CITIZEN SCIENCE IN ARCHAEOLOGY

Monica L. Smith

Citizen science, as a process of volunteer participation through crowdsourcing, facilitates the creation of mass data sets needed to address subtle and large-scale patterns in complex phenomena. Citizen science efforts in other field disciplines such as biology, geography, and astronomy indicate how new web-based interfaces can enhance and expand upon archaeologists' existing platforms of volunteer engagement such as field schools, community archaeology, site stewardship, and professional–avocational partnerships. Archaeological research can benefit from the citizen science paradigm in four ways: fieldwork that makes use of widely available technologies such as mobile applications for photography and data upload; searches of large satellite image collections for site identification and monitoring; crowdfunding; and crowdsourced computer entry of heritage data.

La ciencia ciudadana, como un proceso de participación voluntaria a través de crowdsourcing, facilita la creación de conjuntos de información masiva necesarios para hacer frente a los patrones sutiles y de gran escala en fenómenos complejos. Los esfuerzos de la ciencia ciudadana en otras disciplinas basadas en trabajo de campo, tales como la biología, la geografía y la astronomía ilustran cómo las nuevas interfaces basadas en internet pueden mejorar y ampliar las plataformas existentes de los arqueólogos sobre compromisos voluntarios tales como las escuelas de campo, arqueología comunitaria, la gestión de sitios y asociaciones profesional-recreativas. La investigación arqueológica puede beneficiarse del paradigma de la ciencia ciudadana en cuatro aspectos: la investigación de campo que hace uso de tecnologías ampliamente disponibles, tales como aplicaciones móviles para cargar fotografía y data; búsquedas de grandes colecciones de imágenes de satélite para la identificación y monitoreo de sitios; financiamientos colectivos; y la entrada de ordenador de datos patrimoniales provenientes de crowdsourcing.

Archaeologists increasingly view mass data sets as the means by which we can analyze multivariate phenomena such as human-environmental dynamics, the development of social complexity, and the integration of ancient economies (e.g., Dannell and Mees 2013; Kintigh et al. 2014; Peterson and Drennan 2012). Mass data sets have been produced through collaborative field projects (e.g., the Southwestern Anthropological Research Group; Euler and Gumerman 1978); regionally-integrated databases held by state and federal agencies (e.g., Childs 2002); technologies such as LiDAR (e.g., Chase et al. 2011, Evans et al. 2013); compilations of heritage data such as the Chaco Research Archive (www.chacoarchive.org); and new forms of data storage and retrieval such as the Digital Archaeological Record (www.tdar.org) and the Alexandria Archive (www.alexandriaarchive.org).

Most mass-data efforts, however, remain dependent on the collection, input, and management of data by professional archaeologists. Although there are opportunities for the public to contribute to data collection through field schools, site-monitoring programs, and community archaeology fora, these activities tend to be of short duration, involve limited numbers of participants, and require in-person mediation by professional archaeologists (e.g., Goodwin 1994, Locatelli et al. 2010). Professionals also control data output through media, lectures, and other forms of dissemination (cf. Alcock et al. 2013; Meisenhelder 2013). Even when creating "interactive" presentations, control of content rests in the hands of professionals who create the parameters within which visitors (both real and virtual) experience archaeology (Boast and Biehl 2011).

An exclusive reliance on professional archae-

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ologists for data collection and management has negative implications for researcher workload as well as for stakeholder satisfaction. Stuart Struever (1971:18) noted that the "magnitude and complexity of data collection and analysis are far beyond the practical capacity of the individual investigator," a lament that has philosophical and practical implications given dwindling resources for archaeological research at precisely the time when computerization enables large-scale data management and analysis. Archaeologists have simultaneously faced critiques of their public-outreach efforts; a generation ago, Francis McManamon (1991) outlined the "many publics" for archaeology, ranging from Congress and tribal members to teachers and students and concluded that all were underserved by professionals. His call for active engagement has been continually echoed by those who have noted the essential role of the public in archaeological research and heritage preservation (e.g., Hicks et al. 2007; Little 2002; Little and Shackel 2007; Sabloff 2008; Stottman 2010).

The Concept of Citizen Science

A powerful solution that addresses both the professional labor bottleneck and the desire for public engagement can be found in the use of a *citizen science* approach. A citizen scientist is defined as "a volunteer who collects and/or processes data as part of a scientific enquiry" (Silvertown 2009:467; cf. Sullivan et al. 2014:31). Citizen science is distinct from other types of volunteered or compiled information (such as blogs or web feeds) because of data-collection protocols through which participants are informed about the scope, goals, and outcomes of the research and actively become partners in the scientific enterprise (Haklay 2013:107). Volunteers can participate through outdoor fieldwork, the evaluation of imagery, the transcription of written records, and other forms of data entry.

Citizen science data collection is increasingly made possible by the Internet and in particular the development of Web 2.0 with its "sociable technologies" that permit user-generated content through data uploads, social networking, file-sharing, and wikis (Boulos and Wheelert 2007:2; Harris 2012; Kansa et al. 2011). Citizen science projects utilizing these modes of interaction enable expedient participation through succinct research questions and simple tutorials that enable visitors to feel productive with a modest investment of time, in contrast to traditional volunteer modes such as serving as docents or lab volunteers. Citizen science is having a revolutionary impact on other disciplines such as biology, geography, and astronomy; the brief description below illustrates the collective scholarly and social effects of this mode of mass data collection.

Models of Citizen Science in Biology

In citizen science biology projects, individuals collect observations on plants, animals, and environmental conditions that enable researchers to create and synthesize large data sets through technologies that include mobile phones and internet interfaces. Because many biological and environmental phenomena are widespread, inputs from multiple geographic locations are required in order to create realistic models and analyses. Jonathan Silvertown (2009:467) has encapsulated the resultant dependence of researchers on participatory efforts, noting that "Large-scale environmental science requires citizen science."

One of the largest projects is eBird (www.ebird.org), a web-based initiative that compiles bird-watchers' sightings into a comprehensive data set (Sullivan et al. 2014). Developed at Cornell University in 2002, the project now includes over 150,000 individual participants and more than 140 million observations logged. Once received, information is coded as CSV files tied to GIS databases and control-input filters track observers as well as their inputs to reduce stray entries, augmented by human-computer feedback mechanisms (Hochachka et al. 2012; Munson et al. 2009). Real-time upload produces data for addressing species diversity and migratory patterns, and aids preservation efforts by forecasting migrations such that, for example, wind-generating plants can be requested to turn off at night and farmers can be requested to irrigate fields at times that coincide with waterfowl movements (Robbins 2013).

Biologists also have designed citizen science projects to address specific research questions. One recent example is Emily Almberg's project to monitor population dynamics and health among wolves in Yellowstone National Park through photographs of mange patterns. On the logic that visitors take large numbers of photographs and that the GPS capacity of cameras and mobile phones enables time-space location recording, Almberg developed a low-cost web portal for visitors to upload images resulting in a dynamic distribution map that tracks contacts among packs and subsequent health changes (Prevost 2013; www.yellowstonewolf.org). Another image project is Snapshot Serengeti, which invites visitors to identify animals on digital photographs from unstaffed camera traps (www.snapshotserengeti.org). Many other biology initiatives can be found on the web portal Zooniverse (www.zooniverse.org) which as of this writing lists twenty active projects.

Citizen science efforts also focus on archival data from botanical, ornithological, and entomological collections by posting specimen labels for transcription using the portal Notes from Nature (notesfromnature.org). The site contains short descriptions of each project as well as "rewards" for participation that start in increments of a single record (with an advertised estimate of as little as three minutes per record). A typical effort is the CalBug project of the University of California, Berkeley in which volunteers transcribe specimen labels from 1880-present in order to "use the collection data to assess how arthropods have responded to climate change and habitat modification" (http://calbug.berkeley.edu).

The widespread global availability of mobile internet access provides an important source of data-capture even when few formal research institutions exist. Observational projects include India's Common Bird Project (www.cbmi.in); the South African biodiversity sites mybirdpatch.adu.org.za and www.ispot.org.za; the Amazon botany project Wikiflora (Fielding 2013); and the Waterkeeper Alliance, a grassroots monitoring group active in 19 countries (www.waterkeeper.org). Global efforts also are streamlined through third-party umbrella organizations such as the Max Planck Institute which sponsors movebank.org, a clearinghouse for data on animal migrations which are, by definition, usually multicountry phenomena.

The participation of citizen scientists in biological data collection produces more than just academic results. Çagan H. Sekercioglu has noted about crowdsourced bird data from Turkey that such projects are "getting young people involved in natural history, which might seem slow and old-fashioned in the age of instant online gratification" (cited in Robbins 2013). Many citizen-science efforts do, however, deliberately engage in "instant online gratification" to encourage participants and validate inputs, with virtual "badges," opportunities for competition, and feedback pop-ups that mimic elements of online gaming.

Models of Citizen Science in Geography

Geography, as the study of human-spatial interfaces, occupies a central theoretical position in the natural and social sciences (Bordogna et al. 2013). Geographic information includes both an objective component (a physical location on the earth) and a subjective component (a description or naming of that location; see Goodchild and Li 2012). Volunteered Geographic Information (VGI) encompasses both field data and image processing and has proven highly effective in longitudinal management efforts such as observations of environmental change as well as providing virtually instant feedback at times of natural disasters and warfare (Goodchild 2007).

The large data sets generated by VGI also capture the variable intensities of unevenly distributed phenomena (such as fires, snowstorms, and earthquakes), enhancing the effectiveness of both short-term management goals (Elwood et al. 2012:576–577) and long-term goals of developing more accurate predictive models (see Bordogna et al. 2013). With regards to image-processing, researchers have emphasized that people are still superior to computer algorithms for evaluating satellite images and photographs (Huynh et al. 2013) and for visual interpretation of handwriting in heritage data archives (http://www.oldweather.org).

Volunteered geographic information is highly cost-effective. As Goodchild (2007:217) has noted, the growth of VGI encompassed in programs such as Wikimapia comes at a time when government support for cartography has declined dramatically in both developed and developing countries. VGI is not wholly unproblematic, however: observers are not evenly distributed, and some places are more frequently visited and updated than others. Competition to establish the "correct" placename among dissenting contributors also can result in "tag wars" in which individuals overwrite prior entries (cf. Ballatore et al. 2013).

Models of Citizen Science in Astronomy

The visible night sky is observed by people world-wide. There are no entry barriers to initial participation in astronomy, given than basic observations can be made with the naked eye. Amateurs have made a number of significant discoveries, and of all of the sciences, astronomy has been the most active in recognizing volunteer efforts through awards and professional-amateur collaborations (a recent example being Hanny van Arkel, a Dutch schoolteacher whose discovery of a distinct gas cloud through the Internet project Galaxy Zoo led to her being listed as a coauthor in numerous scholarly papers, e.g., Keel et al. 2012). Other forms of public recognition include the naming of comets for those who first sight them, a list that includes many amateur astronomers (Mobberly 2011).

Volunteers participate through both active observation projects and passive contributions of computer processing time. One of the largest efforts is the SETI@home program started in 1999 (setiathome.berkeley.edu; Anderson et al. 2002). In order to search for "spikes" in radio frequencies, the SETI project sent out recorded data from radio telescopes to volunteered personal computers. Data was processed through a program that, once installed, ran in the background and required no further direct user interaction. Within a week of its launch, 200,000 people downloaded the program and started processing data; over six million volunteers have since participated (Anderson et al. 2002; Korpela 2012). Information is stored in a relational database, with accuracy achieved through redundancy: multiple computers are utilized for each data packet to filter out faulty processors and malicious users (Anderson et al. 2002:57).

Active observation projects also garner numerous volunteers, such as the Citizen Sky program which registered over six thousand participants to monitor the bright variable star epsilon Aurigae from 2009–2012. The project was ideally suited to citizen science because the star was bright enough to be easily visible even in cities (and in fact was so bright that it overwhelmed sensitive professional equipment; Price and Lee 2013:777). Other projects ask volunteers to scrutinize images, rather than the actual sky, for anomalies. In Galaxy Zoo (www.galaxyzoo.org), individuals classify galaxies utilizing a simple sorting rubric that takes only a few moments per image. Thus far, over 150,000 participants have logged a total of more than 50 million classifications. Another example is Stardust@home, in which viewers scrutinize "focus movies" for interstellar dust particles (startdustathome.ssl.berkeley.edu). Although the site frankly advises volunteers that there are likely to be only about a dozen particles in the collection of over a million images, the project has logged over 21,000 volunteers who have undertaken image searches.

A Background for Citizen Science in Archaeology

Citizen science projects are just beginning in archaeology, but can be established as a productive and transformative outgrowth of existing commitments to data collection and public engagement. The intellectual infrastructure for citizen science includes field schools; collaborations with avocational archaeologists; site-steward programs; donor-supported fieldwork; and community archaeology.

Field Schools

The traditional goal of archaeological field schools has been to provide academic training (Mytum 2012). More recently, the concept has been expanded to provide an engaged scientific experience for students who are not anticipated to become professional archaeologists (e.g., Boytner 2012, Morrison 2012), and as a means of fostering collaborative relationships with descent communities (e.g., Young 2012). Although field schools usually are highly regarded by their alumni, there are limits to the number of people who can be accommodated, and there often are significant financial costs to attendees (along with opportunity costs given that students forego other work during academic breaks). Field schools, even those that fund research projects, also contribute to the professional labor bottleneck for principal investigators who must simultaneously manage the project's intellectual components, field logistics, and the myriad anxieties and emergencies that ensue when inexperienced young people are immersed in field situations.

Avocational Archaeology

Although archaeology has become increasingly professionalized in the past forty years, dedicated volunteers remain an important component of our discipline's identity and workforce (Goldstein 1994; Snead and Sabloff 2010). As Poetschat et al. (2012) observe, avocational archaeologists outnumber professionals in the U.S. and constitute the majority of fieldworkers in domains such as rock-art recording. Regional societies reward and recognize their members and since 1985 the Society for American Archaeology has bestowed the annual Crabtree award to an avocational archaeologist. The SAA website also provides links to more than thirty-five local societies whose goals and activities are compatible with the Society's mission (www.saa.org/coas).

Responsible avocational archaeologists comply with legal requirements and engage in systematic data collection, recording, and publication. Individuals may work alongside professionals through regional archaeological societies, federal programs such as Passports in Time (www.passportintime.com), or collaborative entities (such as the Colorado Program for Avocational Archaeological Certification jointly sponsored by the Office of the State Archaeologist of Colorado and the avocational Colorado Archaeological Society).

Avocational groups respond to local conditions and enable a year-round research presence, as illustrated in Smith and Moore's (2013) detailed discussion of volunteer archaeologists in Tennessee over the past fifty years. Members of the Middle Cumberland Archaeological Society have provided thousands of hours of volunteer labor, collecting valuable information that otherwise would have been lost as well as contributing funds for publications and raising awareness about site preservation (Smith and Moore 2013). Avocational groups elsewhere have been responsible for significant initiatives at both historical and prehistoric sites including Historical Annapolis, Inc. (Matthews and Palus 2007) and the Chimney Rock National Monument (Mark Varien, personal communication 2013).

Site-Steward and Archaeological Monitoring Programs

Site-steward programs are a specific manifestation of avocational archaeology that also represents knowledge co-creation, enlisting volunteers to serve as "eyes and ears" for site monitoring beyond the workday capacities of salaried employees. In the United States, site-steward programs have been developed by government land agencies (National Park Service, Bureau of Land Management) as well as by state-level professional societies that train volunteers to visit, monitor, and report on site conditions. The Bureau of Land Management notes that in Arizona alone, there are 670 trained volunteers who have provided a collective 96,000 hours of monitoring time (BLM 2013). These programs do entail costs, however, as there is a time commitment required by both staff and volunteers for training in addition to the time expended in site monitoring, some of which takes place in relatively remote areas.

Donor-Support Fieldwork

Participation in archaeology through donor funding has a considerable history both in the United States and abroad (Snead 1999; Thornton 2013). In the twentieth century, contributions began to include physical labor through programs such as Earthwatch (earthwatch.org) and Adventures in Preservation (adventuresinpreservation.org). Volunteers pay fees that provide financial support in return for the opportunity to excavate, survey, or catalog finds within a specific time period, typically two weeks or less. Participants include professionals such as teachers, lawyers, and doctors who respond positively to the "romance of archaeology" and to the novelty of team participation in exotic settings. Because of the costs of transportation and enrollment, however, pay-to-volunteer participation is generally limited to a certain economic and social stratum.

Community-Based Archaeology

Archaeologists have long interacted with local stakeholders in the recording and preservation of sites, but formal "community archaeology" emerged from shifts in both the theory and practice of our discipline. Archaeologists engaging with postmodern/postprocessual theory emphasize local trajectories of culture history and the connective link between material remains and descent communities (Atalay 2012; Colwell-Chanthaphonh and Ferguson 2008; Klassen 2013; Little and Shackel 2007; Mills and Ferguson 1998; Silliman and Ferguson 2010). In such programs, professional archaeologists design and implement projects with stakeholder input and within an academic or other institutional context.

Community archaeology has been boosted by logistical changes related to permissions and research methods. The establishment of the Native American Graves Protection and Repatriation Act (NAGPRA) in the US in 1990 and the Heritage Conservation Act in Canada in 1996 has resulted in more tightly integrated research collaborations with indigenous peoples. Community archaeology also has been undertaken abroad, with prominent exemplars being the Maya-focused MACHI project in Mexico and adjacent Central America nations (McAnany and Parks 2012) and the reflexive research at Çatalhöyük in Turkey (Hodder 2003; summarized in Atalay 2012). Community archaeology projects often address a broad demographic including youth (Jóhannesdóttir and Ingason 2009; Paz 2010) and the elderly (Stewart et al. 2004) with capacity-building that enables participants to acquire transferable skills such as surveying, project management, and computer proficiency.

Although community archaeology has many positive aspects, there are limitations given the amount of time required of participants and investigators. Participation is usually episodic in the life of an individual, with limited scope for continued engagement once fieldwork has ended. Projects also can become adversely affected by pre-existing strife within the community, resulting in truncated research and significant investments of time to mitigate underlying community issues (e.g., Faulkner 2009).

In sum, field schools, avocational programs, and community-stakeholder projects demonstrate archaeologists' commitment to the integration of research with public outreach. Given the intensive person-to-person interactions required by these approaches, however, any scaling-up of participation can only be achieved through technological means. Archaeologists already have utilized crowdsourcing techniques via questionnaires as a way to gather data from fellow professionals (Kintigh et al. 2014; Zeder 1997), and museum practitioners have used similar means to gather public feedback on exhibits (e.g., Paardekooper 2012). These steps indicate the discipline's readiness to move towards mass collection of actual archaeological data.

Archaeological Citizen Science Projects

Citizen science projects in archaeology are in an explosive phase of growth for both the collection of original field observations and the compilation of heritage data. Scholars in the United Kingdom are particularly advanced in their development of mass-data projects that integrate public participation, institutional investments, and government initiatives, including recently-launched efforts on the Bronze Age (crowdsourced.micropasts.org), medieval churches (www.medieval-graffiti.co.uk), and twentieth-century conflict (new.archaeologyuk.org/first-world-war). Cultural heritage projects in the Netherlands similarly have utilized crowdsourcing through photography upload and data transcription (velehanden.nl).

In the United States, the historic site of Montpelier in Virginia provides an example of volunteer fieldwork encompassed within a broader research initiative on the economics of early Euro-American life (Reeves 2010; Reeves and Clark 2013). In 2013, metal-detector enthusiasts were invited to map and verify the locations of historic metal artifacts indicative of structures within the site's 2,700 acre (1,100 hectare) core area. Workshops and a Certificate Program provided opportunities for the co-creation of knowledge between volunteers and staff, resulting in multiple benefits including efficient site survey, public outreach, the development of mutual understanding, and a recognition of the factors that attract both professional and avocational archaeologists to the pursuit of the past. Tellingly, the project accommodated the volunteers' interest in artifacts by offering the opportunity for "digital collecting" in which their scientifically recovered artifacts could be displayed to their friends through photography and web dissemination (Reeves and Clark 2013).

Some types of archaeological phenomena may appear and disappear so rapidly that volunteer reporting is the only practical method of data collection. Shipwrecks and other maritime debris, which are unpredictably exposed and then reburied through wave and wind action, are good examples of evidence more likely to be encountered through happenstance than through targeted programs of archaeological survey. In Massachusetts, avocational and state agencies created the SHIPS program to collect and synthesize local beach-walkers' sightings (Bensley and Mastone 2014; Mastone and Trubey 2007). The collaboration has succeeded in compiling valid data for coastal maritime studies, preservation, and heritage management in a time of limited government resources. The project also brought participatory maritime archaeology to a wider audience beyond the recreational divers who are usually the focus of public-outreach efforts, such that "almost anyone and everyone could participate" (Mastone and Trubey 2007:149).

In addition to field research, citizen scientists have collected data from satellite imagery in the Valley of the Khans project (http://exploration.nationalgeographic.com/mongolia/). The project was created with two distinct objectives: a high-profile goal to use 85,000 satellite images from Mongolia in a search for the tomb of the legendary warrior Genghis Khan, and a more routine goal of searching for all human-made structures in the vast reaches of an otherwise unexplored area.[1] As of early 2014, the web site has logged more than 150,000 online explorers who have processed nearly one million image views. The project is tied to field research in a way that allows vicarious participation in the validation of efforts, including a recent expedition to Mongolia that discovered fifty previously unknown sites on the basis of the crowdsourced image analysis (Huynh et al. 2013).

The Valley of the Khans web site is straightforward, with appealing graphics and well-designed interfaces. After registering, participants encounter a set of ten training frames in a quiz format to learn the drag-and-drop placement of icons identifying roads, rivers, ancient structures, modern structures, and other features. The site tracks participants, initially identifying them as "novice" but allowing them to earn higher rankings through an index of proficiency. Visitor engagement is reinforced by pop-up phrases such as "Good work! 7 other explorers also saw a modern structure in this map." Safeguards are in place against overpopulation of icons on both an individual level ("You have reached the maximum number of annotations for a map") and through a comparison with others ("4 previous explorers saw a road on this map. Do you agree?").

Archaeologists also are utilizing crowdsourced satellite image searches to monitor site damage. In an innovative use of Google Earth's Outreach and Spreadsheet Mapper tools to track looting in Jordan, Contreras and Brodie (2010:30) explicitly noted that the project goal was to enable non-archaeologists as well as professional colleagues to access information for heritage awareness. The regular patterning of constructed features such as canals and walls along with the recognizably irregular trenches of looters' pits enabled standard and repeatable assessments. The use of satellite imagery also enables participation at low risk compared to physical monitoring in areas where looting is accompanied by other illegal activities such as recreational drug use or the trafficking of humans and narcotics.

Mass Participation through Crowdfunding

In the past, only wealthy donors could afford to sponsor research, but web-based "crowdfunding" democratizes support by allowing people to contribute much smaller sums while still gaining a level of familiarity and participatory satisfaction. The science-specific Microryza web site, for example, has in its opening frame the invitational phrase "When you fund science, we all get closer to the moment of discovery" (microryza.com). Other science web sites use similarly encouraging language: "Real science online" (zooniverse.org); "Science we can do together" (scistarter.org); and "Be a part of science history!" (petridish.org).

Some crowdfunding web sites require that the entire funding target be reached for an all-or-nothing provision of funds, while others allow researchers to access any collected resources. Web sites often take a small percentage of the collected funds as overhead (note the explicitly commercial status of some websites as noted by the ".com" suffix), although the overhead is still relatively low at 4.5–12 percent compared with rates levied by research institutions on federal grants (averaging 48 percent in the United States; see Sale and Sale 2011). Moreover, sums raised through crowdfunding websites are given directly to the investigator for the immediate start of work, unlike traditional grants for which investigators must continually negotiate the release of awarded funds banked by their institutions.

Archaeological uses of crowdfunding include Ian Slayton's "Climate Change in the Cradle of Civilization" funded by rockethub.com in 2012, and Justin Lowry's excavations at the site of Chiquilistagua in Nicaragua funded by kickstarter.com in 2013. Matthew Piscitelli (2013) has noted two distinct advantages to the use of crowdfunding. First, crowdfunding is suited for raising small sums of money that enable projects to get started. Secondly, crowdfunding provides a more rapid turnaround than traditional grant programs, enabling resources to be more quickly mobilized at moments of discovery or urgency as was the case for his research on a threatened site in Peru (another recent example is Jennifer Pournelle's use of crowdfunding through experiment.com to attend a short-notice government meeting in Iraq, a successful effort that was matched by her university's research grants office).[2] Crowdfunding need not be limited to initial research efforts, as shown by the well-established Ziyaret Tepe project which has augmented its institutional funding through the British organization The Big Give (www.thebiggive.org.uk).

Archaeologists ~~and administrators might~~ understandably be wary of reliance on popular review instead of peer review as a basis for funding scholarly projects. Viewed as a form of remunerative public outreach, however, crowdfunding provides opportunities for researchers to explain their work to a broader audience and to develop lively, crisp media presentations of the type required by crowdfunding web sites. Academic and professional use of crowdfunding is likely to become a necessity in the near future, given recent dramatic cuts in government support and research institutions' expectations for entrepreneurial engagement with donors (in late 2013, for example, Georgia Tech and Northeastern University independently pioneered the development of their own university crowdfunding web sites; Perlstein 2013).

The Future of Citizen Science in Archaeology

Archaeologists have always been interested in finding sites as a component of regional analysis, and predictive modeling has increased with the advent of more powerful tools for multivariate landscape analysis and in recognition of the need to maximize ground truthing time for budgetary and logistical reasons (Ford et al. 2009; Verhagen and Whitley 2012). Modern material culture sites and historical sites such as cemeteries are particularly amenable to crowdsourcing approaches that focus on abundant phenomena, analogous to biology projects that focus on common species. Examples of such projects might include asking participants to track locations of trash that can be encoded as the result of particular social events (e.g., backroads partying) compared to cumulative patterns of discard (such as roadside trash). Projects that tally commemorations (such as memorial trees) or roadside shrines (in remembrance of accident victims) similarly could collect geolocation and descriptive information.

Volunteer archaeological fieldwork can recover information on phenomena that are unevenly distributed or obscure except when viewed under the right conditions (such as mounds or bedrock mortars that are visible only in raking sunlight or immediately after light snowfalls). Shorelines and riverbanks, present in all fifty states, also provide an ideal scenario for citizen science initiatives through the use of interactive technologies. Surprisingly, however, discussions of the Internet and web-based interactions are absent from even the most recent overviews of volunteer shoreline surveys in the US (see Bensley and Mastone 2014; for a project in development in the UK, see Kennedy 2014). The potential for using citizen scientists as partners in groundtruthing, site monitoring, and site discovery is particularly strong in the developing world where mobile computing and recreational landscape use by a growing middle class of educated and environmentally committed individuals combine to provide productive opportunities (cf. Davies et al. 2014; Elwood et al. 2012).

Finally, archaeologists would benefit considerably from crowdsourced data entry for both historical archives and contemporary projects. As Shawn Ross has noted, archaeology has until recently been primarily recorded through pencil-and-paper approaches, a factor that has kept an enormous amount of data unavailable to comparative projects.[3] Utilizing models such as Snapshot Serengeti, Calbug, and Old Weather, museums and archives could load scanned data pages online along with templates for spreadsheet data entry and transcription of field notes into searchable databases (one such project is already underway on British Museum archaeological holdings; see crowdsourced.micropasts.org). Contract firms also have vast libraries of unpublished data that could be productively brought into broader access.

Discussion

As seen in other disciplines, citizen science has the potential for significant impacts beyond just collecting "more data" to the creation and fulfillment of new research agendas. Biology projects focusing on common birds such as pigeons and sparrows, for example, have been designed to provide an experience that virtually guarantees a satisfactory "sighting." However, these projects have transformative benefits through their ability to track populations that are almost too large and ubiquitous for standard research programs but provide data essential for monitoring changes in wildlife behavior linked to anthropogenic impacts and environmental shifts (Hochachka et al. 2012). Geographers have observed that volunteered geographic information has resulted in greater scholarly awareness of alternate modes of spatial experience that expand feminist and critical geography interpretations (Haklay 2013). And, as noted above, volunteers are widely acknowledged as essential partners in astronomy research.

Critical studies of citizen science in other fields provide insights on participants' motivations and rubrics for the development of successful projects (e.g., Noordegraaf et al. 2014, Sullivan et al. 2014). Research indicates that volunteers' primary motivation is "to contribute to original scientific research" (Raddick et al. 2013), with the opportunity to engage in teamwork as an additional important component (Nov et al. 2010). For archaeologists, a shift to a collaborative interface between professionals and interested non-professionals also addresses the vast and expanding market for information about the human past, as evidenced in the popularity of television shows, magazines, web sites, and university courses devoted to the subject.

Archaeologists may be reticent to initiate crowdsourced fieldwork projects for fear of encouraging looting. But the corpus of professional archaeologists is inadequate to stem the tide of archaeological destruction that is already occurring; as in other fields, volunteers are the only mechanism by which increased numbers of observations can be achieved. Concerns for the security of archaeological sites can be addressed through training modules on web interfaces, the integration of research projects with recognized institutions, an emphasis on ethics as a component of research, and the selective release of compiled data back to the public (the latter includes, for example, the masking of pinpoint GPS location data into larger generic "dots" on a map, e.g., Wienhold and Robinson 2014). The predicted or actual locations of some site types clearly are not suitable for dissemination due to their sensitive nature, but some site types are relatively abundant and/or immutable such as cairns, shell middens, bedrock mortars, grinding slicks, historic discards, and inscriptions. Portable items that have lost their specific local provenience, such as maritime debris or rural family collections of projectile points, also could yield mass-data significance when mapped on a continental scale.

Some intellectual caveats do apply to the citizen science model of data collection, however. Standardized compilations are difficult to achieve even when participants are working together within a single team (Hawkins et al. 2003), and even when all of the participants are trained professionals (e.g., Sullivan and Schiffer 1978 on SARG). Professional archaeologists tend to rely on the idiosyncracies of their own training when engaged in basic tasks such as sorting ceramics, separating "debitage" from flakes, or delineating primary from secondary deposits although these initial activities have significant implications for interpretation (e.g., Adams and Adams 1991; Tomášková 2003). The necessary standardization of data collection for citizen science provides a moment of philosophical introspection by compelling archaeologists to articulate distinctions instead of relying on a "gestalt" approach to classification.

In citizen science, the sheer quantity of inputs means that some incorrect data will inevitably be introduced (Conrad and Hilchey 2011; Robbins 2013), but data sets can be protected against erroneous outliers in several ways. Web sites can build in nested pull-down menus in a process of "scaffolding" that guides both novice and experienced users to consistent results (Noordegraf et al. 2014). Projects also can request self-reporting in order to tailor online tasks to individuals' skill levels (cf. British Trust for Ornithology, www.bto.org); use volunteers to monitor inputs ~~(cf. Wikimapia~~ and eBird; Goodchild 2007:212; Sullivan et al. 2014); or create a hierarchy endowing some volunteers with greater editorial powers (e.g., OpenStreetMap, Wikipedia; see Goodchild and Li 2012). Automated data checking through machine learning (artificial intelligence) also is an effective way to discern when multiple individuals have entered the same data thus representing a reliable input (a strategy utilized by Snapshot Serengeti, SETI@home, and the Valley of the Khans project). A low number of repetitions appears to be sufficient to weed out inconsistencies; on both a theoretical level (Blanco et al. 2011:930) and experiential level (Anderson et al. 2002:57), $n = 3$ different observers provides a high level of reliability.

Citizen-science projects that involve data transmission over the Internet require a consideration of software as well as hardware requirements for different operating systems (e.g., Windows, Macintosh OS, Linux); in addition, project designers need to ensure security against viruses and other malware (for a complete list of considerations see Korpela 2012). Although mobile computing technology is widespread, the persistence of a "digital divide" among socio-economic groups can be exacerbated by the structure and presentation of projects (Elwood et al. 2012:583). Fortunately, there are a growing number of easy-to-use software packages that are either specifically designed for crowdsourced data collection (e.g., pybossa.com) or can be modified for that purpose (e.g., mukurtu.org).

Participation rates can be disparate: assessments from other research realms (including those that reward participants with actual money, such as the Amazon Mechanical Turk marketplace) all report that in crowdsourced data, a large number of participants make one or two entries and the majority of data is entered by a relatively small number of people (e.g., Blanco et al. 2011:928; Boulos et al. 2007:5; Goodchild and Li 2012:114; Noordegraf et al. 2014:30). Rather than being discouraged by this fact, however, archaeologists should consider that even a single "click" by a participant results in increased awareness of local and global heritage.

In sum, citizen science projects are successful when they identify specific research goals and a clear set of questions in an easy-to-use, graphic interface. Designers of mass-data compilations in biology, geography, and astronomy provide other insights on the necessary components of crowdsourcing projects:

* A database structure that includes both a scientific component and accounting for purposes of data management and tests of replicability (see Anderson et al. 2002; Boulos et al. 2007).

*Ease of use, including automatic updates rather than requiring users to update software manually (Korpela 2012:70).

*Pull-down menus (Noordegraaf et al. 2014) and feedback that enables users to improve their knowledge with concomitant improvements in data quality (Sullivan et al. 2014).

*Rewards for volunteers (recognition on web sites; incremental indicators of status such as Valley of the Khans project; or "badges" of achievement such as Calbug).

Conclusions

A participatory citizen science framework addresses two of the most pressing problems in archaeological research: insufficient professional personnel relative to the number of historical and archaeological sites, and the outdated mode of unidirectional knowledge transmission from professionals to the public. Citizen scientists can actively assist with site discovery and can monitor sites for looting and other adverse impacts, and can take part in data-recording projects to efficiently address the backlog of heritage data and expand researchers' ability to test broad and complex hypotheses about ancient human activities.

Crowdsourcing expands the parameters of "community-based archaeology" to audiences often overlooked by field archaeologists, including children and teenagers, the physically-challenged, the growing retirement-age population, and those for whom the opportunity costs of on-site participation are too high (e.g., Andrew and Pitblado 2014). Through greater inclusion, our discipline can gain not only new sources of data but also new understandings of participants' roles in shaping research agendas and results. Through Web 2.0 applications and the capacity to integrate data from multiple sources, the field of geography is currently moving towards *synthesis* rather than mere analysis (Elwood et al. 2012:582, emphasis added). Archaeology similarly has the scope for integrating a long timescale of human activity, complex environmental configurations in the past, and multiple communities of practice in the present.

A shift of data collection and management tasks to a broader human resource pool can increase the effectiveness of archaeological finances, although citizen science efforts should not be considered merely as a substitute or stopgap for diminishing budgets. Instead, citizen science provides energizing and transformative opportunities for public-professional interactions that reflect the excitement of studying the human past. Indeed, it may be more difficult to persuade professional archaeologists of the benefits of crowdsourced and citizen science archaeology than it will be to find individuals willing to participate. Through their engagement in the few web-based projects that currently exist, the public already has demonstrated its interest in contributing to real archaeological research.

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References Cited

Adams, William Y., and Ernest W. Adams
1991 *Archaeological Typology and Practical Reality*. Cambridge University Press, Cambridge.

Alcock, Susan E., Andrew Dufton, and Müge Durusu-Tanriöver
2013 Archaeology for the People: A First Foray into the World of MOOCs. *Anthropology News* 54(11–12):24.

Anderson, David P., Jeff Cobb, Eric Korpela, Matt Lebofsky, and Dan Werthimer
2002 SETI@home: An Experiment in Public-Resource Computing. *Communications of the ACM* 45(11):56–61.

Andrew, Holly, and Bonnie Pitblado
2014 Engaging and Empowering Citizen Archaeologists through the Co-Creative Process: A Case Study Involving the Oklahoma Anthropological Society. Paper presented at the 79th Annual Meeting of the Society for American Archaeology, Austin, Texas.

Atalay, Sonya
2012 *Community-Based Archaeology: Research With, By, and For Indigenous and Local Communities*. University of California Press, Berkeley.

Ballatore, Andrea, Michela Bertolotto, and David C. Wilson
2013 Geographic Knowledge Extraction and Semantic Similarity in OpenStreetMap. *Knowledge and Information Systems* 37:61–81.

Bensley, Justin J., and Victor T. Mastone
2014 Shifting Sand: A Model for Facilitating Public Assistance in Coastal Archaeology. In *Meeting Challenges in the Public Interpretation of Maritime Cultural Heritage*, edited by Della A. Scott-Ireton, pp. 63–72. Springer, New York.

Blanco, Roi, Harry Halpin, Daniel M. Herzig, Peter Mika, Jeffrey Pound, and Henry S. Thompson
2011 Repeatable and Reliable Search System Evaluation using Crowdsourcing. *Proceedings of the 34th International ACM SIGIR Conference on Research and Development in Information Retrieval, Beijing*, pp. 923–932.

BLM (Bureau of Land Management)
2013 Partnerships. Electronic document, www.blm.gov/az/st/en/prog/cultural/partner.html, accessed September 26, 2013.

Boast, Robin, and Peter Biehl
2011 Archaeological Knowledge Production and Dissemination in the Digital Age. In *Archaeology 2.0: New Approaches to Communication and Collaboration*, edited by Eric C. Kansa, Sarah Whitcher Kansa, and Ethan Watrall, pp. 119–155. Cotsen Institute of Archaeology, University of California, Los Angeles.

Bordogna, Gloria, Paola Carrara, Laura Criscuolo, Monica Pepe, and Anna Rampini
2013 A Linguistic Decision Making Approach to Assess the Quality of Volunteer Geographic Information for Citizen Science. *Information Sciences* 258:312–327.

Boulos, Maged N. Kamel, and Steve Wheelert
2007 The Emerging Web 2.0 Social Software: An Enabling Suite of Sociable Technologies in Health and Health Care Education. *Health Information and Libraries Journal* 24:2–23.

Boytner, Ran
2012 The Changing Nature of Archaeological Field Schools. *The SAA Archaeological Record* 12(1):29–32.

Chase, Arlen F., Diane Z. Chase, John F. Weishampel, Jason B. Drake, Ramesh L. Shrestha, K. Clint Slatton, Jaime J. Awe, and William E. Carter

2011 Airborne LiDAR, Archaeology, and the Ancient Maya Landscape at Caracol, Belize. *Journal of Archaeological Science* 38:387–398.

Childs, S. Terry
2002 The Web of Archaeology: Its Many Values and Opportunities. In *Public Benefits of Archaeology*, edited by Barbara J. Little, pp. 228–238. University Press of Florida, Gainesville.

Colwell-Chanthaphonh, Chip, and T. J. Ferguson (editors)
2008 *Collaboration in Archaeological Practice: Engaging Descendant Communities*. AltaMira, Lanham, Maryland.

Conrad, Cathy C., and Krista G. Hilchey
2011 A Review of Citizen Science and Community-Based Environmental Monitoring: Issues and Opportunities. *Environmental Monitoring and Assessment* 176:273–291.

Contreras, Daniel A., and Neil Brodie
2010 Shining Light on Looting: Using Google Earth to Quantify Damage and Raise Public Awareness. *The SAA Archaeological Record* 10(3):30–33.

Dannell, Geoffrey, and Allard Mees
2013 The Mainz Internet Database of Names on *Terra Sigillata*. In *Seeing Red: New Economic and Social Perspectives on Terra Sigillata*, edited by Michael Fulford and Emma Durham, pp. 28–35. Institute of Classical Studies, University of London, London.

Davies, Matthew, Agathe Dupeyron, and Henrietta L. Moore
2014 Mobile Internet Technologies and the Possibilities for Public Archaeology in Africa: Marakwet, Kenya. Antiquity project gallery 88, 340, http://journal.antiquity.ac.uk/projgall/davies340, accessed March 11, 2014.

Elwood, Sarah, Michael F. Goodchild, and Daniel Z. Sui
2012 Researching Volunteered Geographic Information: Spatial Data, Geographic Research, and New Social Practice. *Annals of the Association of American Geographers* 102:571–590.

Euler, Robert C., and George J. Gumerman (editors)
1978 *Investigations of the Southwestern Anthropological Research Group: An Experiment in Archaeological Cooperation*. Museum of Northern Arizona, Flagstaff.

Evans, Damian H., Roland J. Fletcher, Christophe Pottier, Jean-Baptiste Chevance, Dominique Soutif, Boun Suy Tan, Sokrithy Im, Darith Ea, Tina Tin, Samnang Kim, Christopher Cromarty, Stéphane De Greef, Kasper Hanus, Pierre Bâty, Robert Kuszinger, Ichita Shimoda, and Glenn Boornazian
2013 Uncovering Archaeological Landscapes at Angkor using Lidar. *Proceedings of the National Academy of Sciences* 110:12595–12600.

Faulkner, Neil
2009 The Sedgeford Crisis. *Public Archaeology* 8:51–61.

Fielding, Nigel G.
2013 Qualitative Research in a Globalizing World. In *Global Dimensions of Qualitative Inquiry*, edited by Norman K. Denzin and Michael D. Giardina, pp. 47–62. Left Coast Press, Walnut Creek, California.

Ford, Anabel, Keith C. Clarke, and Gary Raines
2009 Modeling Settlement Patterns of the Late Classic Maya Civilization with Bayesian Methods and Geographic Information Systems. *Annals of the Association of American Geographers* 99:496–520.

Goldstein, Daniel
1994 "Yours for Science": The Smithsonian Institution's Correspondents and the Shape of Scientific Community in Nineteenth-Century America. *Isis* 85:573–599.

Goodchild, Michael F.
2007 Citizens as Sensors: The World of Volunteered Geography. *GeoJournal* 69:211–221.

Goodchild, Michael F., and Linna Li
2012 Assuring the Quality of Volunteered Geographic Information. *Spatial Statistics* 1:110–120.

Goodwin, Charles
1994 Professional Vision. *American Anthropologist* 96:606–633.

Haklay, Muki
2013 Citizen Science and Volunteered Geographic Information: Overview and Typology of Participation. In *Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice*, edited by Daniel Sui, Sarah Elwood, and Michael Goodchild, pp. 105–122. Springer, Dordrecht.

Harris, Trevor
2012 Interfacing Archaeology and the World of Citizen Sensors: Exploring the Impact of Neogeography and Volunteered Geographic Information on an Authenticated Archaeology. *World Archaeology* 44:580–591.

Hawkins, A. L., S. T. Stewart, and E. B. Banning
2003 Interobserver Bias in Enumerated Data from Archaeological Survey. *Journal of Archaeological Science* 30:1503–1512.

Hicks, Dan, Laura McAtackney, and Graham Fairclough (editors)
2007 *Envisioning Landscape: Situations and Standpoints in Archaeology and Heritage*. Left Coast Press, Walnut Creek, California.

Hochachka, Wesley M., Daniel Fink, Rebecca A. Hutchinson, Daniel Sheldon, Weng-Keen Wong, and Steve Kelling
2012 Data-Intensive Science Applied to Broad-Scale Citizen Science. *Trends in Ecology and Evolution* 27:130–137.

Hodder, Ian
2003 Archaeological Reflexivity and the "Local" Voice. *Anthropological Quarterly* 76:55–69.

Huynh, Andrew, Kevin Ponto, Albert Yu-Min Lin, and Falko Kuester
2013 Visual Analytics of Inherently Noisy Crowdsourced Data on Ultra High Resolution Displays. Aerospace Conference, Institute of Electrical and Electronics Engineers, pp. 1–8.

Jóhannesdóttir, Sif, and Unnsteinn Ingason
2009 The Kids' Archaeology Program, Iceland: Goals and Activities. Electronic document, http://www.nabohome.org/projects/kap/fornleifaskolibarnanna1.pdf, accessed 6 March 2014.

Kansa, Eric C., Sarah Whitcher Kansa, and Ethan Watrall (editors)
2011 *Archaeology 2.0: New Approaches to Communication and Collaboration*. Cotsen Institute of Archaeology, University of California, Los Angeles.

Keel, William C., Chris J. Lintott, Kevin Schawinski, Vardha N. Bennert, Daniel Thomas, Anna Manning, S. Drew Chojnowski, Hanny van Arkel, and Stuart Lynn
2012 The History and Environment of a Faded Quasar: *Hubble Space Telescope* Observations of Hanny's Voorwerp and IC 2497. *The Astronomical Journal* 144(2):1–16.

Kennedy, Maev
2014 Volunteer Army Set Up to Examine Archaeological Sites Uncovered by Floods. Electronic document, http://www.theguardian.com/science/2014/feb/04/volunteer-army-archaeological-sites-uncovered-floods, accessed 7 March 2014.

Kintigh, Keith W., Jeffrey H. Altschul, Mary C. Beaudry, Robert D. Drennan, Ann P. Kinzig, Timothy A. Kohler, W. Fredrick Limp, Herbert D. G. Maschner, William K. Michener, Timothy R. Pauketat, Peter Peregrine, Jeremy A. Sabloff, Tony J. Wilkinson, Henry T. Wright, and Melinda A. Zeder

2014 Grand Challenges for Archaeology. *American Antiquity* 79:5–24.
Klassen, Michael A.
2013 *Indigenous Heritage Stewardship and the Transformation of Archaeological Practice: Two Case Studies from the Mid-Fraser Region of British Columbia*. Ph.D. dissertation, Department of Archaeology, Simon Fraser University.
Korpela, Eric J.
2012 SETI@home, BOINC, and Volunteer Distributed Computing. *Annual Review of Earth and Planetary Sciences* 40:69–87.
Little, Barbara J. (editor)
2002 *Public Benefits of Archaeology*. University Press of Florida, Gainesville.
Little, Barbara J., and Paul A. Shackel (editors)
2007 *Archaeology as a Tool of Civic Engagement*. AltaMira, Lanham, Maryland.
Locatelli, Marco P., Carla Simone, and Viviana Ardesia
2010 Collocated Social Practices Surrounding Photo Usage in Archaeology. In *Proceedings of COOP 2010 Computer Supported Cooperative Work*, edited by Myriam Lewkowicz, Parina Hassanaly, Markus Rohde, and Volker Wulf, pp. 163–182. Springer-Verlag, London.
Mastone, Victor T., and David W. Trubey
2007 Not Just Another Piece of a Boat: Massachusetts' Shoreline Heritage Partnerships Strategy (SHIPS). In *Out of the Blue: Public Interpretation of Maritime Cultural Resources*, edited by John H. Jameson Jr. and Della A. Scott-Ireton, pp. 145–157. Springer, New York.
Matthews, Christopher, and Matthew Palus
2007 A Landscape of Ruins: Building Historic Annapolis. In *Envisioning Landscape: Situations and Standpoints in Archaeology and Heritage*, edited by Dan Hicks, Laura McAtackney, and Graham Fairclough, pp. 226–250. Left Coast Press, Walnut Creek, California.
McAnany, Patricia A., and Shoshaunna Parks
2012 Casualties of Heritage Distancing: Children, Ch'orti' Indigeneity, and the Copán Archaeoscape. *Current Anthropology* 53:80–107.
McManamon, Francis P.
1991 The Many Publics for Archaeology. *American Antiquity* 56:121–130.
Meisenhelder, Susan
2013 "MOOC Mania." *Thought and Action* 29:7–26.
Mills, Barbara J., and T. J. Ferguson
1998 Preservation and Research of Sacred Sites by the Zuni Indian Tribe of New Mexico. *Human Organization* 57:30–42.
Mobberly, Martin
2011 *Hunting and Imaging Comets*. Springer, New York.
Morrison, Bethany A.
2012 More than Digging Square Holes: The New Role of Archaeological Field Schools. *The SAA Archaeological Record* 12(1):23–24.
Munson, M. Arthur, Kevin Webb, Daniel Sheldon, Daniel Fink, Wesley M. Hochachka, Marshall Ili, Mirek Riedewald, Daria Sorokina, Brian Sullivan, Christopher Wood, and Steve Kelling
2009 The eBird Reference Dataset, Version 1.0. Cornell Lab of Ornithology and National Audubon Society, Ithaca, NY, June 2009.
Mytum, Harold
2012 Introduction: Constructing Education and Knowledge in the Field. In *Global Perspectives on Archaeological Field Schools: Constructions of Knowledge and Experience*, edited by Harold Mytum, pp. 3–7. Springer, New York.
Noordegraaf, Julia, and Andrew Bartholomew, with Alexandra Eveleigh
2014 Modeling Crowdsourcing for Cultural Heritage. *Museums and the Web 2014: Selected Papers from an International Conference*, edited by N. Proctor and R. Cherry, pp. 25–37. Museums and the Web, Silver Spring, Maryland.
Nov, Oded, David Anderson, and Ofer Arazy
2010 Volunteer Computing: A Model of the Factors Determining Contribution to Community-Based Scientific Research. *Proceedings of the 19th International World Wide Web Conference, Raleigh, North Carolina,* pp. 741–750.
Paardekooper, Roeland
2012 *The Value of an Archaeological Open-Air Museum is in Its Use: Understanding Archaeological Open-Air Museums and Their Visitors*. Sidestone Press, Leiden.
Paz, Yitzhak
2010 Community Archaeology in Proto-Historical Tel Bareqet, Israel: School Children and Agency for Active Public Engagement in Cultural Heritage Projects. *Public Archaeology* 9:34–47.
Pearlstein, Ethan O.
2013 The Science Crowdfunding Landscape. Electronic document. http://www.perlsteinlab.com/blog/the-science-crowdfunding-landscape, accessed November 12, 2013.
Peterson, Christian A., and Robert D. Drennan
2012 Patterned Variation in Regional Trajectories of Community Growth. In *The Comparative Archaeology of Complex Societies*, edited by Michael E. Smith, pp. 88–137. Cambridge University Press, Cambridge.
Piscitelli, Matthew
2013 Using Social Networks to Fundraise: Crowdfunding for the Archaeologist. *The SAA Archaeological Record* 13(4):36–39.
Poetschat, Cathy, Marcel Kornfield, and James D. Keyser
2012 Avocational Archaeology: A Half-Century of Increasing Contributions. *The SAA Archaeological Record* 12(3):5–11.
Prevost, Ruffin
2013 Yellowstone Crowdsources Visitor Photos to Help Study Wolf Disease, Dynamics. Electronic document, http://www.yellowstonegate.com/2013/02/yellowstone-crowdsources-visitor-photos-help-study-wolf-disease-dynamics/, accessed September 14, 2014.
Price, C. Aaron, and Hee-Sun Lee
2013 Changes in Participants' Scientific Attitudes and Epistemological Beliefs during an Astronomical Citizen Science Project. *Journal of Research in Science Teaching* 50:773–801.
Raddick, M. Jordan, Georgia Bracey, Pamela L. Gay, Chris J. Lintott, Carie Cardamone, Phil Murray, Kevin Schawinski, Alexander S. Szalay, and Jan Vandenberg
2013 Galaxy Zoo: Motivations of Citizen Scientists. *Astronomy Education Review* 12(1): 010106 http://dx.doi.org/10.3847/AER2011021 .
Reeves, Matthew
2010 A Community of Households: Early 19th Century Enslaved Landscapes at James Madison's Montpelier. *The African Diaspora Archaeology Network Newsletter*, December 2010:1–26.
Reeves, Matthew, and Scott Clark
2013 Open Minds, Clearer Signals – Metal Detectorist and Archaeologist Cooperation Takes Another Step. Electronic document , www.sha.org/blog, accessed November 19, 2013.
Robbins, Jim
2013 Crowdsourcing, For the Birds. Electronic document,

http://www.nytimes.com/2013/08/20/science/earth/crowd-sourcing-for-the-birds.html?pagewanted=all&_r=1&, accessed September 25, 2013.

Sabloff, Jeremy A.
2008 *Archaeology Matters: Action Archaeology in the Modern World*. Left Coast Press, Walnut Creek, California.

Sale, Martha Lair, and R. Samuel Sale
2010 Indirect Cost Rate Variation Determinants in University Research, an Empirical Investigation. *Research in Higher* Education 6. Electronic document, OC09049 - Higher Education, www.aabri.com, accessed November 19, 2013.

Silliman, Steven W., and T. J. Ferguson
2010 Consultation and Collaboration with Descendant Communities. In *Voices in American Archaeology*, edited by Wendy Ashmore, Dorothy T. Lippert, and Barbara J. Mills, pp. 48–72. Society for American Archaeology Press, Washington, D.C.

Silvertown, Jonathan
2009 A New Dawn for Citizen Science. *Trends in Ecology and Evolution* 24:467–471.

Smith, Kevin E., and Michael C. Moore
2013 Professional and Avocational Partnerships: Alive and Well in Tennessee. *The SAA Archaeological Record* 13(2):18–23.

Snead, James E.
1999 Science, Commerce, and Control: Patronage and the Development of Anthropological Archaeology in the Americas. *American Anthropologist* 101:256–271.

Snead, James E., and Jeremy A. Sabloff
2010 Professional Societies and the Lives of American Archaeologists. In *Voices in American Archaeology*, edited by Wendy Ashmore, Dorothy Lippert, and Barbara J. Mills, pp. 67–82. Society for American Archaeology Press, Washington, D.C.

Stewart, Andrew M., Darren Keith, and Joan Scottie
2004 Caribou Crossings and Cultural Meanings: Placing Traditional Knowledge and Archaeology in Context in an Inuit Landscape. *Journal of Archaeological Method and Theory* 11:183–211.

Stottman, M. Jay (editor)
2010 *Archaeologists as Activists: Can Archaeologists Change the World?* The University of Alabama Press, Tuscaloosa.

Struever, Stuart
1971 Comments on Archaeological Data Requirements and Research Strategy. *American Antiquity* 36:9–19.

Sullivan, Alan P., and Michael B. Schiffer
1978 A Critical Examination of SARG. In *Investigations of the Southwestern Anthropological Research Group: An Experiment in Archaeological Cooperation*, edited by Robert C. Euler and George J. Gumerman, pp. 168–176. Museum of Northern Arizona, Flagstaff.

Sullivan, Brian L., Joceyln L. Aycrigg, Jessie H. Barry, Rick E. Bonney, Nicholas Bruns, Caren B. Cooper, Theo Damoulas, André A. Dhondt, Tom Dietterich, Andrew Farnsworth, Daniel Fink, John W. Fitzpatrick, Thomas Fredericks, Jeff Gerbracht, Carla Gomes, Wesley M. Hochachka, Marshall J. Iliff, Carl Lagoze, Frank A. La Sorte, Matthew Merrifield, Will Morris, Tina B. Phillips, Mark Reynolds, Amanda D. Rodewald, Kenneth V. Rosenberg, Nancy M. Trautmann, Andrea Wiggins, David W. Winkler, Weng-Keen Wong, Christopher L. Wood, Jun Yu, and Steve Kelling
2014 The eBird Enterprise: An Integrated Approach to Development and Application of Citizen Science. *Biological Conservation* 169:31–40.

Thornton, Amara
2013 '...a certain faculty for extricating cash': Collective Sponsorship in Late 19th and Early 20th Century British Archaeology. *Present Pasts* 5(1). DOI: http:/dx.doi.org/10.5334/pp. 559:485–507.

Tomášková, Silvia
2003 Nationalism, Local Histories and the Making of Data in Archaeology. *Journal of the Royal Anthropological Institute* 9:485–507.

Verhagen, Philip, and Thomas G. Whitley
2012 Integrating Archaeological Theory and Predictive Modeling: a Live Report from the Scene. *Journal of Archaeological Method and Theory* 19:49–100.

Wienhold, Michelle, and David R. Robinson
2014 Open Geospatial Data: Discussions and Solutions for Publishing Sensitive Rock Art Data Online. Paper presented at the 79th Annual Meeting of the Society for American Archaeology, Austin, Texas.

Young, Lisa C.
2012 *Suvoyuki* Means Joint Effort: Archaeologists, the Hopi Tribe, and the Public at Homol'ovi. In *Global Perspectives on Archaeological Field Schools: Constructions of Knowledge and Experience*, edited by Harold Mytum, pp. 229–241. Springer, New York.

Zeder, Melinda A.
1997 *The American Archaeologist: A Profile*. AltaMira, Walnut Creek, California.

Notes

1. http://www.washingtonpost.com/national/science/citizen-scientists-help-search-for-tomb-of-genghis-khan-via-photos-of-mongolia/2011/03/09/AFmhmKeC_story.html, accessed September 24, 2013.

2. www.sc.edu/uofsc/stories/2014/03_research_crowdfunding_pournelle.php#.U3Z65ChR6M2, accessed April 14, 2014

3. http://www.foxnews.com/science/2013/04/23/new-archaeology-apps-may-make-armchair-indiana-jones/, accessed September 24, 2013.

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