in the 1969 series, and 5 additional ones were viewed in the 1972 series.

The total number of remotely identified anomalies for the Fortaleza Valley is 92, all identified using Google Earth®. An additional 22 were identified in the field. Out of 114 total anomalies, 68%, or 78 anomalies, were ground truthed (Table 4). Of these, 95% were positive IDs, and 5% were negative IDs.

To assess the reliability of the remote imagery for location of fortified sites, one can look at only those anomalies that were identified remotely (Fig. 6). For Huaura, 82% of remotely identified anomalies were positive, versus 77% of anomalies identified in the field. For Fortaleza, 92% of remotely identified anomalies were positive, while 100% of anomalies identified in the field were positive.

From a remote sensing perspective, false positives can be defined as anomalies that, when ground truthed, were not sites. False negatives can be defined as failure to identify a positive anomaly remotely. Field anomalies can be thought of as a measure of false negatives. The second valley surveyed (Fortaleza) had lower numbers of false positives for both remotely identified and field identified anomalies. 31% of the total anomalies in the Huaura Valley, those identified in the field, can be thought of as false negatives. For the Fortaleza Valley, only 19% of the total anomalies were false negatives.

### 4.1. Defensibility Index (DI)

No positive anomaly met all 6 of the defensive criteria described above that comprise the DI (Table 5). 85% of all positive anomalies had at least one defensive attribute. 11 of the positive anomalies (7.9%) did not have fortified attributes. However, we reiterate that all positive anomalies met the basic criterion of being located on naturally defensible locations. While these sites are in a defensive location, no fortifications or weaponry were detected. Of the 21 anomalies (15%) that have a defensive index of 0, 10 are associated with larger fortified complexes. Thus, roughly half (48%) of the category 0 anomalies are in close proximity to other anomalies associated with fortifications or weaponry (Figs. 7 and 8).

### 4.2. Grouping and temporal assignment

A single fort complex may encompass multiple anomalies. Thus, a certain level of grouping of positive anomalies is appropriate. Some anomalies lie along the same ridge, with easy access between them. Such anomalies were grouped together in the interest of a more conservative enumeration of total forts per valley. Based on a preliminary assessment of fortified attributes and the propinquity of some positive anomalies, we have tentatively identified 35 fortified sites or defensive architectural complexes in the Huaura Valley. Using the same method for grouping, we have tentatively identified 47 fortified sites or defensive architectural complexes for the Fortaleza Valley. Based on revisions in our grouping, the total number of forts reflected by this sample may change. Bear in mind, these numbers reflect a 68% sample (158 of 231) of the total number of anomalies for these two valleys. As our research continues the number of fortified sites in these two valleys will no doubt increase.

As mentioned above, field observations, temporally diagnostic surface assemblages, and architectural styles permitted a tentative determination of when forts were built and in use. This determination might be complicated by diagnostic subsurface features that were not visible. Nevertheless, we have identified multicomponent sites based on surface characteristics. According to our tentative temporal assignments, 34 of the Huaura Valley fortifications are associated with EH materials, 12 are associated with MH materials, and 21 are associated with LIP materials. For the Fortaleza Valley, 39 are associated with EH materials, 5 with EIP materials, 19 with MH materials, 16 with LIP materials, and 12 with LH materials. 2 fortifications cannot be tentatively assigned to a time period (Table 7).

### Table 3

<table>
<thead>
<tr>
<th>Anomalies</th>
<th>Google Earth</th>
<th>Aerial Photo</th>
<th>Field Anomalies</th>
<th>Total</th>
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<tr>
<td>Ground truthed</td>
<td>51</td>
<td>7</td>
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### Table 4

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<td>114</td>
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<tr>
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<td>13</td>
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### Table 5

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<th>4</th>
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<tr>
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<td>56</td>
<td>32</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>140</td>
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</table>
5. Discussion

5.1. Comparison to full-coverage surveys

As mentioned above, prior full-coverage surveys have been carried out for both valleys (Nelson and Ruiz Rubio, 2005; Perales Munguía, 2007). Four fortifications were identified in the report for the Huaura Valley (Nelson and Ruiz Rubio, 2005: 11). A more recent attempt to enumerate the number of known fortifications in the Huaura Valley indicated there were 6 (Brown Vega, 2010: Figs. 9.2 and 9.3). The results of our remote sensing aided survey increase this number fivefold.

The report for the Fortaleza Valley does not indicate the function of any of the sites reported (i.e. fortification, administrative, civic-ceremonial, residential, etc). This fact renders it extremely difficult to glean the number of fortified sites that were documented by the survey. A digital copy of the report for this survey was searched for terms that relate to defensive architecture. The common words or phrases indicative of defensive function that we searched are shown in Table 6 along with the results of each of these search terms; many of the expected words related to defensive function were not found in the report. Based on the search results, we can gather that 5 fortified sites were documented in this full-coverage survey.

The one fortification that was recorded in the above-mentioned survey that we did not ground truth was the well-known Fortress of Paramonga (Espinoza Soriano, 1974; Giesecke, 1939; Kosok, 1965: 217–218; Langlois, 1938). Paramonga is a local tourist attraction, and we know this site from prior visits. Our results, when compared to the number of prior reported forts, increase the number of fortifications for the Fortaleza Valley ninefold.

5.2. Implications by time period

Prior to initiating this research, in 11 of the 13 valleys surveyed, slightly more than 70 fortifications were known for the EH and LIP. Based on our tentative grouping of positive anomalies, there are at least 35 fortified sites in the Huaura Valley, and 47 in the Fortaleza Valley. The addition of the Fortress of Paramonga mentioned above brings the number in Fortaleza to 48. Thus, the number of hilltop fortified sites in these two valleys alone exceeds the prior reported number from 11 valleys.

<table>
<thead>
<tr>
<th>Term</th>
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<tbody>
<tr>
<td>Canto rodado (river cobble*)</td>
<td>9</td>
<td>Refers to construction material, not slingstones</td>
</tr>
<tr>
<td>Perimétrico (adj. perimeter)</td>
<td>4</td>
<td>Mentioned for 3 sites (PV38-11, PV38-22, PV38-364)</td>
</tr>
<tr>
<td>Fortaleza (fortress, not the valley)</td>
<td>2</td>
<td>Mentioned for 2 sites (PV38-7, PV38-11)</td>
</tr>
<tr>
<td>Concéntrico/a (concentric)</td>
<td>1</td>
<td>Mentioned for 1 site (PV38-243)</td>
</tr>
<tr>
<td>Muralla (large wall)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Defensivo/a (defensive)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Bastión/atalaya (bastion/lookout)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Parapeto (parapet)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Zanja (ditch)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Waraku/huaraca/honda (sling)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Fortificado/a (fortified)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Fortificación (fortification)</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
The highest number of fortifications now known in the Huaura and Fortaleza valleys pertains to the EH (Table 7). EH warfare has received much attention in the north coast, particularly in the Casma to the Santa Valleys, where fortification construction has long been recognized for this period (Daggett, 1984; Proulx, 1973, 1985; Topic and Topic, 1978, 1987; Willey, 1953; Wilson, 1988, 1995). Data from the Virú valley were used to suggest the prevalence of internecine warfare during this period (Carneiro, 1970).

Some suggest that this militarization coincided with resistance against influences or an outright invasion emanating from highland polities (Burger, 2008: 699; Pozorski, 1987). Other scholars have argued that the concentration of fortifications between the Casma and Santa Valleys represents endemic intervalley warfare (Wilson, 1988: 357, 1995: 189). Our results from Huaura and Fortaleza reveal that the construction and use of fortifications during the EH is potentially far more extensive than was previously documented. These three models for the first appearance of warfare in the sequence will need to be reevaluated in light of these new data.

The first empires may appear in the Andes during the MH (Isbell, 2008). The MH in the Huaura and Fortaleza valleys is not yet well studied. However, in a recent publication on the Huaura Valley that referenced a systematic comprehensive siteless survey the authors assert in six instances within the paper that MH sites lack the “classic hallmarks of defensive architecture” or that a lack of defensive posturing in part defines MH settlement patterns within the valley (Nelson et al., 2010: 173, 176, 178, 179, 182, 183). Our discovery of 12 fortifications in the Huaura Valley that have MH components (Table 7), some of which are quite large (see Figs. 4 and 5), suggests settlement patterns have been mischaracterized for this period in this valley. The number of MH fortifications in the Fortaleza Valley is even higher. These results demonstrate the need to reconsider conflict and the adoption of a defensive posture during the MH in both valleys.

The LIP in other parts of the Andes has long been characterized as a period of warring regional polities (Arkush, 2006; Parsons et al., 2000; Wernke, 2006: 191–193). Only one LIP fortification, Acaray, has been excavated in the Huaura Valley (Brown Vega, 2008, 2009). Based on data reported in this paper (Table 7), it is now clear that Acaray is not an isolated fort. The number of forts with LIP components is slightly higher in Huaura than in Fortaleza, yet conflict during this time in both valleys may be underrecognized. Given the expansion of the Chimú Empire southward into the central coast valleys during the LIP, conflict related to imperialism must be considered as well as intervalley or intravalley warfare.

Fortifications with LH components may be related to Inka imperial strategies, or resistance to Inka territorial expansion (Alconini, 2004; Covey, 2008: 819–821). Comparing the number of possible LH fortifications between these two valleys suggests differential imperial control, or different imperial and local strategies employed, as they were annexed into the Inka Empire (Table 7).

For all time periods more intensive future work, including subsurface sampling, will help refine the tentative chronological characterizations made thus far. We do not claim that the occupations or nature of use of these sites are concretely established. We suspect that there is considerable variation in the fortifications that remains to be explored further. Nevertheless, our results call attention to new evidence for conflict that has not yet been recognized.

5.3. Implications for the macroregion

The implications for the continued study of the large coastal macroregion we defined are significant. The reiterative process of interpretation leads to improvement over time in the identification of both remote and field anomalies. We expect comparable or improved results from future work. Given the total number of anomalies identified for all 13 valleys (n = 682), there is the potential to transform the current understanding of defensive sites and warfare through time, as well as settlement patterns more generally. For the Huaura Valley we had an 82.5% success rate of positively identifying fortifications. For the Fortaleza Valley, the success rate was 95%. Using a conservative 82% success rate for identifying positive anomalies, there could be 559 total positive anomalies in the 13-valley macroregion. Subtracting the 140 positive ones we have already identified, there could be over 400 more positive anomalies once all anomalies are ground truthed. We are currently cross-checking our remotely identified anomalies with fortifications reported by other investigators for other valleys. Nonetheless it seems apparent that there are many more fortifications in the macroregion than originally anticipated.

6. Conclusion

With respect to prospecting for fortifications in a large macroregion, this case study demonstrates the feasibility, in terms of time and cost-efficiency, of using fine spatial resolution imagery that is freely available for viewing in Google Earth®. It was possible to identify more anomalies using satellite imagery in Google Earth® compared to lower elevation historic aerial photographs. In the Fortaleza Valley very few anomalies were identified in the aerial photographs at all. This is due to incomplete coverage and large-scale imagery that would require enlargement to detect forts. In general, the ease of accessibility of Google Earth® over physical aerial photographs is a great advantage. Additionally, the use of remote imagery enabled Awaqa Pacha to cover areas not typically included in pedestrian surveys, such as minor river affluents, dry washes that branch off of major river valleys, and intervalley areas. These areas are difficult to reach, even by vehicle, and might not otherwise be documented without prior knowledge of the possibility for discovering a site.

Aerial photography and satellite remote sensing have roots in military reconnaissance and surveillance. From their very inception and throughout their development, these imaging technologies were used to identify and quantify military installations in hostile and difficult to access locations (Babington Smith, 1957; Clarke and Cloud, 2000: 198–199; Cloud and Clarke, 1999: 38, 43; Hilderbrandt, 1908: 139, 285). By employing satellite imagery to study archaeological fortifications in difficult to access locations, we are simply applying modern remotely sensed imagery to the reevaluation of ancient military installations. On historical and empirical grounds, remotely sensed imagery holds great promise for direct discovery and systematic survey of fortified architecture not only in Perú but in other world regions where ancient stone fortifications were built.

We must point out, however, that anomalies were also identified in the field. This indicates that remote imagery alone will not identify all fortifications in a given area. Moreover, establishing conclusively that a remote anomaly is actually fortified requires ground truth confirmation. Our research demonstrates that freely available satellite imagery in Google Earth® is most effectively used in

Table 7

<table>
<thead>
<tr>
<th>Period</th>
<th>Huaura</th>
<th>Fortaleza</th>
</tr>
</thead>
<tbody>
<tr>
<td>EH, ca. 900–200 B.C.</td>
<td>34</td>
<td>39</td>
</tr>
<tr>
<td>ELF, ca. 200 B.C.–A.D. 500</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>MH, ca. A.D. 500–1000</td>
<td>12</td>
<td>19</td>
</tr>
<tr>
<td>LIP, ca. A.D. 1000–1470</td>
<td>21</td>
<td>16</td>
</tr>
<tr>
<td>LH, ca. A.D. 1470–1532</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Not determined</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>
archaeological research when coupled with field survey (Parcak, 2009: 51). We do not claim to have found all of the hilltop fortifications that are located in the Huaura and Fortaleza valleys. Our results, however, demonstrate that pedestrian survey targeting hilltops and rough terrain can identify fortifications where they exist. The fact that we identified hilltop fortifications that were missed in two recent prior full-coverage pedestrian surveys (Nelson and Ruiz Rubio, 2005; Perales Munguía, 2007) suggests that hilltop, mountaintop, or otherwise marginal areas in rough terrain may not be systematically included when designing and executing surveys.

War clearly represents one of the focal points in any historical sequence. As we argued at the outset, studies from around the globe are demonstrating that warfare is often widespread yet frequently understudied. Fortifications are a critical but under represented type of site that has major implications for understanding ancient culture history and process. Remote sensing and targeted ground truthing of hilltop anomalies is one effective means to fill in empirical gaps and enlarge the sample of hilltop fortifications.

Acknowledgements

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