geosciences

MDPI

Article

The American Schools of Oriental Research Cultural Heritage Initiatives: Monitoring Cultural Heritage in Syria and Northern Iraq by Geospatial Imagery

Michael Danti [1,*], Scott Branting [2] and Susan Penacho [1]

[1] ASOR Cultural Heritage Initiatives, 650 Beacon Street 2nd Floor, Boston, MA 02215, USA; asormaps@bu.edu
[2] Department of Anthropology at the University of Central Florida, 4000 Central Florida Blvd, Orlando, FL 32816, USA; scott.branting@ucf.edu
* Correspondence: michaeldanti@asor.org; Tel.: +1-857-990-3139

Received: 1 August 2017; Accepted: 23 September 2017; Published: 28 September 2017

Abstract: The American Schools of Oriental Research Cultural Heritage Initiatives (ASOR CHI) continues to address the cultural heritage crisis in Syria and Northern Iraq by: (1) monitoring, reporting, and fact-finding; (2) promoting global awareness; and (3) conducting emergency response projects and developing post-conflict rehabilitation plans. As part of this mission, ASOR CHI, through a public–government collaboration with the United States of America (US) Department of State, has been provided with access to hundreds of thousands of satellite images, some within 24 h of the image being taken, in order to assess reports of damage to cultural heritage sites, to discover unreported damage, and to evaluate the impacts of such incidents. This work is being done across an inventory of over 13,000 cultural heritage sites in the affected regions. The available dataset of satellite imagery is significantly larger than the scales that geospatial specialists within archaeology have dealt with in the past. This has necessitated a rethinking of how the project uses satellite imagery and how ASOR CHI and future projects can more effectively undertake the important work of cultural heritage monitoring and damage assessment.

Keywords: endangered cultural heritage; remote sensing; large dataset; crowd-sourcing information; condition assessment; real-time processing; Syria; Iraq; conflict; Nimrud; Palmyra; Mosul

1. Introduction

The American Schools of Oriental Research (ASOR) established the Cultural Heritage Initiatives (CHI) in 2014 to assist in addressing the current cultural heritage crises in the conflict zones of Syria and Northern Iraq, the worst such catastrophe since the Second World War. Since that time, on a daily basis, CHI has documented new incidents of looting, theft, damage, and destruction. Sustained ground and aerial combat, intensified by long-standing ethno-sectarian tensions and international intervention, have resulted in widespread damage and destruction to individual heritage sites and whole urbanscapes. Extremists such as the so-called Islamic State (ISIS) have deliberately destroyed hundreds of ancient monuments, mosques, churches, shrines, cemeteries, and other sites, as part of a systematized campaign of cultural cleansing, enacted to advance radical ideologies and to achieve more worldly military, political, and economic objectives. Years of warfare and instability have subjected local populations to unspeakable suffering, abysmal living conditions, and abject poverty. Millions of Syrians and Iraqis are internally displaced, living in makeshift camps or even archaeological ruins, or have undertaken the perilous journey to live abroad. Criminal activity inevitably peaks when such appalling conditions co-occur with rampant regional corruption, transnational organized crime, and predatory terrorist networks. One seemingly inevitable tragedy has been the systematic pillaging of the region's renowned cultural repositories, private collections, and archaeological

sites, as locals struggle to support their families by trading away irreplaceable cultural assets for a pittance to exploitive mobsters, warlords, and terrorists, seeking easy profits from the global illicit art and antiquities markets. Hundreds of archaeological sites have been mined for antiquities, resulting in untold losses of archaeological data in the ancient Near East, home to the world's earliest known agricultural communities and literate state-level societies and the wellspring of several of the world's major religions and powerful empires. The loss to our global cultural patrimony is staggering and highlights the importance of rethinking the current international response within the modalities of cultural security and cultural property protection during conflicts (for recent overviews see [1–4]).

The CHI project began in August of 2014, with a focus on cultural heritage within Syria, but has since expanded to include Northern Iraq and Libya. The core mission of CHI entails monitoring and fact-finding activities, disseminating results to the United States of America (US) Department of State (DOS) and the public, implementing emergency response projects, developing post-conflict rehabilitation plans, and producing public outreach and education initiatives. In order to undertake these activities, the project has synthesized expansive data collected by its wide-ranging international network of heritage experts and analysts, including activists and institutions in the conflict zone of the Middle East and North Africa, from three principal sources: news outlets and social media, in-country contacts, and satellite imagery [5–8]. While the intersection of all three sources of information has proven critical to CHI's success, this article will primarily focus on the analysis enabled by the third of these sources—satellite imagery—within the modality of monitoring and assessing cultural heritage damage to the built environment, in Syria and Northern Iraq. CHI's ongoing data acquisition and analysis of the impacts of the Syrian and Iraqi conflicts on cultural heritage in real time, represents the first such comprehensive effort borne out of a public–government collaboration.

Results of CHI have been made available since August 2014 in weekly, bi-weekly, and monthly reports, submitted to the US Department of State and subsequently appearing on the CHI website in redacted form [9]. Additional special reports have been compiled in response to particular events or tactics of significance to cultural heritage, and some of these also appear on the CHI website. In addition to reporting, public and private presentations in various venues form an important component of promoting the awareness of impacts to cultural heritage. Our overriding vision entails empowering local communities to preserve and protect cultural resources through the establishment of broad and diverse coalitions. Such nimble, adaptive, and cost-effective responses appear to be the future of the field and form an integral part of broader international humanitarian conflict resolution, and post-conflict peacebuilding and recovery efforts [10].

The use of satellite imagery is not a new method in either cultural heritage monitoring or archaeology. Since the 1970s, archaeologists have made use of satellite imagery—which has grown out of extensive prior use of aerial photography—for discovering new cultural heritage sites and contextualizing both newly discovered sites and known sites within their broader cultural, political, and environmental landscapes ([11] (p. 33); [12] (pp. 18–28); [13] (p. 27)). However, fundamental changes in access to geospatial data granted to the CHI team in 2014 have greatly facilitated this work and have also offered a glimpse into future monitoring and research trajectories. Furthermore, the methods implemented by CHI to analyze and present reliable and verifiable deliverables under time-sensitive conditions represent a fundamental departure from traditional archaeological research projects. This article will discuss these changes and how they enable the ongoing work of CHI. Cultural heritage case studies, monitored by the project, will illustrate the importance of these developments and the challenges faced in monitoring and assessing cultural heritage during times of instability and conflict.

2. The ASOR CHI Methodology and Geospatial Data

The ASOR CHI methodology was initially developed in 2014, in response to a fundamental need to integrate both the geospatial and non-geospatial portions of the project. The geospatial team was tasked with analyzing satellite imagery to discover and document previously unreported damage to

cultural heritage sites, or to confirm and, when possible, document the extent of reported damage uncovered by the non-geospatial reporting teams, through their use of networks of individuals located in-country, or by monitoring social and traditional media reports. This integrated method has proven powerful in thousands of cases, including those discussed in greater depth in the results section. The geospatial team has discovered unreported cases of cultural heritage destruction. They have also supported the reporting team by confirming, detailing, and correcting information on heritage incidents reported in the media or from private sources. Meanwhile, the reporting team has been able to make use of in-country contacts to, when possible, visit the location and assess, on the ground, the events first discovered by the geospatial team. Together this integrated pairing has provided detailed and verifiable reports from within the conflict zones in a timely fashion.

It should be stressed that this methodology was developed within the context of an existing conflict situation that encompassed a broad geographic area spanning all of Syria and large portions of Northern Iraq. This is a major difference between ASOR CHI and the Endangered Archaeology in the Middle East and North Africa (EAMENA) project, which started a year later, in 2015, and which strives to monitor an even larger area, most of which falls in countries that have been relatively peaceful during the past two years [14,15]. Both the open conflict, and the broad and expanding geographic scope of the CHI project's coverage, presented major challenges to successful implementation. Conflict areas create limitations in communication with in-country contacts as well as risks to their lives. Data from satellite platforms, high above the reach of the conflict, are necessary to provide information in areas where communication is impossible or where there are significant physical risks to individuals on the ground. The broad territorial expanse, encompassing many subregions lacking authoritative or standardized heritage site inventories, necessitated an immense amount of constantly refreshing geospatial data. From CHI's inception, it was apparent that access to resources well beyond the capabilities of freely provided satellite imagery, through platforms such as Google Earth or Bing Maps, would be needed to keep up with the fast-moving conflict situation. At the request of ASOR, in 2014, access to hundreds of thousands of satellite images, purchased by the US government, was granted through the mechanism of the collaborative agreement between CHI and the DOS. This benefit, gained from the public–government collaboration, went well beyond the access that had previously been granted to other archaeological projects.

The core geospatial dataset provided to the project is comprised of a subset of all DigitalGlobe orthorectified imagery available through the EV WebHosting service [16]. The imagery is available for download or for direct linkage through an ArcMap add-on that provides web map and tile services. The accuracy of the rectification of the imagery provided by the service has proven to be more than sufficient in most cases for immediate overlay and analysis, without the need for subsequent rectification by CHI. The geographic scope of the dataset has grown with CHI's increasing scope of work to encompass Syria and Northern Iraq, as well as more recently, Libya. The available image sets include WorldView-1 to WorldView-4 and GeoEye-1 satellite collections and are available to CHI as single band panchromatic and true-color pan-sharpened images at less than 50 cm resolution. The subset of imagery frequently changes, both with older images being removed and newly-collected imagery being added. Collection dates for the available imagery range from just prior to the start of the Syrian conflict in 2011, to the present. The dataset also includes ongoing new data collections and the regular tasking of satellites incorporating CHI's requests and lists of endangered cultural heritage sites—some requested sites have been collected and processed within 24 h of a major cultural heritage event. This rate of incorporation of new imagery is essential to timely analysis and reporting within the context of a rapidly and dynamically evolving conflict, and is not available through publicly available platforms, such as Google Earth.

The amount of geospatial data, while essential, presents a significant change to prevailing imagery analysis routines within archaeology. Typically, in terms of high resolution images, single images or sets of up to a few dozen images have been used within archaeological research for detecting, investigating, or monitoring cultural heritage locations [17,18]. The requirements for monitoring the

rampant looting of southern Iraq following the second Gulf War raised the upper threshold of image datasets to 1000–2000 images [19]. This functional cap can largely be attributed to the cost of the imagery. Since the 1970s, freely available lower resolution satellite images, like Landsat, or higher resolution satellite images from earlier decades, like the declassified US spy satellites, have seen much more widespread use in regional archaeological applications involving higher numbers of images ([11] (p. 33); [13,20–22]). Likewise, large amounts of periodically updated imagery, available freely through online platforms, like Google Earth, have inspired archaeological projects on countrywide or larger scales [15,23,24]. For CHI, access to hundreds of thousands of images through the public–government collaboration necessitated some adaptation of prevailing methodologies, particularly in time-sensitive analysis situations with a quick turnaround for reporting, and have been the catalyst for even further methodological developments.

Initially CHI was tasked with simultaneously assessing large quantities of geospatial data and assembling an inventory of cultural heritage sites within the area of work. To achieve the latter objective and proceed with site monitoring and assessment activities, CHI required the locational and descriptive data for thousands of cultural heritage sites. No available comprehensive inventory had been undertaken for these areas, and so CHI compiled one from existing, overlapping inventories and by sorting through centuries of published material. This task would have been impossible without the support of collaborators within CHI, public inventories such as the ANE Placemarks for Google Earth [25], and networks of contacts willing to share sizable inventories of subsets of the area such as the Computational Research on the Ancient Near East (CRANE) Project [26], Ross Burns [27], The Fragile Crescent Project [28], and the Deutsches Archäologisches Institut (DAI) [29]. Merging these datasets posed some challenges. In many cases, these different inventories and other published sources did not agree on precise site locations or site names, which were inconsistently recorded going back centuries. This necessitated significant cross-checking between the inventories and manual reconfirmation of most locations using the imagery dataset at CHI's disposal and the assistance of personnel from the CRANE Project. It should be stressed that all of this inventory creation took place in the midst of open conflict, which severely curtailed access on the ground to cultural heritage site locations, unlike the impressive inventories that have been assembled by EAMENA in other portions of the Middle East [14]. As of 30 June 2017, the inventory consists of 13,186 unique cultural heritage sites across Syria, Northern Iraq, and Libya. While the core of the inventory consists of archaeological sites and monuments, it also includes other important heritage sites, such as mosques and churches, historic houses, and museums and libraries located within these geographic areas. This inventory continues to be a work in progress, with site locations revised in light of new information and additional research. It also remains of vital importance that access to this inventory is restricted, though the CHI project has shared this expanding inventory with other groups undertaking cultural heritage monitoring such as the United Nations Institute for Training and Research's Operational Satellite Applications Program (UNITAR-UNOSAT) [30], the CRANE Project, the Fragile Crescent Project, Shirín [31], Ross Burns, the DAI, and EAMENA. An inventory like this would be of use to not only those monitoring cultural heritage, but also by those seeking to intentionally loot or destroy these same sites. Balancing security risks with the need for access to the inventory by CHI members, collaborators, and others is an issue that will continue into the future.

With the inventory and access to geospatial data, CHI developed a cultural property protection and preservation methodology, building on existing methodologies employed for archaeological research projects, and workflows to analyze and present information gained from geospatial and non-geospatial datasets, for use by local stakeholders, cultural heritage professionals, activists, law enforcement, decision makers, and policy makers. Typical workflows depend on the source of the report of damage, either originating with the satellite imagery that is being monitored by the geospatial team, or with on-the-ground or media sources being monitored by the reporting team. For damage reports originating from the geospatial team, typical workflows include using trained analysts to visually assess new satellite imagery daily, over inventoried cultural heritage sites, as the

imagery becomes available within the EV WebHosting service. Changes impacting the cultural heritage site detected between consecutive temporal images are recorded as spatial and attribute data, and are categorized according to a CHI schema of threats and damage, which expanded on the MEGA Jordan Guidelines' Threats and Disturbances Schema developed by the Getty Conservation Institute and World Monuments Fund [32,33]. The schema expansions by CHI included new threats and damages categories to cover military conflict, looting, and intentional destructions of cultural heritage. CHI chose the Middle Eastern Geodatabase for Antiquities (MEGA) - Jordan schema because of its standardization, which facilitates data sharing with partnering projects, and because it underpins the Arches open-source heritage inventory and management system, chosen by CHI and other projects as a cross-collaborative data sharing platform [34]. In 2014–2015, an initial rapid assessment protocol was used to quickly assess tens of thousands of images for the backlog of incidents that occurred between 2011 and 2014. These initial assessments identified the presence of damage, bracketed the dates of the damage incidents, identified damage type(s) according to the CHI schema, and categorized the severity of damage, along with defining the extent of the cultural heritage location. This initial rapid assessment protocol was altered as the backlog became more manageable. The current protocol includes adding background information concerning the particular cultural heritage site and cross-checking the incident against data being generated by the non-geospatial reporting team. This cross-checking can also include engaging local in-country sources to visit the site and further assess the damage if the dangers of the conflict allow such access.

Workflows are different in cases where the report of damage originates from in-country individuals or the social and traditional media sources being monitored by the reporting team. In these cases, the incorporation of these non-spatial sources of information are critical to the overall CHI methodology and its ultimate reporting activities [6]. Not only must CHI rapidly and regularly produce a diverse range of reports that cover a broad geographic area, subjected to intense damage and destruction, but these reports must address the needs of a diverse range of cultural property protection and preservation modalities and, most importantly, prove to be reliable and verifiable under time-sensitive conditions. Given the irregularities in data dissemination on heritage incidents in the conflict zone, new data may prove or disprove our published analyses in a matter of a few days—a frequent potentiality for famous heritage sites such as Palmyra or urban environments such as Aleppo and Mosul—or it may take months or even years for new information to surface, as is often the case for remote rural sites under the control of radical extremist groups, such as the so-called Islamic State.

To address these needs, information from conflict-zone sources or from media reports must intersect the geospatial data assessment workflow at several points depending on circumstances of data availability and reliability. CHI often develops initial reports of heritage incidents through these other channels, and we then assess available satellite imagery using the standard workflow described above to confirm, refine, or refute these reports. This is especially important since open-source streams, such as social media and online news sites, often provide near-instantaneous coverage but frequently contain inaccurate, propagandistic, and deliberately falsified information. Furthermore, ground-based sources provide highly reliable information, such as reports from CHI in-country site assessment teams, but they usually can only provide localized information, given the difficulty of travel and access to sites in active war zones. The integration of information from each of these data streams is key to establishing a higher confidence level in the reporting of a given incident during the assessment process. Over a three-year period, we have steadily refined our methods and have continued to achieve a high degree of verification and reliability, based on the constant re-evaluation of previous CHI incident reporting. This does not mean that CHI has been able to identify every instance of cultural heritage damage within the conflict, but it has expanded and reshaped knowledge of this important element in the conflict and it has often been the source for information subsequently disseminated by traditional news outlets.

The integration between in-country sources and the satellite imagery also carries with it further benefits and risks. Cultural heritage has regularly been at the center of conflicts in the Middle East and North Africa, vastly elevating danger levels for in-country experts and activists attempting to address looting and cultural heritage damage and destruction. Beyond the daily risks associated with conducting cultural property protection and preservation initiatives in active war zones, multiple radical extremist groups have enacted brutal campaigns of cultural cleansing, involving the deliberate targeting of both cultural assets and personnel. Ethno-sectarian tensions fuel violence against noncombatants and have created complex and constantly shifting zones of political and military control—even short-distance travel can be perilous. Complex, entangled networks of terrorists, criminal organizations, and highly corrupt state and non-state actors in the conflict zones of Syria and Northern Iraq have engaged in the looting of archaeological sites, thefts of cultural property from private and public collections, and smuggling—investigating these crimes is fraught with hazards. At times the satellite imagery assessments have been used to keep people out of danger by assessing areas that would have been too dangerous for a person to access, such as active combat zones, illegal border crossings used by smugglers and terrorists, and archaeological sites occupied by military forces or controlled by criminal gangs. At other times, satellite assessments have provided an alternative and publishable source of information about an incident in which it would otherwise have been too dangerous to reveal that an in-country contact had provided the original information. At the same time, when the situation on the ground becomes less dangerous, even if months or years after the incident, ground truthings of assessments have been an essential and powerful component in further verifying information in the CHI satellite imagery assessments. This power of the integration of geospatial and non-geospatial components within the methodology of CHI will, it is hoped, be a model which can be replicated, customized, and enhanced for monitoring cultural heritage within future conflict situations.

In terms of refining methods, CHI has been working to address key issues encountered since 2014. With a distributed core team and numerous collaborators throughout the world, the sharing of data, and especially geospatial data, is one key issue. A collaboration between the Getty Conservation Institute and CHI allowed our team to assist in specifying key elements of Version 4 of the Arches open-source heritage management software that was developed by the Getty Conservation Initiative (GCI) and the World Monuments Fund [34]. This includes a tile server component that will allow internal sharing of geospatial information among members of the team and their collaborators. Spatial queries, as well as non-spatial queries, of the assembled information will also contribute to long-term archival aspects of CHI.

A second new direction utilized by CHI in collaboration with University of California San Diego's Center for Cyber-Archaeology and Sustainability (CCAS) has been a pilot project, which has crowdsourced preliminary assessments of cultural heritage through the TerraWatchers portal [35]. The project utilizes the inventory developed by CHI, and therefore the dozens of participants in the crowdsourcing effort are vetted and trained prior to their participation. Participants do not directly access the DigitalGlobe imagery available to CHI through EV Webhosting, given access limitations, but rather work with Google Earth/Maps data and with a subset of DigitalGlobe data available through Qualcomm Institute's Big Pixel Initiative [36]. To date, the TerraWatchers collaboration has trained 131 students from the Universities of California at San Diego, Merced, and Berkeley, in assessing damage via satellite imagery. While the project is still assessing the overall results, during the project's first phase from 7 April 2016 to 5 May 2016, the participants made 4500 observations on over 3500 individual sites. They correctly identified damage based on looting, modern development, agricultural encroachment, and military-based earthworks and trenching. Students were most accurate in identifying modern settlements and burials on sites, while they had more difficulty identifying roadworks and mining or quarrying at archaeological sites. Through the process of training, students learned to identify specific forms of damage; the crowdsourcing project went from 7% accuracy during its first trial run to 39% accuracy [37].

Another new direction that has been developed by CHI in collaboration with the University of Central Florida's Center for Research in Computer Vision (CRCV), is automation of change detection analysis within the hundreds of thousands of satellite images. The project has undertaken initial change identification for incidents such as looting, bomb damage, and collapsed heritage, with the primary goal of prioritizing new images for analysts' attention based on the likelihood that a new image contains evidence of such events. This would help to mitigate the bottleneck created by the quantity of imagery in relation to the numbers of analysts (limited by cost factors) and is in line with similar work being undertaken by archaeologists elsewhere in the world [38–40].

3. Results

While all of the redacted incident reports compiled by CHI are available online [41], a selection of incidents that highlight the methodologies and results of this work are presented here by way of illustration. In addition to the reporting series published online, our team of geospatial analysts has also visually assessed 6662 heritage sites in Syria, Iraq, and Libya—assessments which are continually being updated and refined. Utilizing the most recently available satellite imagery, each heritage site was assessed for damage occurring since the start of the conflict and assigned a percentage of total visible damage. Figure 1 displays these assessments, broken down by site type. Although our reporting series focuses on damaged sites, the majority of assessed heritage sites display no visible damage—a total of 63%. The second highest percentage of damage falls under some damage, between 10% and 60%, at 26% of total assessed sites.

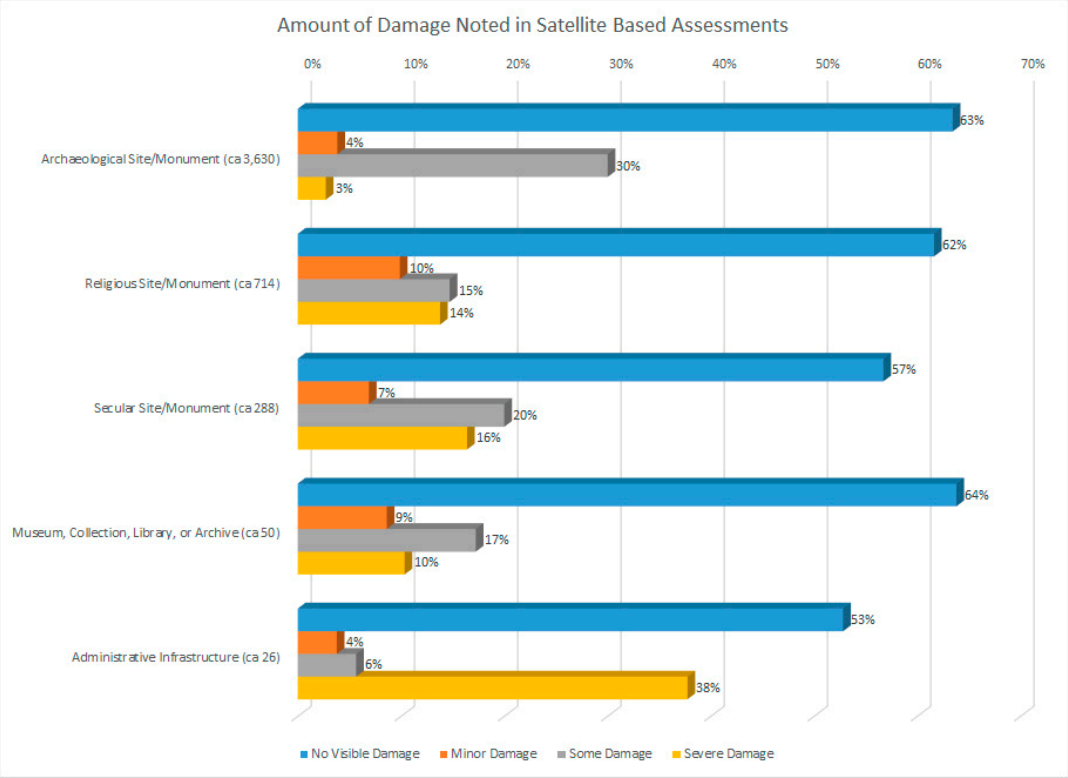


Figure 1. Satellite based assessments of heritage sites within the Cultural Heritage Initiatives (CHI) Inventory (mainly Syria and northern Iraq) according to site types and levels of assessed damage (ASOR CHI; 26 July 2017).

As of the 30 June 2017, CHI has produced 870 reports of cultural heritage damage in Syria and Northern Iraq over the past three years. This covers 1100 unique cultural heritage sites that have been affected by the ongoing conflicts in these areas. Over the last three years, CHI has recorded damage to

heritage sites due to a variety of disturbances, including military activity and human activity, such as illegal excavations, agriculture, and urban encroachment. Each damage incident is assigned a pattern of damage, based on the primary cause of the destruction or damage. The full list of damage patterns can be seen in Figure 2. Military activity ranks as the most frequent damage source, primarily incidents caused by explosives—mainly artillery strikes and airstrikes—as well as from gunfire.

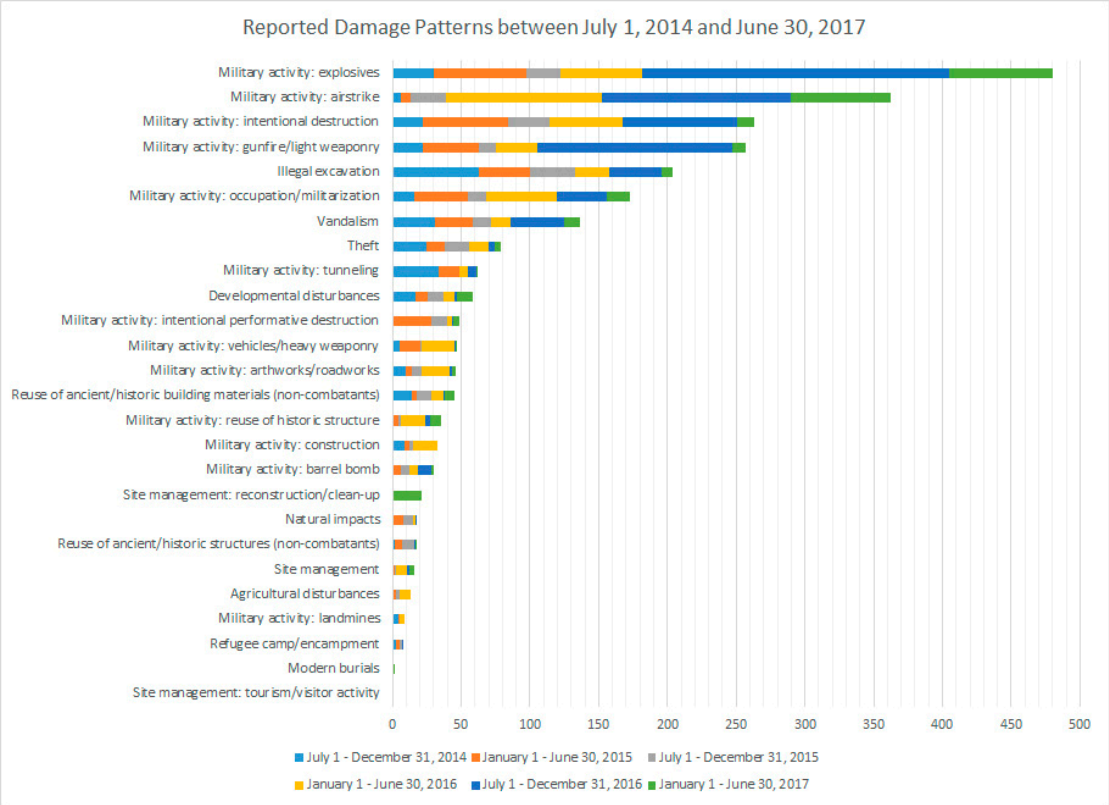


Figure 2. Damage patterns reported by CHI in the ongoing weekly and monthly report series since the project's inception in 2014. The horizontal bars representing incident totals (horizontal axis) by causes of damage are subdivided (stacked) according to report dates rather than the date(s) that the incidents occurred, to account for those incidents currently without known dates (ASOR CHI; 26 July 2017).

During the first six months of the project, CHI documented twice as many reported illegal excavations of archaeological sites as compared to explosive damage to heritage sites. During this period, the conflict kinetics were less intense, but also, at project startup, the overall number of reported conflict-related looting incidents was artificially elevated, given that such activity had been ongoing since late 2011–2012—although looters were especially active in 2014 and early 2015—and the evidence of illegal open-pit excavation in this largely arid and unvegetated region is highly visible and readily identifiable. Conversely, the spread of the practice of tunnel looting later in the conflict, presented some challenges for satellite based site assessment and has likely resulted in a slight underreporting of the incidence of looting activity assessed through satellite imagery. In the subsequent 32 months of the project, damage patterns flipped, with increasing damage to heritage sites due to explosives, primarily artillery shelling. In addition, airstrikes, the second- ranked cause of damage, dramatically increased starting from 1 January 2015, as aircraft from the Syrian Arab Republican Guard, Russian Military, US-led Coalition Forces, and Iraqi Government Forces carried out major offensives within Syria and Iraq. Intentional destruction of heritage sites, primarily carried out by ISIS, represents the third most common cause of damage to heritage sites, impacting most site categories (i.e., archaeological, religious, and secular). Such acts were prominent in reporting from 1 January to 30 June 2015, as ISIS and other

groups targeted shrines and other religious sites in Iraq and Syria as well as archaeological sites such as Palmyra, Nimrud, and Hatra.

The analysis of satellite imagery has helped to redress biases in our understanding of the cultural impacts of the conflict in Syria and Northern Iraq, stemming from open source and traditional media coverage. A comparison of causes of damage to the most common site types in the CHI inventory, archaeological sites and monuments versus religious sites and monuments, illustrates two complex and contrasting patterns of heritage damage (Figure 3). Archaeological sites and monuments are impacted by a wide range of factors, including urban development and encroachment, military earthworks and construction, as well as the reuse of ancient structures and buildings by both combatants and noncombatants. The leading causes of damage are illegal excavations and military occupation. Yet traditional media outlets and social media sites have largely focused on covering intentional destruction and looting, rather than the much more complex situation on the ground, in which instability, lack of rule of law and regulation, population displacements and deterioration and neglect play major roles in the loss of cultural assets. Religious sites and monuments, including mosques, churches, and shrines, have been devastated by military explosives and airstrikes, intentional destructions, and gunfire. Although ubiquitous, such incidents have received less media coverage, particularly outside the Middle East, relative to the less frequent spectacles of intentional destructions at famous archaeological sites, despite the deleterious long-term impacts that such attacks exert on the region's communities, conflict resolution, and regional stability.

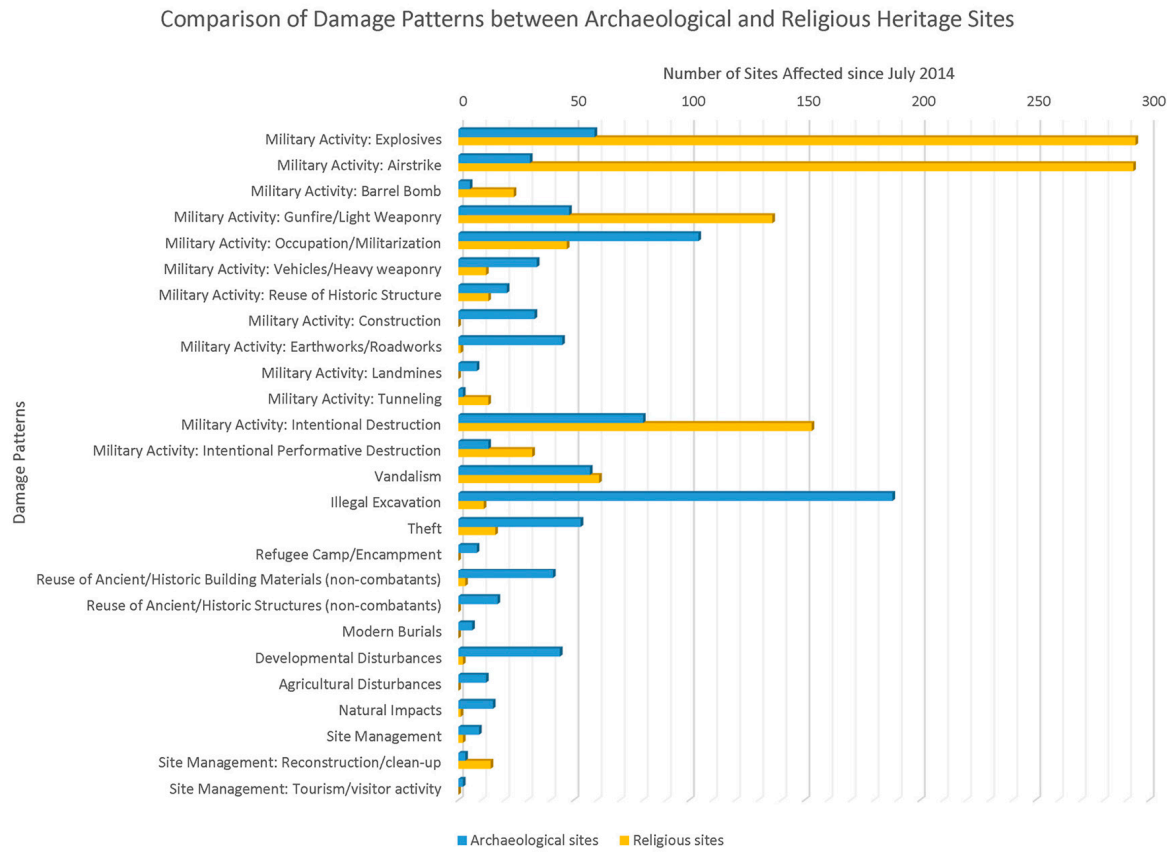


Figure 3. Comparison of the causes of damage to archaeological and religious heritage sites in Syria and Northern Iraq between 1 July 2014 and 30 June 2017 (ASOR CHI; 26 July 2017).

In the first three years of the project, unredacted CHI reporting has been regularly consulted by various government and non-government organizations to assess the overall situation and to develop and implement policies and actions, including but not limited to, presentations and written

submissions for multiple US government agencies and congressional committees, the European Union, United Nations Educational, Scientific, and Cultural Organization (UNESCO), the United Nations, the United Nations Security Council and, it is our understanding, for the US National Counterterrorism Center and multiple Presidential Daily Briefs. In terms of raising public awareness, redacted CHI analyses have been featured in hundreds of news reports and public presentations detailing the impacts of the conflict on cultural heritage and cultural memory, identity, and diversity. CHI has supported investigations by activists, journalists, and law enforcement agencies worldwide to recover stolen cultural property, combat looting, and counter violent extremism. Most importantly, the program strives to support Syrian, Iraqi, and Libyan cultural heritage experts and local stakeholders in their struggle to save their beleaguered cultural patrimony. In this regard, CHI monitoring and reporting has supported multiple in-country initiatives to preserve and protect cultural heritage, by reducing risks, mitigating threats, repairing damage and, ultimately, maintaining local access to cultural heritage.

To illustrate the results of the reporting methodology, three case studies are presented below. They were selected to reflect the development of the methodology and how it utilizes workflows, and originated with reports from both the geospatial and non-geospatial portions of the project. These three examples also represent instances in which media organizations utilized ASOR CHI reporting to develop stories to inform the public of damage to cultural heritage as the incidents were transpiring or shortly thereafter. The monitoring of Nimrud between January and April of 2015, and the reports published during that time, are one of the earliest examples from a single cultural heritage site where the CHI-integrated methodology was implemented. The monitoring of Palmyra from 2014 to 2017 provides a series of events across a wider expanse of associated cultural heritage sites that were monitored using this integrated methodology, including incidents that were first made known at the time by CHI in its reports. Finally, the ongoing monitoring of damage to the old city of Mosul shows the power of this integrated approach when it is expanded to an urban scale, encompassing numerous cultural heritage sites.

3.1. Early Implementation of the ASOR CHI Methodology at Nimrud

Nimrud, a multi-period site, best known for its 9th and 8th century BCE occupation as an early capital of the Neo-Assyrian Empire, was one of the first cultural heritage sites where the CHI methodology was fully implemented over an extended period of time. The archaeological site had come under threat prior to the start of the project in June 2014, but between January and April of 2015 the walled Acropolis, and particularly the Northwest Palace of Ashurnasirpal II and its famous sculpted bas reliefs, were the subject of filmed acts of destruction by ISIS (i.e., performative deliberate destructions).

CHI received the earliest reports of intended ISIS attacks from in-country contacts in January 2015, by which time Nimrud had already been added to a short list of priority sites requiring ongoing tasking of satellites for imagery. No evidence of destruction from assessments of satellite imagery were noted until a 7 March image, following increasing reports from 5 March to 7 March, that ISIS had deployed personnel and equipment to destroy standing architecture at Nimrud (Figure 4a,b). This incident was part of a larger pattern of performative deliberate destructions targeting cultural heritage in the Mosul area, including ancient sculptures and replicas in the city's museum and monumental architecture and sculptures at Nineveh, another Neo-Assyrian capital, which attracted widespread attention and worldwide condemnation in late February.

(**a**) (**b**)

Figure 4. The Northwest Palace at Nimrud in DigitalGlobe satellite imagery (**a**) prior to damage from ISIS with protective roofing over the stone reliefs in situ (DigitalGlobe NextView License; 26 February 2015); (**b**) with arrows indicating a pile of rubble and vehicle tracks within the palace walls (DigitalGlobe NextView License; 7 March 2015).

In the 7 March imagery, CHI noted evidence for cuts in walls at key access points in the Northwest Palace, as well as piles of rubble in areas adjacent to the Throne Room, that exceeded the volumes of missing portions of walls. These rubble piles appeared to consist of freshly broken stone matching the color of stone used in Nimrud's bas reliefs. CHI analysts posited that ISIS had targeted the reliefs lining the entranceway and walls within the Throne Room for destruction. CHI shared this information with in-country and international experts, including the State Board of Antiquities and Heritage of Iraq (SBAH) and UNOSAT, shortly after the release of the imagery to CHI on 8 March, and updates continued as new imagery was released into early April, showing further evidence of ongoing damage. In an image from 1 April, further damage is visible in the Throne Room, evidenced by the removal of a protective cover over the reliefs and heavy vehicle tracks within the palace (Figure 5a). Around 2 April, ISIS demolished the Northwest Palace through the detonation of a series of barrel bombs set along the face of the relief-covered walls. ISIS released a video of this criminal act on 11 April. The destruction appears in satellite imagery taken on 17 April (Figure 5b). Analysis of both the released footage and the satellite image allowed preliminary assessments of the damage, setting up subsequent on-the-ground damage assessments as ISIS was pushed back from the area. The entire event was reported publicly, within CHI Weekly Reports 31, 34, and 36, as well as in a special summary report published on 5 May 2015 [42–45]. This case demonstrates the utility of the integrated CHI methodology and of the public–government collaboration for following cultural heritage threats over an extended period of time. The case highlights the capability of cultural property protection programs to monitor and alert the international community to impending and ongoing attacks on cultural assets. Such situational awareness allows the international community to seize the initiative and to conduct public outreach and awareness activities prior to the online release of extremist propaganda featuring performative deliberate destructions.

(**a**) (**b**)

Figure 5. Further destruction at the Northwest Palace of Nimrud (**a**) with more vehicle tracks and removal of stone reliefs noted with the red arrows (DigitalGlobe NextView License; 1 April 2015); (**b**) after the detonation of bombs by ISIS within the palace walls (DigitalGlobe NextView License; 17 April 2015).

3.2. Intentional Destructions at Palmyra in 2015

The UNESCO World Heritage Site of Palmyra (the ancient site and adjacent modern town are known as Tadmor in Arabic) has been under heightened threat and damaged during multiple periods of the Syrian conflict due to the area's strategic significance. This desert oasis was controlled by ISIS from May 2015 through March 2016, and again from December 2016 until 2 March 2017 until it was recaptured by Syrian Arab Republic Government (SARG) forces. During the time in which ISIS held Palmyra, the archaeological site was looted and standing architecture was repeatedly targeted for intentional destruction—some performative acts were released in videos and photos as part of ISIS's propaganda campaign.

ISIS committed large numbers of atrocities in the Tadmor area, targeting the town's inhabitants and more modern religious heritage. Most telling of all, prior to targeting Palmyra's ancient monuments for intentional destruction, in fact almost immediately upon capturing the area, the group carried out destructions and vandalisms of Sunni, Sufi, Shia, and Christian heritage. Such acts reveal the organization's prioritization of cultural cleansing and the intimidation and subjugation of modern populations. Many of these sites were located in the remote desert areas surrounding Tadmor, increasing the importance of geospatial analysis for investigating alleged incidents, given the paucity of other information.

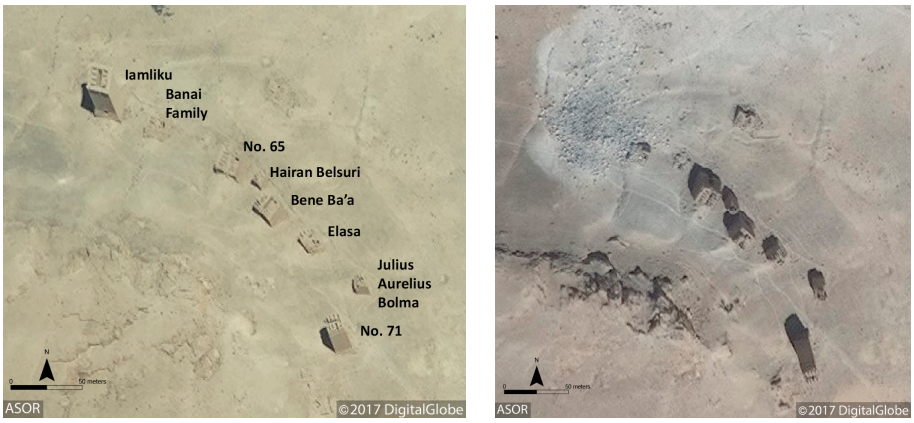
The destruction of Palmyra's famous Temple of Baalshamin and Temple of Bel formed the middle stages in this campaign of performative destruction [46,47]. Soon after ISIS took over the site in May 2015, reports began to emerge that ISIS militants had planted explosive devices within the archaeological site, which was confirmed by 23 June 2015 through CHI sources, who reported that locals had seen members of ISIS place "large mines/bombs in the ruins of many buildings in Palmyra", and told Tadmor's residents of their intent to destroy the ruins—using loudspeakers in Tadmor—to gain media coverage and possibly as a deterrent to counterattacks. During this time, ISIS leaders also allegedly lived at the site, to protect themselves from airstrikes, and munitions were stored on-site. ISIS has regularly repurposed heritage sites and cultural and educational buildings for military and political use, throughout the conflict zone. On 23 August 2015, reports began to emerge that ISIS had destroyed the Baalshamin Temple (largely of the 2nd century CE). Soon after, ISIS released photographs showing the temple walls lined with barrels of explosives and the subsequent explosion. DigitalGlobe satellite imagery taken on 27 August 2015 acquired by CHI confirmed this destruction. A few days later, on 30 August 2015, the pattern repeated at the Temple of Bel, which dated to the 1st century CE,

with reports of its destruction using explosives. This was confirmed via satellite imagery a few days later (Figure 6a,b). ISIS later published images of the destruction in its online magazine.

(**a**) (**b**)

Figure 6. DigitalGlobe satellite imagery of the Temple of Bel: (**a**) prior to intentional destruction (DigitalGlobe NextView License; 26 June 2015); (**b**) post-destruction with the cella of the temple destroyed (DigitalGlobe NextView License; 2 September 2015).

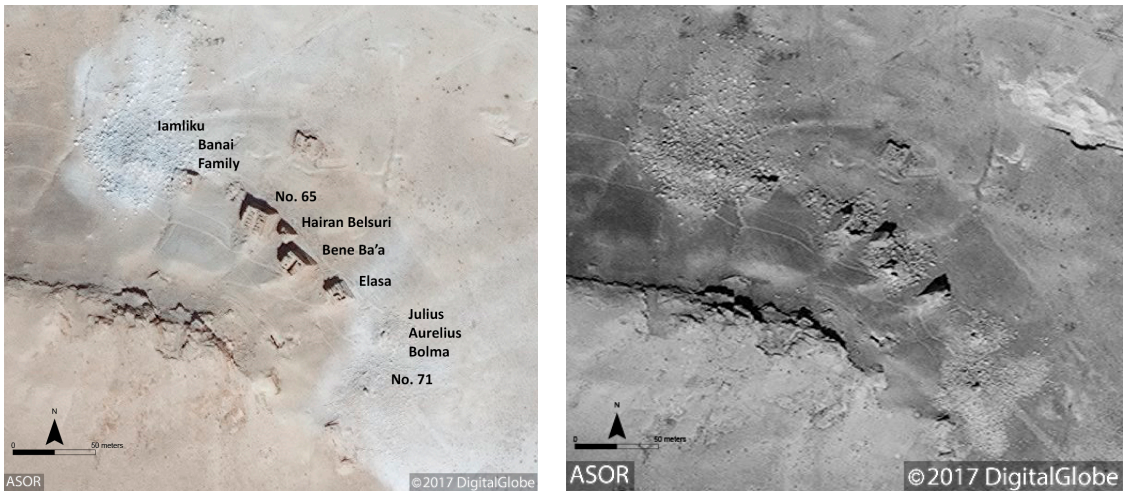
At the same time as these performative destructions at the Temples of Bel and Baalshamin, ISIS destroyed large parts of the Valley of the Tombs, though less publicly. During three phases, the tallest and most well-known tower tombs, all located on the northern slopes of the Umm al-Belqis, were destroyed by ISIS, using explosives. This act and others suggest ISIS leadership optimizes heritage targeting, in targeted rich environments, based on its perceived significance. The Valley of the Tombs is an area of the Palmyra necropolis located west of the city's ancient walls, containing around 100 tower tombs, hypogea (underground tombs), and funerary temples (tombs built to look like small temples or houses). The most eye-catching monuments in this area are the tower tombs. Often several stories high, each floor of a tower had multiple chambers, containing loculi, or small spaces for individual interments. No reports of this destruction were known prior to their assessment by CHI in DigitalGlobe satellite imagery. Between 26 June 2015 and 27 August 2015 the Tomb of Iamliku was destroyed and the Banai Family Tomb directly to its east was badly damaged (Figure 7a,b).



(**a**) (**b**)

Figure 7. DigitalGlobe satellite imagery of the Valley of the Tombs: (**a**) with no visible damage (DigitalGlobe NextView License; 26 June 2015); (**b**) with visible damage to Tomb of Iamliku and Tomb of the Banai Family (DigitalGlobe NextView License; 27 August 2015).

During a second phase of destruction, between 27 August 2015 and 2 September 2015, ISIS destroyed more tower tombs, including the Tomb of Elahbel, the Tomb of Kithoth in the Northern necropolis, and two additional unnamed tombs near the Tomb of Iamliku (Figure 8a). Then, between 2 September 2015 and 30 March 2016, the Tower Tombs of Elasa, Bene Ba'a, Hairan Belsuri, and No. 65 were severely damaged, as seen in DigitalGlobe imagery (Figure 8b). The tomb of Elasa appears to still be standing without damage, while the three structures to the east have all sustained various degrees of damage. Some walls are still standing, but the large rubble piles at their bases indicate some destruction with explosives. ISIS never published photos or videos of the damage done to these monuments. In addition to these destructions, tombs in Western, Southeastern, and Southwestern Necropoli were also intentionally destroyed with explosives, which was only revealed in satellite imagery [48,49]. Lastly, in January 2017, ISIS intentionally destroyed the Tetrapylon and part of the Roman Theater's stage backdrop, which CHI identified, as part of our monitoring of the archaeological site using DigitalGlobe satellite imagery [50,51].



(**a**) (**b**)

Figure 8. DigitalGlobe satellite imagery of the second and third phases of destruction in the Valley of the Tombs: (**a**) with visible damage to Tomb of Julius Aurelius Bolma and Tomb No. 71 (DigitalGlobe NextView License; 2 September 2015); (**b**) with new damage to the Tombs of Bene Ba'a, Hairan Belsuri, and No. 65 although some of the structures are still intact (DigitalGlobe NextView License; 30 March 2016).

Since the site has been recaptured by SARG forces, cultural heritage professionals have been able to access the site and assess the damage, using small drones as well as on the ground photography. CHI has incorporated these images into its monitoring to better understand the extent of the damage to cultural heritage and evaluate our earlier interpretation of satellite imagery.

The site of Palmyra and other heritage sites in the city of Tadmor and surrounding area have suffered severe damage since 2011. While ISIS has caused the majority of damage, all belligerents in the conflict have committed or been complicit in cultural property crimes in Tadmor or logistical blunders, such as the construction of a military base on the site by Russian forces [52]. Our understanding of these events has heavily depended on rapid-paced geospatial analysis. As in the case of Nimrud, situational awareness did not prevent these incidents, but it is hoped that the documentary efforts of CHI and other organizations will facilitate the rehabilitation of Tadmor and help to bring the perpetrators of these crimes to justice. The careful documentation of Palmyra has provided one of our most comprehensive examples of ISIS cultural cleansing and pillage, which reveals the intentions and priorities of ISIS leadership to persecute and uproot ethnic and religious minorities first, and later, loot and destroy ancient cultural resources, to impose and propagate ideology and finance global terrorism.

3.3. Assessment of Damage to the Old City of Mosul

On 11 June 2017, Iraqi Prime Minister, Haider al-Abadi, announced Iraq's victory over ISIS in the militant group's former Northern Iraqi stronghold of Mosul [53–57]. His announcement followed months of fighting, extensive aerial bombardment, massive infrastructure damage, human displacement, and thousands of civilian casualties [58]. The struggle for Mosul spanned nine months, with the most intense fighting occurring in the labyrinthine confines of the Old City. The final month of military operations brought the worst damage and high numbers of civilian casualties as ISIS militants unleashed waves of car bombings, suicide bombers, and snipers to target both Iraqi forces and Mosul residents [59,60]. The Old City of Mosul, located on the Western Bank of the Tigris, dates back to the Zengid Dynasty (1127–1250 CE) with historic souqs, mosques, churches, and government buildings dating from 1200 to 1800 CE. In June 2014, a force of about 1000 ISIS militants invaded the city [61].

Between June 2014 and late December 2015, ISIS carried out multiple intentional destructions of major cultural heritage sites across Mosul. Using a combination of satellite imagery, media, and in-country sources, CHI has confirmed the total destruction of 32 religious sites across the city of Mosul, including shrines, mosques, churches, and cemeteries, during ISIS's three-year occupation [42,62–66]. In the Old City alone, ISIS conducted 13 intentional destructions during that period, with mosques, churches, and shrines demolished with explosives or heavy machinery. Many of those sites were then cleared of all debris, paved, and used as parking lots by ISIS. After that initial burst of destruction, ISIS militants turned their attention elsewhere until the recent destructions of al-Nuri al-Kabir Mosque and al-Hadba Minaret— ISIS's final cruel acts of retributory violence.

CHI has monitored recapturing operations in Mosul and has documented damage to dozens of cultural heritage sites. Much of the heavy combat during the recapture of the city was focused on the Old City of Mosul (Figure 9). As of 30 June 2017, CHI has reported 23 individual incidents of damage to religious heritage in the Old City of Mosul, including mosques (14 incidents), churches (six incidents), and shrines (three incidents). Of these reported incidents, 16 were ISIS intentional destructions of Muslim and Christian sites during the occupation of the city, and the other seven were due to military explosives, possibly from shelling, heavy artillery, or airstrikes. Information on heritage incidents inside Mosul was not easy to acquire, and CHI regularly relied on available satellite imagery to monitor and confirm destructions of heritage sites.

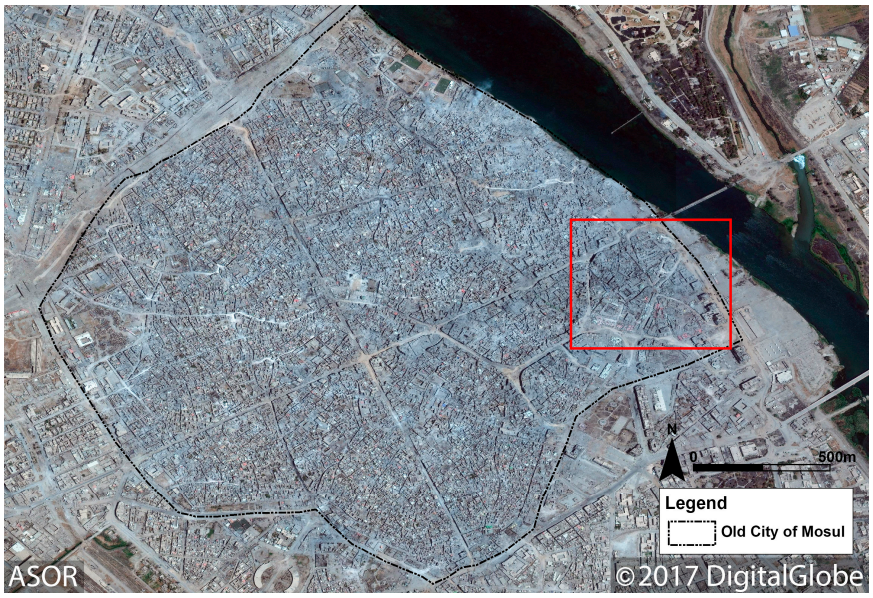


Figure 9. Old City of Mosul with the area of the souqs outlined in red. See below for insets of damage before and after the offensive (ASOR CHI/DigitalGlobe NextView License; 12 July 2017).

During CHI monitoring of the occupation of Mosul, our assessments were aided by the continuing advancements in satellite technology. Urban areas posed a problem when the project first started, since much of the damage was too small to see, even on 46 cm resolution imagery, such as the WorldView-2 satellite. With newer imagery available from WorldView-3, at 34 cm resolution, we are able to focus on damage at the level of single, small buildings and identify and assess areas of damage and destruction with increased spatial precision and interpretive accuracy and detail.

The ongoing bombardment and street warfare continues to leave its mark on the historically and culturally significant locations within the city, none more so than the area of the souqs. Much of this damage has occurred within the last year, beginning in March 2017, as visible in DigitalGlobe satellite imagery. Since May 2016, the streets and courtyards of this area have been systematically covered with metal roofs, including in the final phase over Nineveh Street and Ghazi Street, as a way to provide cover from airstrikes. In March, severe aerial bombardment damaged much of the area, including Bab al-Tub Police Headquarters, Souq al-Alwah Mosque, and Bab al-Tub Mosque. The damage was so severe that pieces of the metal roofing were visible in satellite imagery floating in the Tigris River. As of 22 May 2017, the ongoing conflict has further damaged these sites as well as the al-Aghawat Mosque, al-Pasha Mosque, and the former site of the Madrasa of the Abdal Mosque, which had been previously razed to the ground in an intentional destruction by ISIS and a new construction built on top of it. By the end of the offensive in the Old City, of the eight heritage sites identified in this area, three were destroyed, four were severely damaged, and one showed some damage (Figure 10).

Figure 10. DigitalGlobe satellite imagery of the souq area within the Old City of Mosul: (**a**) prior to the offensive to retake the Old City (DigitalGlobe NextView License; 9 May 2016); (**b**) after recapture by Iraqi forces (DigitalGlobe NextView License; 12 July 2017).

As of 30 June 2017, CHI has assessed the damage to 64 heritage sites within the Old City of Mosul. We have noted 37 heritage sites that exhibit severe damage (60–100% damaged), 12 of which have some damage (10–60%), nine with minor damage (1–10%), and six with no visible damage (Figure 11). These assessments will continue to be updated as more photographs are taken and heritage professionals on the ground complete assessments. In comparison, United Nations Institute for Training and Research's Operational Satellite Applications Program (UNITAR-UNOSAT) identified 5536 affected structures of all types within the Old City from imagery dated 30 June 2017, with almost 500 of those destroyed and 3310 severely damaged [67]. This was an increase of 37% from their previous report, just 14 days prior. Geospatial analysis shows this area of the city has sustained intense damage to all buildings, and the effort to rebuild the lives of those living in Mosul will be a long and difficult process.

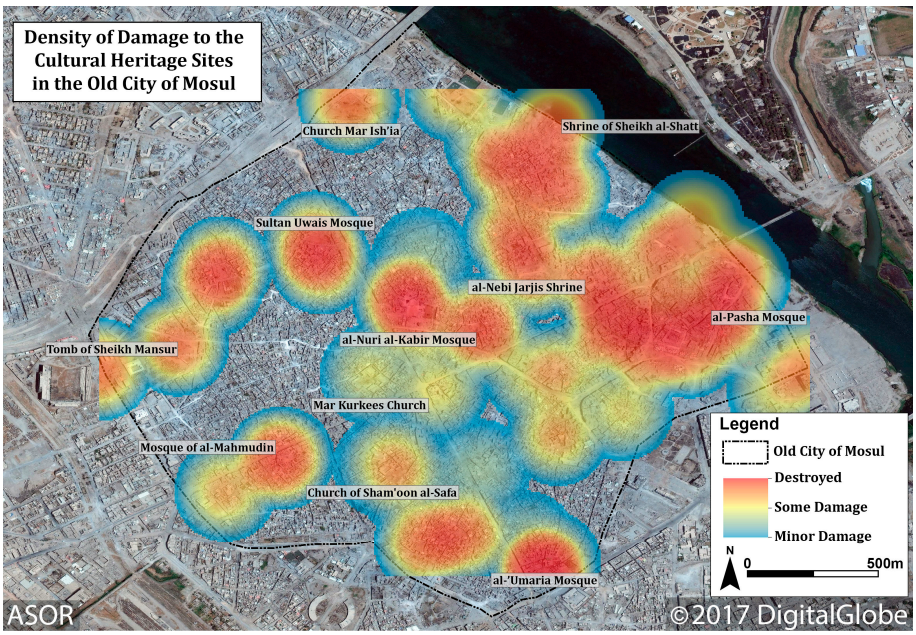


Figure 11. Density of damage to cultural heritage sites within the Old City of Mosul (ASOR CHI/DigitalGlobe NextView License; 12 July 2017).

4. Discussion

Conflict situations present a number of unique difficulties for monitoring and protecting cultural heritage. Foremost among these, is the risk to stakeholders living in the vicinity. They are the essential key to the long-term protection and monitoring of cultural heritage. Particularly in a conflict where cultural heritage has been purposefully targeted for propagandistic, psychological, and strategic goals, the risk of loss and even the death of local stakeholders is a very real and ever present danger. Methodologies that prioritize their safety are essential. While gaining information during the conflict is important, it should never endanger the lives of local stakeholders.

The methodology developed by CHI for integrating assessments of satellite data with ground-based observations and open-source information has wide applicability for addressing aspects of cultural heritage crises in conflict zones. In situations such as those in Syria and Northern Iraq, where direct ground-based observations have often been impossible or carried considerable risk for individuals in the vicinity, the methodology offers various alternatives for providing or publicly attributing sources of reliable information. When the on-the-ground situation allows, the methodology also incorporates ground verification to further strengthen conclusions.

The work of CHI benefits enormously from the unique public–government partnership, made possible by the collaboration with the DOS. While access to enormous numbers of satellite images creates bottlenecks and issues with workflows, it is essential for providing data necessary for producing the reliable and verifiable reports, for which CHI is now known. It furthermore necessitated that CHI find effective ways to address the needs for an authoritative inventory of the locations of cultural heritage and for a way to cross-compare reports of damage being collected by different analysts and organizations. Both of these goals have been attained through a strong network of project collaborators and through access to this large body of satellite imagery. Furthermore, the extended standardized schema of threats and disturbances developed by CHI to address this second need will have widespread applicability in future conflict zones that see military damage, looting, or performative destruction of cultural heritage.

The impact of CHI extends beyond the important role it is playing in Syria, Northern Iraq, and Libya. Projects monitoring cultural heritage crises in future conflicts will have a model in place for how to effectively pair big data from remote sensing with a broad network of collaborators, including

area specialists and local stakeholders. New technologies will no doubt change the specifics of the data being used, but the essential methodology employed is flexible enough to incorporate any datasets. Ongoing work by CHI to refine the methodology, through initiatives such as crowd-sourcing and automation, or to press for the further development of cross-collaborative data sharing platforms, like Arches, will likewise impact how such projects are undertaken in future conflict situations and in the post-conflict periods that follow. However, in the end, it is the people involved, and particularly the local stakeholders that will enable the power of cultural heritage to impact our present and future.

Acknowledgments: ASOR CHI has received financial support through two consecutive cooperative agreements awarded by the U.S. Department of State (NEA-PSHSS-14-001 and S-IZ-100-17-CA021). Additional support for complementary aspects of the project has been provided by the J.M. Kaplan Fund, National Endowment for the Humanities, Getty Conservation Institute, and the Whiting Foundation. The University of Central Florida supported work on the automated detection of cultural heritage in satellite imagery through a COS/ORC Seed Grant.

Author Contributions: All authors conceived and designed the methodology, performed the methodology, analyzed the data, and wrote the paper.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Kila, J.D. *Heritage under Siege: Military Implementation of Cultural Property Protection Following the 1954 Hague Convention*; Brill: Leiden, The Netherlands, 2012.
2. Kila, J.D.; Zeidler, J.A. *Cultural Heritage in the Crosshairs: Protecting Cultural Property during Conflict*; Brill: Leiden, The Netherlands, 2013.
3. Kila, J.D.; Balcells, M. *Cultural Property Crime: An Overview and Analysis of Contemporary Perspectives and Trends*; Brill: Leiden, The Netherlands, 2014.
4. Nemeth, E. *Cultural Security: Evaluating the Power of Culture in International Affairs*; Imperial College Press: London, UK, 2015.
5. Casana, J. Satellite imagery-based analysis of archaeological looting in Syria. *Near East. Archaeol.* **2015**, *78*, 142–152. [CrossRef]
6. Danti, M.D. Ground-based observations of cultural heritage incidents in Syria and Iraq. *Near East. Archaeol.* **2015**, *78*, 132–141. [CrossRef]
7. Danti, M.D. ISIS, war and the threat to cultural heritage in Iraq and Syria: Recent cultural heritage developments: Recent Cultural Heritage Developments. *IFAR J.* **2016**, *16*, 33–46.
8. Danti, M.D. Protecting endangered cultural heritage in Syria and Iraq: The role of international organizations and governments. In Proceedings of the One Hundred Tenth Annual Meeting of the American Society of International Law, Washington, DC, USA, 31 March 2016; Cambridge University Press: Cambridge, UK, 2017; pp. 95–112.
9. ASOR Cultural Heritage Initiatives. Available online: http://www.asor-syrianheritage.org (accessed on 31 August 2017).
10. Danti, M.D. Near Eastern archaeology and the Arab Spring: Avoiding the ostrich effect. *Antiquity* **2014**, *88*, 639–643. [CrossRef]
11. Adams, R.M. *The Heartland of Cities*; University of Chicago Press: Chicago, IL, USA, 1981.
12. Parcak, S.H. *Satellite Remote Sensing for Archaeology*; Routledge: London, UK, 2009.
13. Masini, N.; Lasaponara, R. Sensing the past from space: Approaches to site detection. In *Sensing the Past: From Artifact to Historical Site*; Masini, N., Soldovieri, F., Eds.; Springer: Cham, Switzerland, 2017; pp. 23–60.
14. EAMENA Endangered Archaeology in the Middle East and North Africa. Available online: http://eamena.arch.ox.ac.uk/ (accessed on 31 August 2017).
15. Rayne, L.; Bewley, R. Using Satellite Imagery To Record Endangered Archaeology. In *Remote Sensing and Photogrammetry Society Archaeology Special Interest Group (RSPSoc Archaeology SIG) Newsletter*; 2016; pp. 15–20. Available online: http://eamena.arch.ox.ac.uk/wp-content/uploads/Bewley_and_Rayne_2016.pdf (accessed on 24 September 2017).
16. EV WebHosting Login. Available online: https://evwhs.digitalglobe.com/myDigitalGlobe/login (accessed on 31 August 2017).

17. Beck, A. Google Earth and World Wind: Remote sensing for the masses. *Antiquity* **2006**, *80*. Available online: http://www.antiquity.ac.uk/projgall/beck308 (accessed on 31 August 2017).
18. Contreras, D.A.; Brodie, N. The utility of publicly-available satellite imagery for investigating looting of archaeological sites in Jordan. *J. Field Archaeol.* **2010**, *35*, 101–114. [CrossRef]
19. Stone, E.C. Patterns of looting in southern Iraq. *Antiquity* **2008**, *82*, 125–138. [CrossRef]
20. Branting, S.; Trampier, J. Geospatial data and theory in archaeology: A view from CAMEL. In *Space—Archaeology's Final Frontier? An Intercontinental Approach*; Salisbury, R.B., Keeler, D., Eds.; Cambridge Scholars Publishing: Cambridge, UK, 2007; pp. 272–289.
21. Fowler, M.J. Declassified intelligence satellite photographs. In *Archaeology from Historical Aerial and Satellite Archives*; Hanson, W.S., Oltean, I.A., Eds.; Springer: New York, NY, USA, 2013; pp. 47–66.
22. Nebbia, M.; Leone, A.; Bockmann, R.; Hddad, M.; Abdouli, H.; Masoud, A.M.; Elkendi, N.M.; Hamoud, H.M.; Adam, S.S.; Khatab, M.N. Developing a collaborative strategy to manage and preserve cultural heritage during the Libyan conflict. The case of the Gebel Nāfusa. *J. Archaeol. Method Theory* **2016**, *23*, 971–988. [CrossRef]
23. Parcak, S.; Gathings, D.; Childs, C.; Mumford, G.; Cline, E. Satellite evidence of archaeological site looting in Egypt: 2002–2013. *Antiquity* **2016**, *90*, 188–205. [CrossRef]
24. Casana, J.; Panahipour, M. Satellite-based monitoring of looting and damage to archaeological sites in Syria. *J. East. Mediterr. Archaeol. Heritage Stud.* **2014**, *2*, 128–151. [CrossRef]
25. ANE Placemarks for Google Earth. Available online: http://www.lingfil.uu.se/research/assyriology/earth/ (accessed on 31 August 2017).
26. The CRANE Project: Computational Research on the Ancient near East. Available online: https://www.crane.utoronto.ca/ (accessed on 31 August 2017).
27. Monuments of Syria. Available online: http://monumentsofsyria.com (accessed on 31 August 2017).
28. The Fragile Crescent Project: Settlement Change during the Urban Transition. Available online: https://www.dur.ac.uk/fragile_crescent_project/ (accessed on 31 August 2017).
29. Syrian Heritage Archive Project. Available online: https://arachne.dainst.org/project/syrher (accessed on 31 August 2017).
30. UNITAR's Operational Satellite Applications Programme—UNOSAT. Available online: https://unitar.org/unosat/ (accessed on 31 August 2017).
31. Shirín. Available online: http://shirin-international.org/ (accessed on 31 August 2017).
32. Getty Conservation Institute; World Monuments Fund. *Middle Eastern Geodatabase for Antiquities (MEGA)—Jordan: Guidelines for Completing Site Cards*; Getty Conservation Institute: Los Angeles, CA, USA, 2010.
33. Barnes Gordon, L.; Rouhani, B.; Cuneo, A.; Penacho, S. A methodology for documenting preservation issues affecting cultural heritage in Syria and Iraq. In Proceedings of the Objects, Joint Architecture + Objects, and Joint Objects + Wooden Artifacts Specialty Group Sessions 44th Annual Meeting, Montreal, QC, Canada, 13–17 May 2016; Hamilton, E., Dodson, K., Eds.; Available online: http://resources.conservation-us.org/osg-postprints/postprints/v23/barnesgordon/ (accessed on 24 September 2017).
34. Arches: An Open Source Data Management Platform for the Heritage Field. Available online: https://www.archesproject.org (accessed on 31 August 2017).
35. TerraWatchers: Crowd Sourced Satellite Image Analysis. Available online: http://terrawatchers.org/ (accessed on 31 August 2017).
36. Big Pixel Initiative at UC San Diego. Available online: http://bigpixel.ucsd.edu (accessed on 31 August 2017).
37. Savage, S.; Johnson, A. Terrawatchers, crowdsourcing, and at-risk world heritage in the Middle East. In *Acquisition, Curation, and Dissemination of Spatial Cultural Heritage Data*; Vincent, M., Bendicho, V.M.L.-M., Ioannides, M., Levy, T.E., Eds.; Springer: New York, NY, USA, 2017; in press.
38. Lauricella, A.; Cannon, J.; Branting, S.; Hammer, E. Semi-automated detection of looting in Afghanistan using multispectral imagery and principal component analysis. *Antiquity* **2017**, *91*, 1344–1355, in press. [CrossRef]
39. Bowen, E.F.W.; Tofel, B.B.; Parcak, S.; Granger, R. Algorithmic identification of looted archaeological sites from space. *Front. ICT* **2017**, *4*, 1–11. [CrossRef]

40. Lasaponara, R.; Danese, M.; Masini, N. Satellite-based monitoring of archaeological looting in Peru. In *Satellite Remote Sensing: A New Tool for Archaeology*; Lasaponara, R., Masini, N., Eds.; Springer: Heidelberg, Germany, 2012; pp. 177–193.
41. ASOR Cultural Heritage Initiatives Reports. Available online: http://www.asor-syrianheritage.org/reports (accessed on 31 August 2017).
42. ASOR Cultural Heritage Initiatives Weekly Report 31 (9 March 2015). Available online: http://www.asor-syrianheritage.org/syrian-heritage-initiative-weekly-report-31-march-9-2015 (accessed on 31 August 2017).
43. ASOR Cultural Heritage Initiatives Weekly Report 34 (30 March 2015). Available online: http://www.asor-syrianheritage.org/syrian-heritage-initiative-weekly-report-34-march-30-2015 (accessed on 31 August 2017).
44. ASOR Cultural Heritage Initiatives Weekly Report 36 (13 April 2015). Available online: http://www.asor-syrianheritage.org/syrian-heritage-initiative-weekly-report-36-april-13-2015 (accessed on 31 August 2017).
45. ASOR Cultural Heritage Initiatives Report on the Destruction of the Northwest Palace at Nimrud. Available online: http://www.asor-syrianheritage.org/report-on-the-destruction-of-the-northwest-palace-at-nimrud (accessed on 31 August 2017).
46. ASOR Cultural Heritage Initiatives Weekly Report 55–56 (18 August 2015–1 September 2015). Available online: http://www.asor-syrianheritage.org/asor-cultural-heritage-initiatives-weekly-report-55-56-august-18-2015-september-1-2015 (accessed on 31 August 2017).
47. ASOR Cultural Heritage Initiatives Weekly Report 57–58 (2 September 2015–15 September 2015). Available online: http://www.asor-syrianheritage.org/asor-cultural-heritage-initiatives-weekly-report-57-58-september-2-2015-september-15-2015 (accessed on 31 August 2017).
48. ASOR Cultural Heritage Initiatives Special Report: Update on the Situation in Palmyra. Available online: http://www.asor-syrianheritage.org/special-report-update-on-the-situation-in-palmyra (accessed on 31 August 2017).
49. ASOR Cultural Heritage Initiatives Special Report: The Recapture of Palmyra. Available online: http://www.asor-syrianheritage.org/4290-2 (accessed on 31 August 2017).
50. ASOR Cultural Heritage Initiatives New Damage in Palmyra Uncovered by ASOR CHI. Available online: http://www.asor-syrianheritage.org/new-damage-in-palmyra-uncovered-by-asor-chi (accessed on 31 August 2017).
51. ASOR Cultural Heritage Initiatives Update Palmyra: New Photographs Detail Damage to the UNESCO World Heritage Site of Palmyra. Available online: http://www.asor-syrianheritage.org/update-palmyra-new-photographs-detail-damage-to-the-unesco-world-heritage-site-of-palmyra (accessed on 31 August 2017).
52. ASOR Cultural Heritage Initiatives Weekly Report 93–94 (11 May 2015–24 May 2016). Available online: http://www.asor-syrianheritage.org/asor-cultural-heritage-initiatives-weekly-report-93-94-may-11-2016-may-24-2016/ (accessed on 31 August 2017).
53. BBC News: Battle for Mosul: Iraq PM Abadi Formally Declares Victory. Available online: http://www.bbc.com/news/world-middle-east-40558836 (accessed on 31 August 2017).
54. Haider Al-Abadi: From the Old City We Announce the Liberation of Mosul and Remember the Heroic Sacrifices of Our Armed Forces and Their Families. Available online: https://twitter.com/HaiderAlAbadi/status/884464192023138304 (accessed on 31 August 2017).
55. U.S. Department of Defense. Iraqi Forces Liberate Mosul from ISIS. Available online: https://www.defense.gov/News/Article/Article/1242101/iraqi-forces-liberate-mosul-from-isis/source/GovDelivery (accessed on 31 August 2017).
56. The New York Times: Iraqi Prime Minister Arrives in Mosul to Declare Victory over ISIS. Available online: https://www.nytimes.com/2017/07/09/world/middleeast/mosul-isis-liberated.html (accessed on 31 August 2017).
57. Reuters: Iraqi PM Declares Victory over Islamic State in Mosul. Available online: http://www.reuters.com/article/us-mideast-crisis-iraq-mosul-idUSKBN19V105 (accessed on 31 August 2017).
58. Reuters: Iraq and Allies Violated International Law in Mosul Battle: Amnesty. Available online: https://www.reuters.com/article/us-mideast-crisis-iraq-civilians-idUSKBN19W0CR (accessed on 31 August 2017).
59. Reuters: Islamic State Makes Desperate Stand in Mosul, Commanders Say. Available online: http://www.reuters.com/article/us-mideast-crisis-iraq-mosul-idUSKBN19R2K1 (accessed on 31 August 2017).

60. Reuters: Old City Bears the Brunt of Islamic State's Last Stand in Mosul. Available online: https://www.reuters.com/article/us-mideast-crisis-iraq-destruction-idUSKBN19V20I (accessed on 31 August 2017).
61. ASOR: A Reflection on Three Years of Occupation by ISIL. Available online: http://www.asor.org/news/2017/07/3rd-anniversary-isil (accessed on 31 August 2017).
62. ASOR Cultural Heritage Initiatives Weekly Report 32 (16 March 2015). Available online: http://www.asor-syrianheritage.org/syrian-heritage-initiative-weekly-report-32-march-16-2015 (accessed on 31 August 2017).
63. ASOR Cultural Heritage Initiatives Weekly Report 39 (5 May 2015). Available online: http://www.asor-syrianheritage.org/syrian-heritage-initiative-weekly-report-39-may-5-2015 (accessed on 31 August 2017).
64. ASOR Cultural Heritage Initiatives Weekly Report 41 (19 May 2015). Available online: http://www.asor-syrianheritage.org/syrian-heritage-initiative-weekly-report-41-may-19-2015 (accessed on 31 August 2017).
65. ASOR Cultural Heritage Initiatives Weekly Report 42–43 (2 June 2015). Available online: http://www.asor-syrianheritage.org/syrian-heritage-initiative-weekly-report-42-43-june-2-2015 (accessed on 31 August 2017).
66. ASOR Cultural Heritage Initiatives Weekly Report 47–48 (7 July 2015). Available online: http://www.asor-syrianheritage.org/syrian-heritage-initiative-weekly-report-47-48-july-7-2015 (accessed on 31 August 2017).
67. UNITAR: Damage Assessment of Old City, Mosul, Ninawa Governorate, Iraq (30 June 2017). Available online: http://www.unitar.org/unosat/node/44/2615?utm_source=unosat-unitar&utm_medium=rss&utm_campaign=maps (accessed on 31 August 2017).