PAPER

A Layered Approach for the Discovery and Mapping of Prehistoric Sites Beneath Lake Huron

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ABSTRACT

For much of modern human history (roughly the last 200,000 years), global sea levels have been lower than present. As such, it is hardly surprising that archaeologists increasingly are looking to submarine environments to address some of their most pressing questions. While underwater archaeology is most commonly associated with shipwrecks, the search for submerged prehistoric sites presents an entirely different set of challenges, even though many of the same technologies are used. For Great Lakes archaeologists, the problem is how best to adapt the range of available seafloor mapping and testing techniques to the problem of identifying prehistoric sites, while operating with smaller vessels and the limited budgets available to "normal" archaeology. In this paper, we briefly describe the approach we have developed at the University of Michigan for identifying 9,000-year-old caribou hunting sites beneath Lake Huron. The research employs a layered research design integrating sonars, remotely operated vehicles (ROVs), and scuba divers at progressively finer scales to discover and investigate these important new archaeological sites.
Keywords: underwater archaeology, Great Lakes, sonar

Introduction

It recently has been noted (Joy, 2020) that, for 90% of modern human history (roughly the last 200,000 years), global sea levels have been lower than present. As such, it is hardly surprising that, from Southeast Asia to the North Sea, Beringia, and South Africa, archaeologists are looking to submarine environments to address some of their most pressing questions. The Great Lakes in North America saw similar oscillations at the beginning of the Holocene, varying from more than 100 m higher to 100 m lower than modern lake levels. In the Lake Huron basin alone, it is estimated that more than 2,500 km^2 of modern lake bottomland was available for human use (Eschman & Karrow, 1985) during the Lake Stanley lowstand (between roughly 10,000 and 8,000 cal BP) (Lewis et al., 2007). As archaeological and paleontological sites from this time period are rare on the surrounding mainland of Michigan and Ontario, it is again unsurprising that archaeologists should look underwater to document this critical period of climatic and cultural change.

While underwater archaeology is most commonly associated with shipwrecks, the search for submerged prehistoric sites presents an entirely different set of challenges, even though many of the same technologies are used. Shipwreck sites represent an anomaly on the seafloor that stands out from their surroundings. Since vessels are rarely placed intentionally, the underwater setting of the shipwreck is typically important only to the extent that it makes the vessel wreckage more or less visible. In most cases, too, researchers are looking for a specific vessel that was lost. Neither condition is true for submerged site archaeology. For prehistoric sites, which are often small and comprise only stone tools and animal bone, the setting of the seafloor is critical since it represents the once dry land surface and environment on which the ancient inhabitants lived. Particularly in the context of small hunter-gatherer sites, the preserved environmental setting often provides the only clues to where the occupation sites might be found. Also in contrast to shipwreck research, the prehistoric archaeologist cannot know a priori that an occupation site even exists within the area to be searched. So while shipwreck archaeology is essentially a search for a known target that will appear as an anomaly, prehistoric research requires that the ancient landscape be mapped and reconstructed before any meaningful search can begin, and it requires modeling of human activities within that reconstructed environment as a basis for executing a search for underwater archaeological sites.

Most research follows this general approach, often termed the "Danish Model" (cf. Fischer, 1993; Benjamin, 2010), to discover submerged sites, particularly those associated with earlier time periods that lack major architecture or historic records. The search for prehistoric sites can be challenging; all archaeologists must deal with potential site destruction in high-energy coastal settings and with post-depositional sedimentation that can bury and/or obscure traces of ancient sites. Archaeologists working in marine environments must also contend with more recent coral and organic growth.

Within the Great Lakes, the cold fresh water can provide extra-ordinary preservation conditions for organic materials, such as wood and even rooted trees. While we do not see the dense accumulation of marine growth and corals as in salt water contexts, invasive species such as zebra (*D. polymorpha*) and quagga mussels (*D. bugensis*) cover every hard surface, and the water clarity they create in turn promotes algal growth at depths previously unprecedented within the Great Lakes. For Great Lakes archaeologists, the problem is how best to exploit the potentials of this freshwater research environment using the range of seafloor mapping and testing techniques available. A related question is how to do so on the limited budgets available to terrestrial archaeology. In this paper, we briefly describe the layered approach that we have developed at the University of Michigan for investigating ancient hunting sites on the Alpena-Amberley Ridge (AAR) in central Lake Huron.

Ancient Hunters on the AAR

The late glacial history of the Great Lakes is complex and is characterized by a series of high and low water stands regulated by the interaction of early Holocene climate, the flows of glacial melt waters, and the isostatic rebound of recently deglaciated land surfaces (cf. Baedke & Thompson, 2000). Modeling these changes is made further complex by short spasmodic readvances of the glacial ice front (cf. Lowell et al., 1999). The most extreme of the low water stands, and the focus of the current investigation, is collectively referred to as the Lake Stanley stage (Lewis, 2016; Lewis et al., 2007) (the equivalent low water stage in the Lake Michigan basin is termed Lake Chippewa). Following Lake Stanley, after 8,000 BP, lake levels never again drop to the lows associated with Lake Stanley; instead, they return to higher levels (Nipissing transgression) before coming to modern levels. This is significant since it means there was a 2,000-year period during which the now submerged portions of the Lake Huron bottomlands would have been available for the colonization of plant, animal, and human communities, but that after which it was never again exposed.

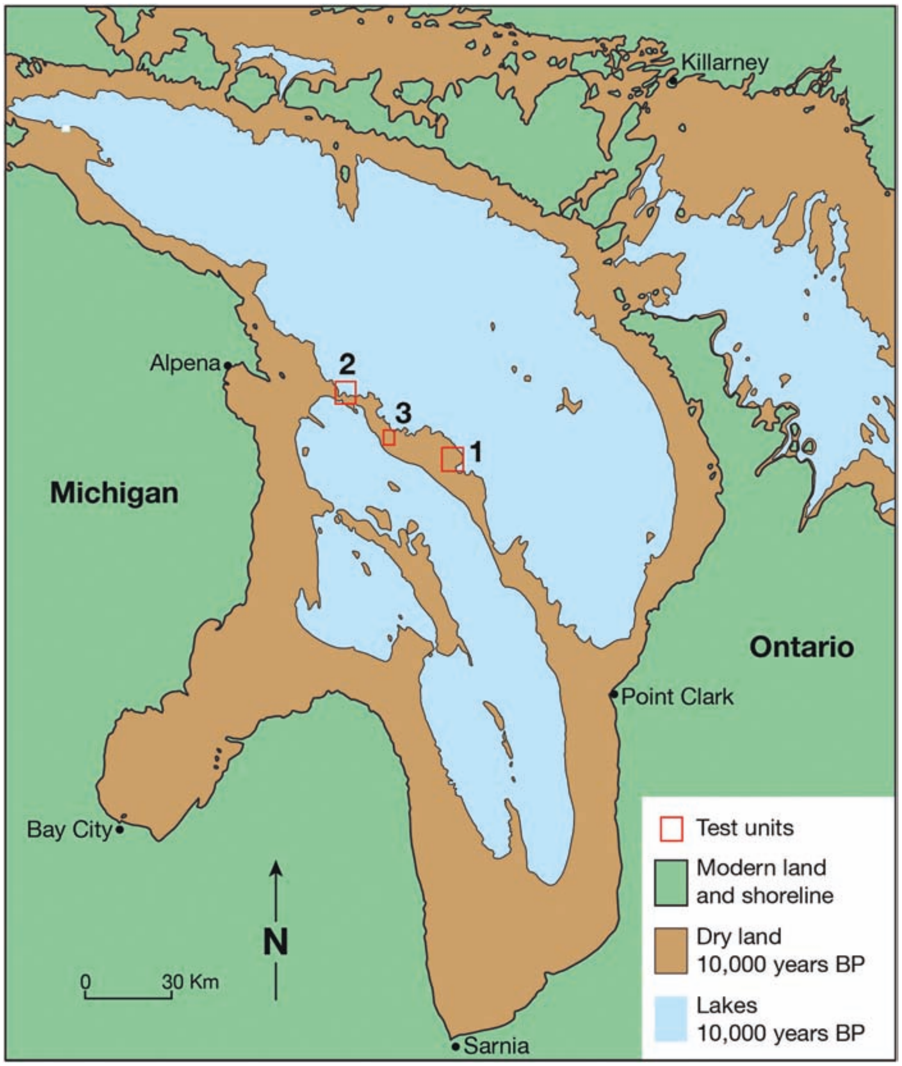
During the low-water Lake Stanley, the Huron basin contained two lakes separated by a feature extending northwest to southeast across the basin from the area of Presque Isle in Michigan to around Point Clark in Ontario (Georgian Bay would similarly have been isolated at this time, creating three separate paleolakes; Janusas et al., 2004). The map (Figure 1) also shows extensive low-lying coastal areas, particularly along the eastern coast of Michigan, Saginaw Bay, and southern Lake Huron that would have been dry land during Lake Stanley times, representing some 250,000 hectares of land, which would have been exposed for settlement (Eschman & Karrow, 1985).

The ridge that divides the central basin deserves particular attention. The feature, termed the AAR, is capped with Middle Devonian limestones and dolomites that resisted both fluvial and glacial erosion (Hough, 1958; Thomas et al., 1973, p. 232). Viewed in finer detail, the formation is found to be roughly 10 miles wide and exhibits a number of interesting features including high northeast-facing cliffs, stretches of low coastal areas, and high plateau regions. The northwest half of the ridge falls in American waters, and the southeast half falls in Canadian waters.

A considerable amount is known about the regional environment during the Lake Stanley low-water phases (cf. Karrow, 2004). The general consensus is that the climate of the region was colder and drier than present and that this changed to warmer and drier than present after about 7,900 BP (Croley & Lewis, 2006; Lewis et al., 2007, p. 449; McCarthy et al., 2015). Sarvis et al. (1999) describe the lake conditions during the period of 10,500–9,000 BP as similar to those in modern Arctic lakes. This expectation is borne out by analyses of environmental samples collected directly from the AAR, which reveal an open subarctic setting with numerous lakes and marshes with scattered spruce and tamarack at 9,000 BP (Sonnenburg & O'Shea, 2017).

FIGURE 1

Map of Lake Huron basin during the Lake Stanley lowstand. Initial three search areas are shown as labeled red boxes.



In terms of the regional archaeology, the earliest generally accepted human occupation in the upper Great Lakes is associated with the regional fluted-point Paleoindian tradition. The Paleoindian period is typically divided into three phases (Ellis, 2004; Julig, 2002; Lothrop et al., 2016) defined primarily on point styles and raw material utilization. With the possible exception of the Gainey phase, none of these complexes is well dated, and few of the sites in either Michigan or Ontario are represented by intact deposits (cf. Storck, 1997). The Paleoindian occupation is followed by the Archaic, which covers the span of time from nearly 10,000 until about 2,000 BP (e.g., Ellis et al., 1990; Monaghan & Lovis, 2005, pp. 72–78; Lovis, 2009; Shott, 1999).

While this progression of phases is widely accepted, it is dating and character is largely inferred from archaeological sequences in other parts of North America. Since there are very few intact sites and few carbon-dated site contexts, and since the region's acidic forest soils rarely preserve faunal assemblages (see Spiess et al., 1985; Storck & Spiess, 1994), hypothesized shifts in technology, target prey species, and population organization are similarly inferred and untested. Essentially, very little is known about the early inhabitants of the Great Lakes from the terrestrial archaeological record.

The lack of firm dates, intact sites, and preserved fauna has left unresolved a number of significant long-term debates regarding Paleoindian technology, subsistence, and settlement systems (cf. Ellis et al., 1998). What most investigators do agree on is that this critical evidence lies beneath the Great Lakes (Jackson, 2004; Jackson et al., 2000; Pengelly & Tinkler, 2004; Shott, 1999).

> *This major event in Great Lakes history [the draining of Lake Algonquian]…exposed about half of the present lake floor areas as dry land. This drainage must have had a significant effect on local climates and flora and fauna, opening large tracts to colonization. Since such drainage was rapid, one can only speculate on its effect on the economy, religion, and society of the human population* (Karrow & Warner, 1990, p. 17).

This is why the AAR has such great significance. It was a unique dry land area during the critical time period between 10,000 and 7,500 BP, and unlike coastal areas that have been subject to extensive reworking and burial due to coastal processes and subsequent lake level rises (cf. Barnett, 2015), sites on the AAR occupy a midwater location with little sediment cover and have sat untouched since the time of human occupation—an ideal setting for submerged archaeology.

Mapping Ancient Hunting Sites Under Water

The AAR provides a number of advantages for an archaeological investigation. On the one hand, it represents a relatively narrow and circumscribed area in which the cultural activity would have been confined and thus where archaeological sites may be found. On the other hand, given what is already known about the paleo environment, the kinds of cultural activities expected and what they might look like can also be predicted. Given the subarctic environment, it is expected that people living on the AAR would have pursued cold-adapted animals, such as caribou. These factors simplified the problem from a search perspective and allowed us to do more serious cultural modeling to predict the specific kinds of settings in which sites would be found. Specifically, we hypothesized that the AAR would have provided a corridor for the seasonal migration of caribou herds and that the hunters pursuing the animals would have exploited similar technologies, in the form of stone lines and hunting blinds known ethnographically among precontact caribou hunters in the Arctic (Brink, 2005; Stewart et al., 2004).

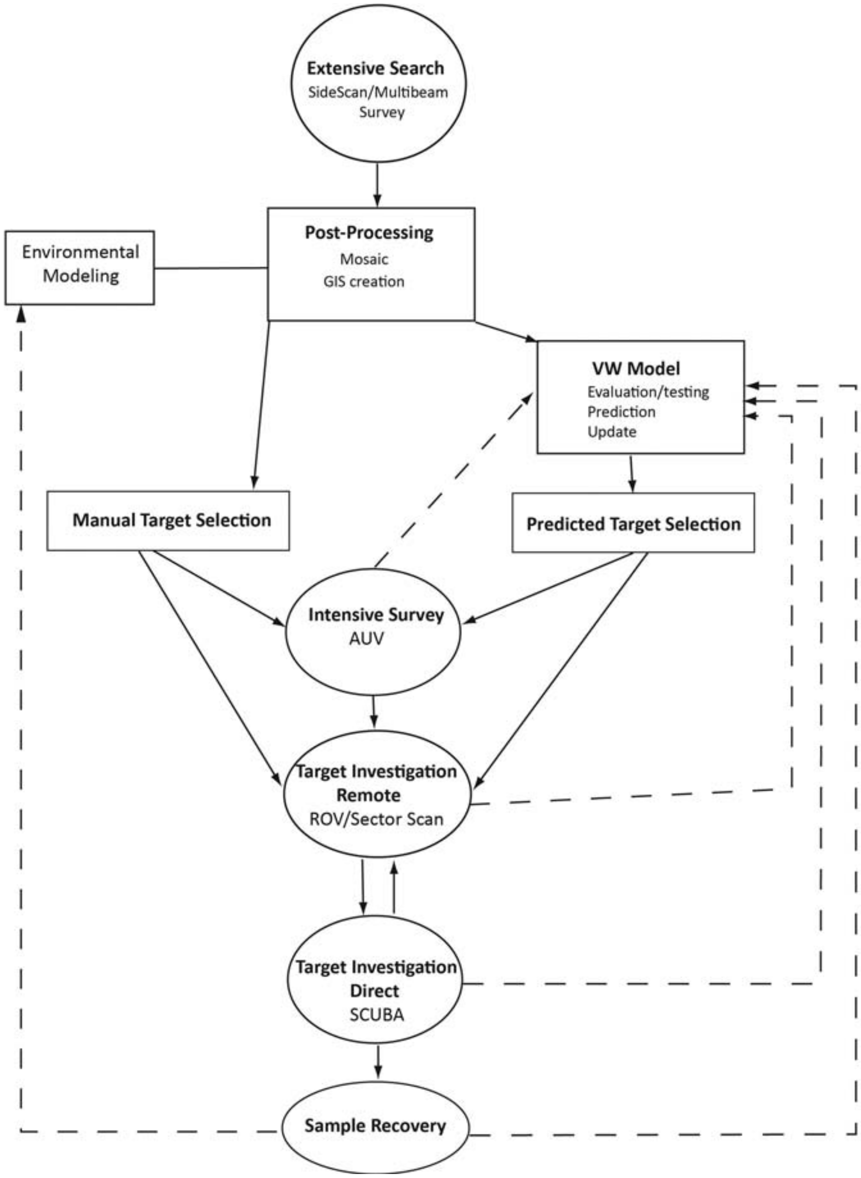
The starting point for the investigation was existing high-resolution bathymetry for the Lake Huron basin. Using these data, we were able to create a generalized model of the ancient land surface that would have been dry land during Lake Stanley, and on this basis, we identified three research areas that presented contrastive landforms that were ethnographically known to be desirable for caribou hunting: a water crossing, a naturally occurring "choke point" (a very narrow section of the AAR), and open ground along a paleolake margin (see Figure 1). These three areas ranged in size from 17 to 56 km^2 with depths ranging from 20 to 50 m (with depth here being a potential surrogate for age, as lake levels gradually rose from the early Lake Stanley levels; i.e., the deeper the site, the older it could be as water levels were at their lowest at the beginning of Lake Stanley). In addition, and in collaboration with Dr. Robert Reynolds of the Department of Computer Science at Wayne State University, we began an effort directed at both modeling the ancient submerged environment and then populating it with migrating caribou, using artificial intelligence (AI) methods to enable the computer-simulated caribou to learn and transit the ancient environment (Fogarty et al., 2015). Together, the physical methods of examination, both remote and direct (see below), and the AI combined to form a layered approach to the investigation. Physical techniques, such as side-scan sonar (SSS) mapping, progressed from extensive to intensive, while the computer simulation provided a virtual database of all the information being generated by the physical examination and testing underwater (Figure 2).

The first level in the layered search strategy saw the complete coverage of the three test areas using SSS at an intermediate frequency of 330 kHz over depths between 20 and 40 m and at a range of 100 m. A 115-km^2 portion of the central AAR, which partially overlapped Area 1, was also surveyed using multibeam (MB) sonar. The MB survey used an R2 Sonic 2024 multibeam echosounder with an F180 vessel attitude and positioning system. The extensive survey was not expected to reveal actual hunting structures—although in one case, it did (O'Shea & Meadows, 2009)—but rather to provide a detailed view of the lake bottom. This more detailed view highlighted the three-dimensionality of the landforms, specifically the water crossing, choke point, and paleolake areas originally selected. In addition, the sharp variation in acoustic reflectivity on the AAR revealed in the backscatter from these surveys also provided a very useful contrast between sandy and harder bottom conditions. This contrast was particularly important given the offshore location of the survey areas (i.e., 55–85 km) and the low likelihood that any substantial quantity of sand would be transported from land. As such, areas of sand observed on the AAR had to have been deposited during Lake Stanley and therefore provided an important indicator of ancient waterways (lakes, rivers) and marshes that existed when the AAR was dry land. This hypothesis was confirmed by the discovery of marsh testate amoebae in these sand deposits (Sonnenburg & O'Shea, 2017).

Following an initial examination of promising locations using a small remotely operated vehicle (ROV; see description below) and teams of SCUBA-trained archaeologists, the next layer of search exploration was initiated. It was clear that the preliminary survey blocks were still very large areas to investigate archaeologically; therefore, the next step involved defining smaller areas of the lake floor that could be examined more

FIGURE 2

Schematic model of layered search strategy.



intensively. Initially, four "micro-regions" were selected for a more concentrated investigation. These localities were selected based on the character of the immediate landscape and also represented areas within which stone hunting features had already been identified during preliminary ROV and SCUBA observations. The total number of micro-regions has been expanded to nine, as the research has broadened to investigate other potential activities not related to caribou hunting.

Each micro-locality has an area of 0.5 km^2 with the typical area surveyed being a 1,000 × 500 m rectangle. The orientation of the micro-region survey block was determined by the shape of the underlying landform in order to produce the most effective sonar mosaic. This layer of investigation employed a small autonomous underwater vehicle (AUV) to conduct close-in acoustic mapping of the micro-regions (as opposed to the traditional towed side scan, which was used to map the much larger preliminary areas).

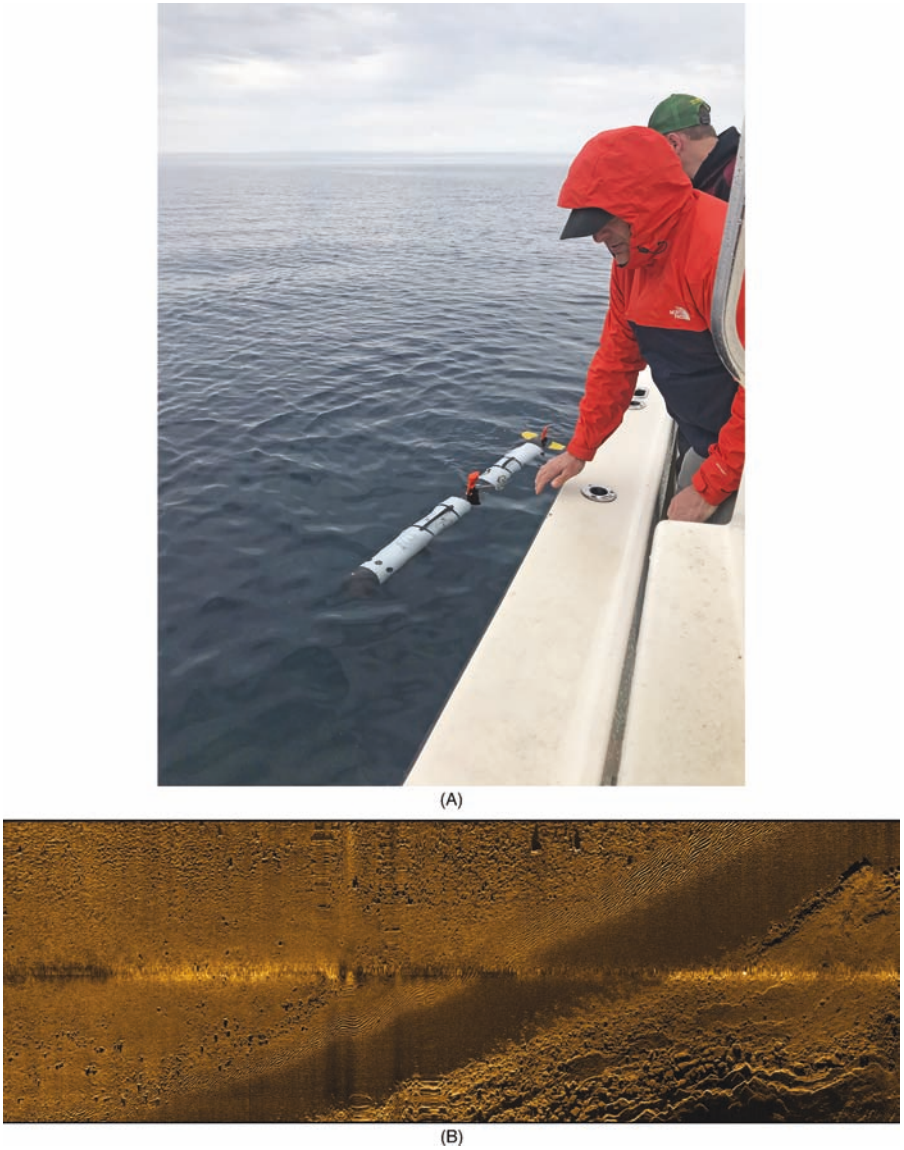
The project utilized a base-level Iver3 AUV, and over the course of the research, we have experimented with differing configurations of acoustic and photography packages (Figure 3). The bulk of the research to date has been conducted using SSS mounted on the AUV (Edgetech 2205 operated at 600 and 1,600 KHz simultaneously). Bottom mapping with an AUV was attractive for several reasons: (1) the AUV can fly much closer to the bottom, which accentuates the three-dimensionality of the seafloor; (2) it obviates the need for complex layback calculations when mosaicking the results of the survey; and (3) it does not experience image distortion produced by heave or other motions transmitted from the surface towing vessel (although it was not entirely immune to weather and sea conditions; see below).

For initial survey coverage, a relatively long 50-m range was utilized with a grid providing 100% overlap coverage of the survey area. Unlike the extensive towed SSS survey, the AUV surveys were expected to reveal potential hunting structures and other built features and alignments, particularly given its closeness to the lake bottom and high-resolution imagery. The more detailed bottom imaging produced a clearer view of the immediate environment and the configuration of natural features, which would have been relevant to ancient hunting and habitation. Finally, the mosaicked AUV imagery represented a detailed and georeferenced map to guide more intensive localized site investigation and mapping.

Using these detailed mosaic maps of the micro-regions, a thorough examination of potential targets was

FIGURE 3

AUV. (A) Iver3 being launched from research vessel. (B) SSS image of high ground area in central Lake Huron from AUV survey; swath is 100 m and clearly shows cliffs, sand ripples, and individual boulders. Photograph taken by A. Lemke.



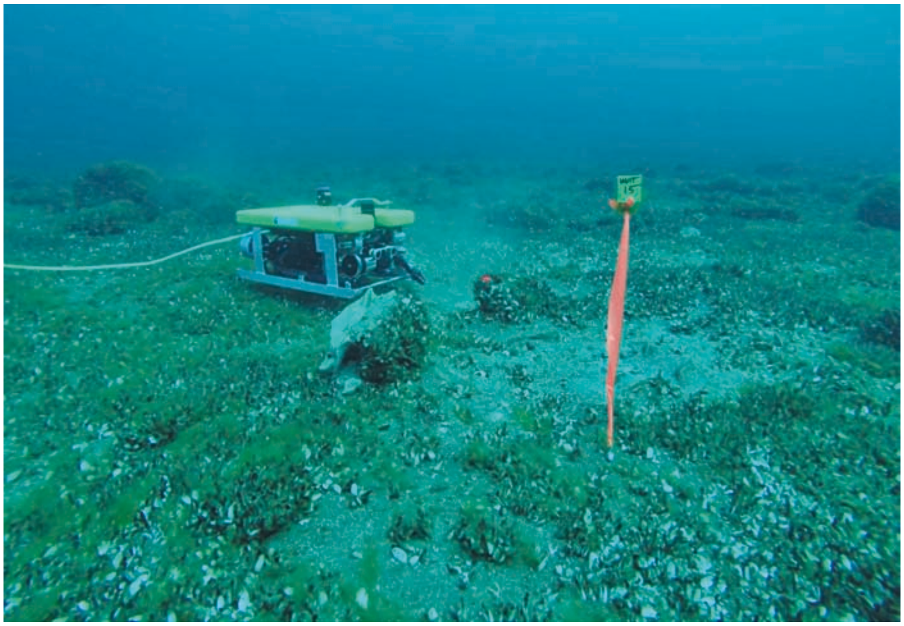
performed using an ROV (Figure 4). An Outland 1000, a hand-deployable ROV, was used for this work. In addition to the standard video cameras and forward scanning sonar, paired forward-pointing parallel red lasers were attached to provide a scale on visual images, and a USBL transponder was added (Tritech Micronav 100) to permit locational control for navigating the ROV to designated targets and for recording the location of recovered video imagery. Potential sites were examined in real time on the research vessel, and later in the laboratory, the video footage was parsed by location and entered into a linked Geographic Information System (GIS) to permit a fuller examination of areas during the off season. An unanticipated benefit of the video database is that, as research has progressed over time and locations have been revisited, a cumulative (12+ year) record of environmental conditions on the Lake Huron bottomlands has been created, which permits changing conditions and the progression of invasive species to be directly observed.

For targets that continue to look promising after ROV inspection, the research shifts from discovery mode to documentation and sampling, which entails both remote and direct access to the site. Since our primary targets were constructed stone features, the creation of an accurate map of the structure is of prime importance. Traditionally, this would involve divers' stretching tapes, a process that is both time consuming and inaccurate. Such maps are also inherently 2-D. To overcome these drawbacks, we adopted two approaches for mapping large features, one remote and one direct.

The remote approach involved the use of scanning sonar. In essence, the sonar head is held in place on a tripod sitting on the lake floor, and the sonar head then rotates through 360° to produce a scaled acoustic image. We utilized a Kongsberg MS1000 unit along with its proprietary software. The scanning unit is deployed from the research vessel and rapidly produces a high-resolution acoustic image of the feature in real time. The operator can vary the range or scale of the image on the fly, and multiple collected images can be mosaicked. As the system can produce either high-resolution acoustic images or point cloud data, it can provide an accurate 3-D image of the target, which can then be manipulated for viewing from multiple angles, accurately measured, georeferenced, and exported into other image analysis or computer simulation systems (see Figure 5).

FIGURE 4

ROV deployed at the Drop45 site in central Lake Huron. Sample marker from archaeological test unit 15 is visible in the foreground.

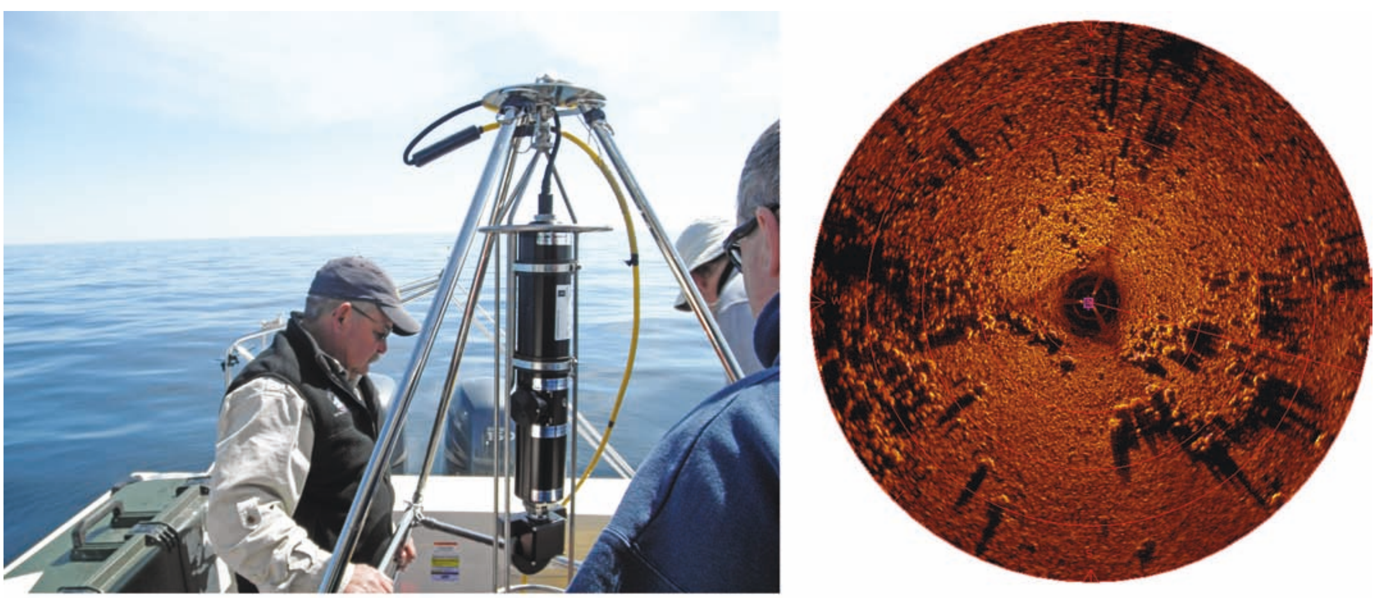


The second approach to documenting and imaging features was photogrammetry, a technique common in maritime archaeology (see McCarthy et al., 2019). Divers equipped with GoPro cameras would slowly swim around the feature to produce the initial overlapped imagery set. While this type of imagery is often collected as HD videos and then frame grabbed to obtain the still images needed, we collected still images at regular intervals of 1–3 s/shot. This approach obviated the intermediate post-processing step, and it ensured that each image contained its unique meta-data, which enhanced the stitching together of the images by the program. We utilized Agisoft Metashape (formerly PhotoScan Pro) software for processing the images. The resulting 3-D images can be accurately measured and, with appropriate texturing, provide a compelling image of the feature that can be scaled and viewed from multiple angles. The images can also be exported to a variety of generally available 3-D viewing formats, such as .pdf, and can be directly placed into an existing computer simulation environment.

With the mapping and documentation steps complete, the work moves on into more traditional archaeological activities of excavation and sample

FIGURE 5

Scanning sonar. (A) Scanning sonar unit being prepared for deployment. Note sonar head at base. (B) Sector scan image of Target 5 in Lake Huron. Image radius is 20 m with unit in the center. Red circles represent 4-m intervals.



(A) (B)

recovery. This work is conducted by SCUBA-trained archaeologists, and the goal of technology at this stage is to reduce the burdens of navigation and documentation on the divers so that their limited bottom time is devoted to sample recovery. For this, the ROV is again the work horse. The ROV is deployed ahead of the divers and provides a critical visual link between the surface and the divers. It confirms the location of the target, creates a visual pre-disturbance record of the site, and directs the divers to their work areas (as well as providing a redundant guide back to the boat). On-site, the ROV records the sampling activities on the lake bottom, and once sampling is completed, it records the precise location of each sample unit collected. The ROV can also remain on-site during dive surface intervals and produce a final, post-testing image of the site.

After Discovery

As should be clear from the preceding narrative, the layered approach to site discovery and documentation produces a diversity of digital data reflecting the differing scales at which data are collected. The effective integration of these differing data streams is essential. For this, we have adopted two approaches, a traditional GIS database and the creation of a *de facto* database within a virtual world (VW) computer simulation.

Since every piece of data collected by the project, regardless of scale, has a spatial component, it can all be accommodated within a single GIS for central Lake Huron. Everything from the largest 56-km^2 search area to the location of a single 100-ml environmental sample can be plotted. By the completion of the research, we hope to have all data streams available for online access.

The second and more experimental approach focuses on the dynamic VW model of the research area created by Robert Reynolds and his team (cf. Fogarty et al., 2015; Stanley, 2019). The idea is by continually updating the VW model as new data on the environment or site locations and structures are accumulated, the VW will come to encompass essentially everything we know about the AAR and will present this information in a form that can be visually inspected and experienced as virtual reality. While finer grained data, such as recovered stone artifacts and wood, are not yet incorporated in the system, initial trials of the VW model conducted with traditional caribou hunters in Alaska have produced encouraging results and suggested ways to both improve and generalize the VW model.

Discussion

Submerged site archaeology, as a field, is still in its infancy as various approaches, some borrowed from maritime and shipwreck research and others from terrestrial archaeology, are being drawn upon to develop ways forward. The layering of techniques described here was developed specifically for the research in Lake Huron, and it has proven an effective method for conducting a multi-year program of archaeological research. The techniques applied were particularly well suited for identifying past environmental conditions and the presence of stone structures—advantages not always shared in other marine archaeology efforts. The efforts have also demonstrated that sustained research can be conducted using small vessels (nearly all the research on the AAR has been conducted using a Parker 2530 as the research platform) and less expensive, hand-deployable survey equipment. In this regard, the Outland 1000 ROV has been particularly valuable due to its smaller size and versatility. Versatility and flexibility are essential if submerged site research is to be conducted within the budgets of (non-glamor) archaeology.

Of course, the use of less expensive gear or options does come with its own price. For example, while the lower-end AUV utilized produced all of the advantages we expected, it also came with a series of limitations. Perhaps, the biggest disappointment was the limited navigational accuracy of the base model Iver3. The absence of the more sophisticated inertial guidance package meant that, even over the relatively short distances of the micro-localities (1,000 m), the AUV could not maintain an accurate track. We were also reminded that, while AUVs are unaffected by the motions of a tow vessel, they are not immune to surface conditions. For example, during rough surface conditions, the unit's ability to acquire an adequate GPS fix was notably degraded, even as wind and waves tended to push the small unit off course. We remain convinced that AUVs have a pivotally important role to play in the layered search system and in underwater archaeology more generally. The technology exists today, but we must await future innovations that will allow more accurate navigation at lower costs.

The same caveat applies to the use of small vessels. Small research vessels, such as the Parker 2530 we use, bring versatility and flexibility to research efforts. They are relatively inexpensive to operate and, through their dedicated use, allow researchers to take advantage of short-term windows of favorable weather and sea conditions. These benefits are achieved, however, at the cost of smaller working spaces, limited crewing capabilities, and the inability to remain continuously on the water for multiple days.

Looking beyond the AAR, it is easy to envision how other common techniques, such as sub-bottom profiling, lidar, and coring, can be fit into a layered search strategy to permit research in areas with differing conditions of bottom visibility and sedimentation. Overall, the twin trends of miniaturization and increasing capability will ensure that important archaeological sites on the bottom of the Great Lakes, or the world's oceans, will become increasingly accessible to archaeological research and discovery.

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