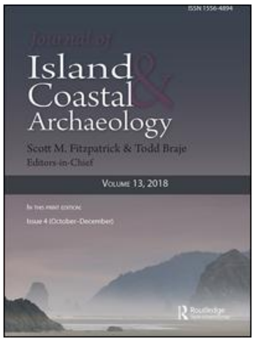

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ABSTRACT
Some of the most pivotal questions in human prehistory hinge on archaeological sites that are now under water. While the discovery of submerged sites presents numerous technological challenges, they offer unique potentials for investigating time periods, cultures, and adaptations that are only poorly known on land. Yet despite this potential, the results from underwater research have, to date, had relatively limited impact. One reason is that underwater research rarely produces the systematic coverage of space and material culture that is needed to conduct anthropologically relevant research. The investigation of micro-regions as a means to elucidate economic and social relations in the past has been widely adopted in terrestrial archaeology, and yet is arguably even better suited to submerged settings. By defining specific and comparable localities as the target for intensive search, a micro-regional approach can provide the framework for generating a rigorous systematic coverage of space and material, while still operating within the physical and financial constraints of underwater research. This paper illustrates how a micro-regional approach to submerged landscapes can be operationalized as represented by survey efforts on the Late Paleoindian occupation of the Alpena-Amberley Ridge beneath modern Lake Huron.

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Introduction

There is now broad recognition that submerged site research offers great potential for addressing a wide range of significant questions in human prehistory (Bailey 2014; Flemming n.d.). From global colonization to catastrophic tectonic events, there is significant archaeological data preserved beyond the water's edge. Yet despite this broad recognition, submerged sites have had surprisingly little impact on our understanding of the past (see Bailey 2014, 291–2; Sturt et al. 2018). There are many reasons for this, such as the limited amount of work done to date and in many cases to the paucity of actual finds generated. But it can also be traced to the perception that finds recovered underwater are essentially novelties, which exist without cultural context or chronological control, and which cannot be subjected to systematic investigation.

For submerged site research to realize its claimed potential, it must be viewed as something more than just a novelty or footnote. The increasing prevalence of underwater projects will move us some in this direction, as will the actual production of significant results. Yet, the ultimate goal should be the seamless integration of terrestrial

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and underwater investigations—in order to best understand the past. To achieve this, the burden is on underwater research not simply to produce results, but to produce data that are comparable to the results generated by terrestrial archaeology.

While the location of the modern shoreline had no bearing on the past societies we study, erasing the distinction between terrestrial and underwater research is much easier said than done. There are inherent differences in the methodologies employed and the cost of research. Much underwater research, particularly many high profile examples, are astoundingly expensive and time consuming. Take for example the recent research on the Dogger Banks (Gaffney, Fitch, and Smith 2009; Flemming et al. 2014). All told, this research alone has consumed decades of geophysical and archaeological prospection and consumed many hundreds of thousands of Euros. In fact, many projects successfully operate on much shorter time frames and smaller budgets (in the range of $50,000 and less), such as the ones described by Halligan and Puckett in this volume, but for more ambitious off shore or deeper water projects, budget will always be a significant issue.

The Dogger Banks case also highlights a second major impediment that submerged site archaeology must address. In underwater research there is rarely the equivalent of the plowed field that can be rapidly evaluated via surface survey. On land, sites are literally *plowed* into view over time, while in underwater contexts sites typically are *deposited* into invisibility via sedimentation and the growth of marine life. As such, site survey, particularly in marine environments, must often rely on cores or dredges, both of which are extremely coarse and time consuming discovery tools. On the other hand, the ancient landscape and sites associated with it underwater often stand a much better chance of preserving continuously intact surfaces, even if buried; providing critical information on the spatial relationship between sites and finds compared to the typically incomplete and discontinuous representation of ancient sites on land.

Submerged sites are discovered in multiple ways. They may be found accidentally via fishing or dredging operations or more intentionally via the application of the 'Danish Model' (see Benjamin 2010) in which environmental modeling and traditional knowledge are applied to predict site locations. While this approach can be useful for finding sites, it does not produce the kind of *systematic* coverage and recovery needed to make the results comparable with equivalent terrestrial efforts.

Several approaches have been adopted by underwater archaeologists to make their results more generalizable and comparable with landscape focused terrestrial survey. The approach followed by Halligan (Figure 1) in her research at Page-Ladson (2012), was essentially to ignore the distinction between land and water. She created a shovel test grid over the swampy landscape which complemented the data recovered in the sink holes. This directly addressed the survey comparability criteria, although as a method it can only be implemented in very specific localities. Probably the most common approach is to model the submerged landscape and environment and then apply predictive models for site location based on existing terrestrial data (see Dunbar and Thulman 2019; Lacroix et al. 2014). This approach permits investigators to make relative statements about the potential for the existence of sites, assuming the models applied are relevant to the submerged landscape, but rarely has the precision to actually predict submerged site locations (Flatman and Evans 2014). Still, even with this modeling as a base, it is not clear how the submerged areas should be sampled.

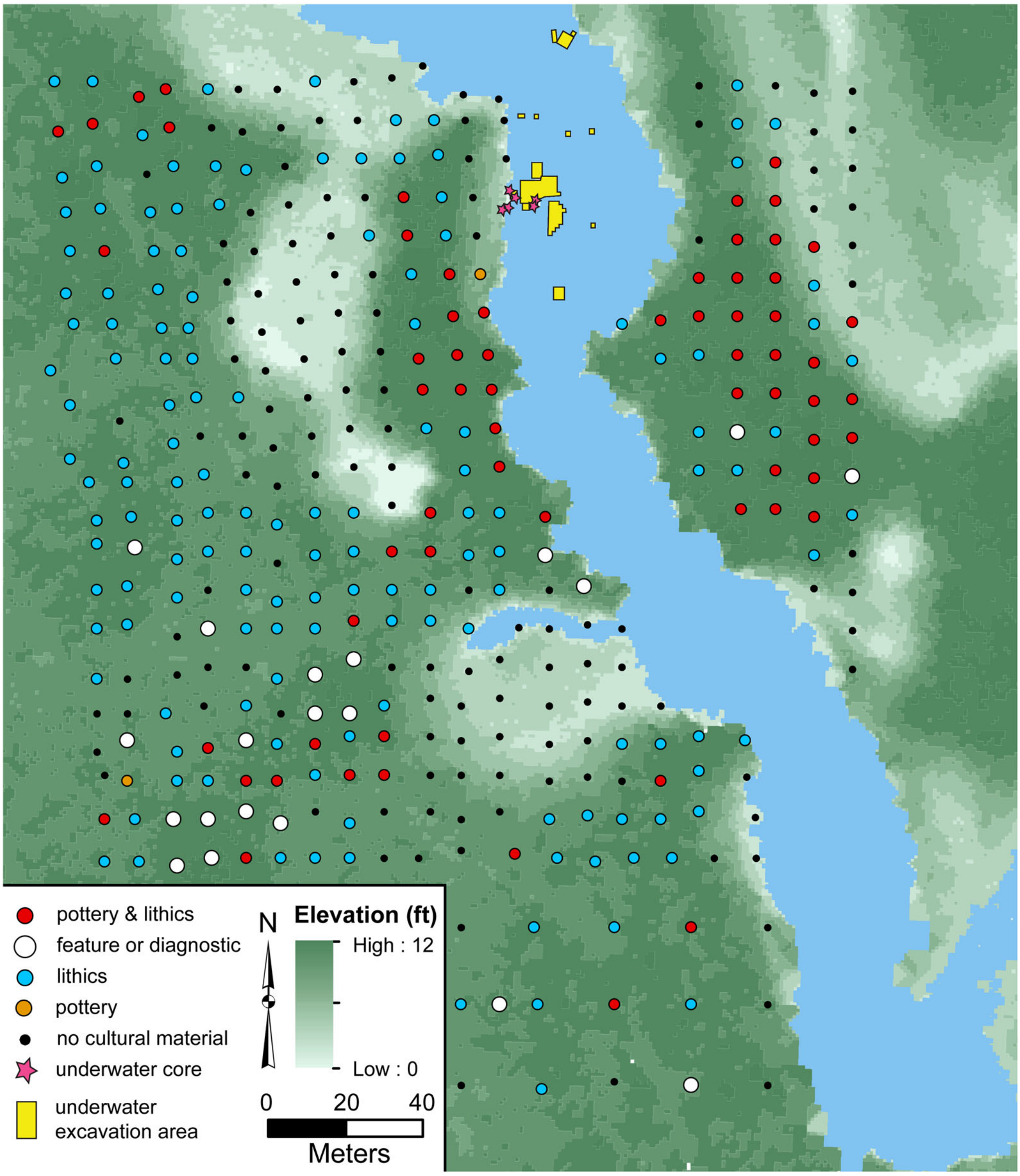

Figure 1. Terrestrial and underwater sampling scheme at the Page-Ladson site in Florida (Halligan 2012). Sampling system combines systematically gridded shovel tests, underwater core samples, and underwater excavation units of varying sizes. Plan provided courtesy of Jessi Halligan.

Other approaches advocate the idea of moving from the known to the unknown for site survey and discovery. One method advocated by Faught (2004, 2014), assumes the existence of a preserved social landscape and first seeks to locate cultural or natural features that are easier to identify, such as prehistoric quarry sites, and then moves out from these to identify related loci of other cultural activities (see Easton and Moore 1991; Faught and Donoghue 1997; Flemming et al. 2003).

When thinking of ways forward, it is clear that some form of predictive modeling is essential to limit the universe of potential site locations (Benjamin 2010), and that sea level curves and paleo-environmental reconstruction are the first necessary steps for any realistic predictive modeling (Pearson et al. 2014). It is also clear, however, that simply overlaying existing terrestrial models on submerged landscapes is not good enough, and that for any hope of success the models must be specifically tailored to the past conditions and environment being investigated underwater (see Fogarty et al. 2015; Stanley 2019). Yet even from this starting point, there is still the problem of how to cover large areas of submerged lands and survey it in a manner which is systematic and comparable to terrestrial survey. In essence, the problem is not simply finding a site, but of sampling areas and discovering sites within them that have an established context and from which parameters such as site density can be estimated.

In considering general approaches to underwater site survey, a desirable approach should satisfy five basic criteria:

(1) Method should produce contextualized results that are qualitatively and quantitatively comparable to terrestrial survey;
(2) Method should capitalize on the inherent strengths of the submerged record;
(3) Method should be adaptable to differing underwater settings and conditions;
(4) Method should be adaptable to constraints on budget and time; and
(5) Method should permit the integration of data accumulated over multiple years and with differing kinds of data collection techniques.

Micro-regional approaches

One set of approaches that have been widely used in terrestrial research, can be grouped under the heading *micro-regional* studies (see Ejarque et al. 2010; Jeffries 1976; Gaffney and Tingle 1985). These studies focus not on sites *per se*, but on localities within which significant human activity of interest is expected. The size of the localities varies depending on the specific questions being asked. For example, if one were interested in resource usage around key sites, the locality might be defined by the size of the predicted site catchment (see Flannery 1976, 91–5; Vita-Finzi et al. 1970; Duffy 2013) (Figure 2). Once defined, the micro-region becomes the focus for in-depth investigation. This provides detailed spatial and material evidence within the locality, which can be compared qualitatively and statistically with similarly sized micro-regions elsewhere.

In general, micro-regional approaches provide a targeted means for collecting comparable archaeological and spatial data in lieu of full scale regional survey or probabilistic sampling, although it can be used in tandem with either. As such it presents a number of advantages for underwater research. It can be applied directly, and with defined statistical parameters, to reconstructed submerged landscapes and takes maximum advantage of the often intact character of the landscapes and spatial relationships preserved underwater. It can also provide data on site distribution, density, and resource use which is comparable to other submerged localities and to equivalent areas on land. Finally, it is conducive to use in differing environmental settings, and can be operationalized at differing intensities with respect to time and level of funding. It also generates data in standardized chunks, which can be compared and accumulated over multiple seasons of investigations. This final property is particularly important since it allows for

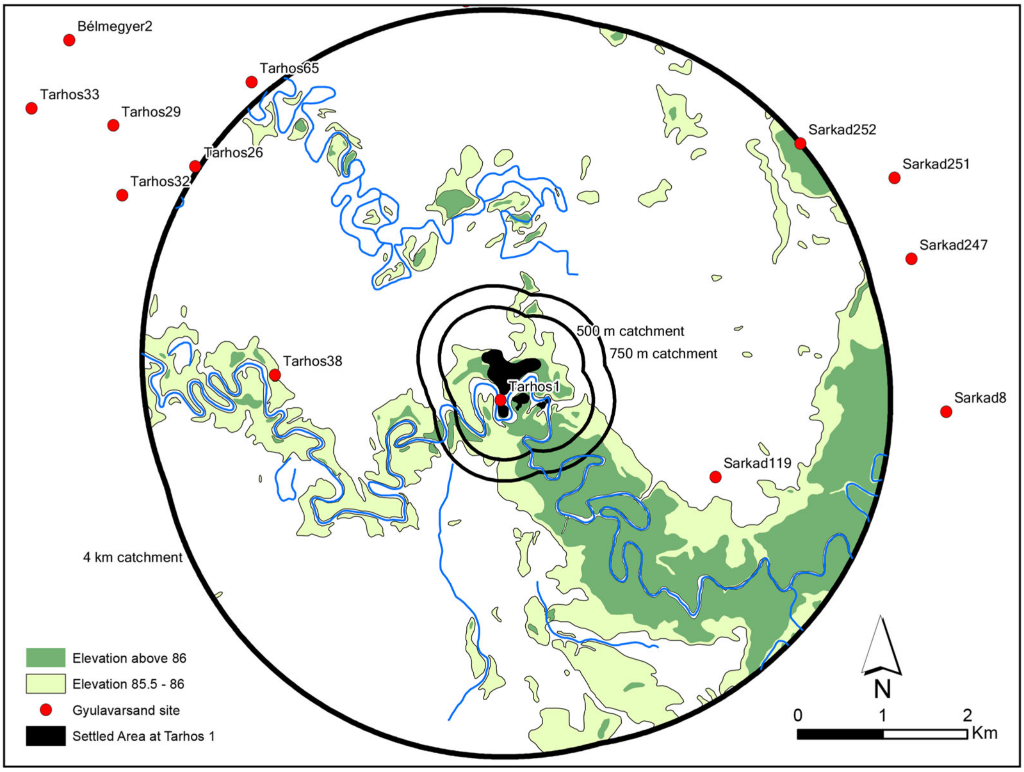

Figure 2. Micro-regional investigations in terrestrial archaeology. In this study of Bronze Age settlement in Eastern Hungary, Duffy (2013) anchored each micro-region on a large tell settlement and then superimposes a series of nested catchments to monitor the distribution of open sites associated with the tell settlements. This example illustrates the distribution of settlements around the tell site of Tarhos 1. Illustration provided courtesy of Paul Duffy.

a layered search strategy and can accommodate differing types of search methods and technologies.

To operationalize a micro-regional approach, it is necessary to identify the size of the micro-regions to be investigated, to determine how many will be evaluated, and how they will be located. For terrestrial research, the size is typically based on the expected scale of the social or economic activities being investigated. This is important, since it requires that the investigator have a model of the targeted land use, settlement, or social phenomenon in mind at the initiation of the study. The same would hold true for underwater research, but the determination must also reflect the size and depth of area that can be investigated in detail given available techniques. The number of micro-regions investigated is primarily a matter of time and funding. Of course, it may be possible to add localities in a multi-season project. The second question is how to locate or anchor the micro-regions. If there are targeted features, such as Faught's quarry sites (2004) or known site locations, these can provide a useful starting point. Another approach is to focus on specific land forms, as might be derived from predictive modeling, to identify localities of expected significance for human occupation (see Pearson et al. 2014). These steps, and the execution of the investigation, are illustrated in the example below.

In practical terms, a micro-regional approach reduces the total survey area, but requires that more intensive search and testing activities be put into the micro-regions. This normally entails a nested set of activities, including the creation of a detailed mapping of the bottom lands area, on to which systematic investigations can be plotted. Specific areas to be examined are then evaluated in detail using remote techniques such as sub-bottom acoustics, coring, and examination via a remote operated vehicle (ROV). These searches are then followed by direct observation by divers or submersibles. This entire range of activities falls within the reconnaissance phase of the research, in which loci of human activity are sought. The intensity of survey and sampling here may depend on the nature of the expected finds and on the time and budgets available for investigation. While nothing in this phase is different in kind from traditional investigations, by limiting the area over which search is undertaken, the same amount of time and effort can produce more detailed results.

Once sites are encountered, their further examination would not differ from traditional approaches; with investigation type and sampling intensity being determined by research questions or the necessary assessments for compliance determinations. But at the end of the process, the finds and features of the individual sites will be systematically embedded within a controlled spatial framework that will permit kinds of rigorous within and between site and region comparisons that would not otherwise be possible.

Micro-regional investigations on the Alpena-Amberley Ridge, Lake Huron

With the final withdrawal of the continental ice sheet, the Laurentian Great Lakes experienced a series of oscillations in water level reflecting the interplay of inflowing glacial melt water and isostatic rebound. The Lake Stanley lowstand (between 10,000 and 7500 cal BP) (Hough 1958; Lewis et al. 2007; Lewis 2016, 192) was some 100 m lower than modern sea level, and exposed more than 250,000 ha of previous lake bottom (Eschman and Karrow 1985, 81). Among the features exposed was the Alpena-Amberley Ridge (AAR), a limestone and dolomite formation which divided the modern Huron basin in two (Figure 3). With the Lake Nipissing transgression, the ARR was again submerged and has never been subsequently exposed.

Since 2008 the AAR has been the focus of archaeological research directed at documenting human use of the region, with a particular emphasis on the potential for seasonal caribou hunting (O'Shea and Meadows 2009; O'Shea et al. 2014; Sonnenburg, Lemke, and O'Shea 2015; Sonnenburg and O'Shea 2017; Lemke and O'Shea 2017, 2019). For the initial work, detailed lake bathymetry was used to model the submerged landforms and on this basis three areas were selected for examination. These areas ranged in size from 56 to 18 km^2, and were placed in three contrasting landscape configurations believed to be suitable for caribou procurement: high ground, a natural choke point, and a water crossing (Figure 3). Once established, the three areas were subject to extensive survey via side scan (SSS) and multibeam sonars. These surveys produced a more detailed view of the topography and landform features, such as lakes and bogs, and also provided the first view of potential stone constructed hunting features. Targets or natural settings of interest, revealed by the preliminary survey, were then more closely investigated via a ROV and if warranted, were mapped and sampled by scuba trained

Figure 3. The Lake Huron basin illustrating the extent of water and dry land during the Lake Stanley low water stage. The Alpena-Amberley Ridge (AAR) is shown as a continuous arc of dry land crossing the lake basin. The initial three research areas described in the text are outlined in red.

archaeologists (O'Shea 2015). To this point, the work on the AAR conformed to the standard, multi-scalar approach to site discovery.

As a result of this preliminary work, a number of likely features were identified, and preliminary samples of cultural materials and environmental indicators were collected. While this initial effort broadly conforms to a micro-regional approach, the effort highlighted two problems. The first was bias in the kinds of sites discovered. Hunting structures, because of their predictable location relative to caribou migrations and their clear

Table 1. Micro-regions on the Alpena-Amberley Ridge.

Micro-region	Location	Setting	Area of investigation	Depth	Comments
Crossing	Area 1	River crossing	150 ha	37 m	Includes potential camp area and drive lines, AUV survey 2018
Dragon	Area 1	Ridge top	150 ha	20 m	Includes at least two complex structure and multiple blinds, AUV survey 2019
Esker	Area 1	Natural funnel/choke point	150 ha	34 m	Previously unexplored, includes multiple drives and caches, AUV survey 2015
North Esker	Area 1	Natural funnel	150 ha	37 m	Previously unexplored, AUV survey 2019
Old Channel	Area 1	Lake shore	150 ha	40 m	Previously unexplored, AUV survey 2019
Overlook	Area 3	Ridge top/choke point	150 ha	37–41 m	Includes at least one complex structure, AUV survey 2015, 2018
Gap	Area 3	Natural funnel	150 ha	32 m	Includes multiple spatial clusters and potential camp area, AUV survey 2018, 2019
Gap Extension	Area 3	Natural funnel	150 ha	32 m	Previously unexplored, AUV survey 2019
Open Plain	Area 3	Open high ground	150 ha	35 m	Previously unexplored, AUV survey 2019

acoustic signatures, were relatively easy to find. Ancillary structures and camp sites were much more difficult to locate and identify due both to their less predictable sonar signatures, and to the fact that they typically would be situated back and separate from the hunting sites. The second problem was the recognition that these areas were simply too large to be investigated in detail. One survey unit, Area 2, also turned out to straddle a main shipping lane on Lake Huron, which posed serious difficulties for anchored operations.

As a result, a series of smaller true micro-regions were defined. These were overlaid on locations within two of the original survey areas where concentrations of built structures had been identified (Table 1). The micro-regions were of comparable size, and were constructed to be large enough to encompass camps and ancillary sites that would not be located immediately adjacent to hunting structure and of a size that could be mapped in greater detail using an autonomous underwater vehicle (AUV). This resulted in a series of boxes of 1000 m by 500 m, although the shape varied depending on the target landform (Figure 4). The initial plan included four micro-regions, and in subsequent years has been expanded to nine. While the initial four micro-regions were anchored to locations with observed stone features, they still reflect diversity in terms of the terrain in which migrating caribou would be sought and as such allow for comparisons between similar and contrastive regional settings (Table 1). In addition to the spatial dispersal of the units, variation in water depth is expected to provide a surrogate for the date (or dates) of sites on the ancient landscape, reflecting the punctuated rise in water levels in the later stages of Lake Stanley. The rising waters will have constricted the lands available for settlement at this time such that shallower micro-regions may contain sites of both earlier and later dates, while deeper areas will only include earlier occupied sites.

Once established, the micro-regions become the focus of more intensive research, beginning with the higher resolution acoustic mapping generated by the AUV, followed by a more concentrated search and examination of potential targets with the ROV, and more intensive archaeological sampling of newly identified features. AUVs have particular potential since they can be flown close to the sea floor and with shorter ranges than normal towed SSS. This produces acoustic images of much higher resolution, which particularly highlight the three dimensionality of the sea floor. The higher resolution acoustic mapping and the smaller area in turn make it practicable to undertake a more

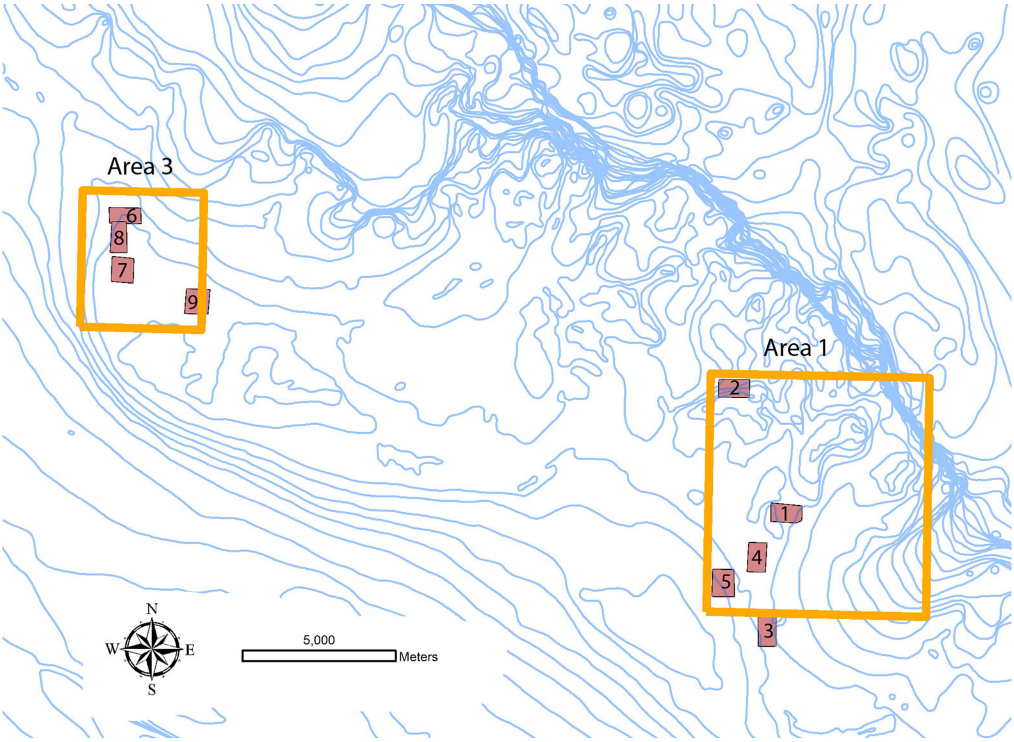

Figure 4. The location of micro-regions on the Alpena-Amberley Ridge. This map shows the central portion of the AAR and two of the initial survey areas (gold rectangles). The location of the nine micro-regions is indicated by solid red rectangles and the numbers in the micro-regions equate with the specific locations described in Table 1. The background contour interval is five meters.

detailed and systematic search for archaeological features (Figure 5). As a result of this effort, a greater variety of site types have been identified and a wider range of material culture associated with the constructed features has been recovered. Initial comparisons between micro-localities has highlighted differences in resource usage and post-depositional histories for differing areas on the AAR, and has also provided preliminary confirmation for the seasonal patterns of caribou hunting (Lemke and O'Shea 2017).

While the work described here is ongoing, future steps for the research can be identified. A limitation of the initial study was that all the micro-localities were tied to areas of known or predicted hunting structures. While this increased the likelihood of encountering sites, an important initial goal, it none the less tended to preclude the discovery of other potential site types associated with differing subsistence or extractive activities (e.g., fishing). In part to address this deficiency, two new micro-regions were initially surveyed in 2019. "Open Plain" was situated in the central portion of the AAR in an area not previously examined and away from known or predicted hunting sites. Micro-region "Old Channel" was located in slightly deeper water in an area believed to be associated with a Lake Stanley era shoreline. As research continues, micro-regions could similarly be placed relative to other environmental criteria focused on other subsistence activities or on other non-subsistence based activities. Likewise, it might be advantageous to located additional micro-region sized units at random on the AAR.

Figure 5. This figure represents a range of activities involved in the documentation of the micro-regions: (A) Recovery of the AUV at the end of a mapping mission; (B) ROV documenting the location of an underwater sample; (C) thru (F) Divers documenting and sampling the submerged environment and sites. (C) measuring the wave length and size of sand ripples; (D) Measuring large boulder component in the Dragon Site blind; (E) Using a portable air lift to collect cultural materials at the Drop45 site; (F) Sample collection at the Funnel Site.

While it might seem counter-intuitive to focus detailed investigations in an area without some specific reason, it would perform the same control function and have the same potential for surprisal, that random sampling does in terrestrial archaeology.

Discussion

Research on the AAR provides two approximations of a micro-regional approach, the initially defined research areas represent comparable localities placed relative to

Table 2. Size and sample fraction of survey areas and micro-regions on the AAR.

Unit	Area km^2	Percentage sample
Full survey area of AAR	845	100%
Area 1	56	6.6%
Area 2	49	5.8%
Area 3	18	2.1%
Areas 1 and 3	74	8.8%
1 Micro-region	0.5	0.06%
Initial 4 micro-regions	2.0	0.24%
Current 9 micro-regions	4.5	0.53%

distinctive large-scaled features of the landscape in a manner not that different from a typical multi-scalar survey. The smaller true micro-regions initially were placed relative to concentrations of previously identified or predicted hunting features or on other fine grained details of the landscape. Table 2 presents the total sample universe for the research, reflecting the portion of the AAR in American waters that is available for testing. The remainder of the rows provides an indication of the size and scale of the various survey units described and the sample fraction they individually and collectively represent. Even combining the larger Areas 1 and 3, the actual sampling fraction is less than the 10% that is often used for initial random sampling in terrestrial surveys, while the sample fraction of the true micro-regions is an order of magnitude smaller. This reflects the inherent difficulties of actually conducting systematic survey underwater, and highlights the fact that simple random sampling in this context is not really viable, except as an adjunct to targeted survey unit placement.

Without a doubt, the implementation of the approach at both scales benefited from the fact that there are identifiable constructed features on the AAR and that the archaeological deposits are not deeply buried by sediments or marine growth. Other high visibility constructed features, such as fishing weirs, may also be found in suitable contexts (see O'Sullivan 2004), but these will be the exception in most settings. Nevertheless, the approach is sufficiently flexible that it can be adapted to less favorable bottom conditions where coring or sub-bottom mapping are critical discovery tools for the initial stage of research.

A micro-regional approach has a number of advantages for both research and compliance efforts. The approach is designed to produce a detailed understanding of activities *within* a micro-region. These include the range of activities and site types present, the spatial relationships between site types and activities, and seasonal and chronological relationships between activities and site types. The approach also facilitates controlled comparisons *between* micro-regions in terms of archaeological comparisons, environmental comparisons, and chronology. Together, these allow for the rigorous testing of hypotheses concerning land use, economy, and organization of past societies, as well as providing a solid and relevant basis for predictive modeling on the larger submerged landscape.

As I hope is clear from the prior discussion and example, the micro-regional approach is not offered as the only or better way to discovery sites. Submerged sites can be found in a multitude of ways both accidental and intentional. Instead, micro-regional survey is a method to sample space, and to parameterize and place into context human activity on a preserved landscape (see Flannery 1976, 132–6). In many ways, the micro-regional approach illustrated here recapitulates the multi-stage strategies employed in terrestrial survey in which an initial low intensity reconnaissance survey precedes a more targeted stratified sampling of the region (see Redman 1973; Judge, Ebert, and Hitchcock 1975). In statistical terms, the micro-regions effectively represent cluster sample units (Banning 2002).

The similarities between the micro-regional approach advocated here and site catchment analysis in terrestrial research is not a coincidence. Both approaches focus on the landscape and the inter-relationships between sites and the relevant local environment. The site catchment approach was initially adopted for understanding economic activities in situations where direct data from site excavation was unavailable (Vita-Finzi et al. 1970). For the underwater case, it maximizes one of the unique assets of submerged landscapes, which is that they often preserve spatial relationships between sites and finds in a way that is rarely found on land. It is also noteworthy that both approaches require the prior development of explicit statements about the relevant size and landscape features that are to be sampled.

While the concept of a micro-regional approach is straight forward, its implementation can present challenges. Perhaps the most significant is how to execute the more intensive local survey and testing that the method requires. In the Lake Huron case, it was accomplished initially by a finer grained acoustic mapping using an AUV. Even leaving aside the precision of AUV survey locations, which varies both on the equipment being used and environmental conditions as the time of the survey, the detailed mapping still left a relatively large area to be examined (Table 2). In theory, the entire area should be systematically tested in the fashion of terrestrial shovel test surveys. This, obviously, could require a huge investment of time and effort, although it can be controlled through the selection of broad sampling intervals. This might also be accomplished via divers (with DPVs), although given greater depths and overburden on the sea floor, initial testing might realistically be limited to sub-bottom imaging and coring. While coring, as has been noted elsewhere, has a relatively low probability of encountering cultural materials (Faught and Smith n.d.), the identification of materials such as micro-debitage (Sonnenburg et al. 2013) can improve the odds. In Lake Huron we adopted a pragmatic approach of examining interesting features and attempting to sample each of the distinct landscapes and landforms represented within the micro-region. This again departs from a purely random or systematic search model, but does allow for most of the benefits of a micro-regional intensive survey to be realized within the limits set by available funds and time.

At the beginning of this paper, five criteria were identified as desirable for a submerged site survey methodology. In terms of the issues introduced at the beginning of this paper, a micro-regional strategy (1) allows for both qualitative and quantitative comparisons between underwater localities, which are directly relevant and comparable to equivalent units on land. The approach, which focuses on a contiguous area, (2) maximizes the advantages inherent to preserved underwater landscapes and can produce detailed data on spatial relationships that are rarely visible on terrestrial sites. Finally, the approach provides (3-4) flexibility to accommodate differing limits of budget, time, and research intensity, and (5) it creates a base of archaeological and environmental data that allows for cumulative development.

Whether adopted as a rigorous statistically relevant method of cluster sampling, or as a conceptual guide to survey and testing, the micro-regional approach forces underwater research to concentrate more on distributions and paleo-landscapes and less on underwater finds as unique and isolated novelties. This shift in focus will enhance the inherent value of our underwater investigations, and will make it considerably easier to link the underwater record with the (sometimes) better known record that survives on land.

Acknowledgements

The approach to submerged landscape sampling described in this paper has grown out of archaeological investigations on the AAR beneath central Lake Huron. The design and execution of the initial surveys was done with Guy Meadows, while the formalization and application of the micro-regional approach was developed in active collaboration with Ashley Lemke and Lisa Sonnenburg. AUV mapping of the micro-regions was conducted with Jamey Anderson. The map in Figure 3 was produced by John Klausmeyer, and the photo mosaic in Figure 5 was created by Ashley Lemke. Archaeological research on the AAR has been supported by awards from the National Science Foundation (BCS-0829324, 0964424, 1441241, 1530628) and from the NOAA OE program (NA10OAR0110187).

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