Refining broad-scale vulnerability assessment of coastal archaeological resources, Lough Foyle, Northern Ireland

Kieran Westley

School of Geography and Environmental Sciences, Ulster University, Coleraine, BT52 1SA, Northern Ireland

ABSTRACT

Increasing evidence indicates that ongoing and future climate change impacts, such as enhanced coastal erosion driven by intensified storms and sea-level rise, will be destructive or problematic for coastal archaeological heritage. Approaches to this problem range from broad-scale GIS-based vulnerability assessments to site-scale monitoring and survey. In all cases, the approach chosen should be based on the best-available data on the local historic environment and pattern of coastal change. Therefore, this paper will demonstrate how such data can be successively acquired and enhanced using an integrated approach that builds on and refines a previously-conducted broad-scale vulnerability assessment. This approach was adopted in the study region (Northern Ireland) owing to a lack of coherent and up-to-date information on shoreline change. This approach incorporated the GIS-based Digital Shoreline Analysis System (DSAS) to quantify and analyse local shoreline change. DSAS is a software extension for ESRI ArcGIS which allows calculation of rate-of-change statistics using past shorelines identified from georeferenced historic maps and vertical aerial imagery. Additionally, a field survey was conducted to assess the condition of recorded sites, and identify unrecorded ones. Results revealed a more complex pattern of shoreline change in the study area (Magilligan Foreland, Lough Foyle) than previously anticipated, with zones of significant erosion interspersed with areas of stability or advance. 51 new sites ranging from the prehistoric period to the Second World War were also identified. The new information
was used to develop a priority classification based on site significance, condition and risk level which improved significantly on the uniform classification of the original broad-scale assessment.

**Keywords:** Coastal erosion; cultural resource management; sea-level rise; climate change; coastal vulnerability

**INTRODUCTION**

Coastal erosion is widely acknowledged as a major threat to archaeological sites and landscapes. Although naturally responsible for the past destruction of countless archaeological remains, there is a growing awareness of the threat and an expectation that it will be exacerbated by future climate change (Erlandson 2008, 2012; Fitzpatrick et al. 2015; Murphy et al. 2009). The driving forces include rising sea-level, melting permafrost (in high latitudes) and potentially changes in extreme events (e.g. storms and coastal flooding), all of which are presently ongoing or predicted to occur over the 21st century (IPCC 2014). The archaeological impact of these changes is well-documented by growing scientific evidence (Daire et al. 2012; Dawson 2015a; Dehn 2014; Fitzpatrick 2012; Ives et al. 2017; Milner 2012; O’Rourke 2017; Radosavljevic et al. 2016) as well as media reports about newly-exposed remains or destruction of known sites (Kennedy 2015; Knapton 2014; Reardon 2011; Rogers 2014; Siggins 2015).

Archaeologists and historic environment managers are therefore faced with the challenge of dealing with this threat and mitigating its impact on valuable, often irreplaceable cultural resources (Dawson 2013; Murphy et al. 2009). Strategies developed in response vary in their method and ambition, and range from relocation, protection, or rescue excavation of
single important sites (Dawson 2015b) to broad-scale vulnerability assessments (Reeder-Myers 2015). In between lie a spectrum of approaches which variously utilize remote sensing and GIS (Radosavljevic et al. 2016; Reeder et al. 2012; Westley et al. 2011; Westley and McNeary 2014), professional field survey (Daire et al. 2012), community-based monitoring (CITIZAN 2017; SCHARP 2017), or some combination thereof (Dawson 2015b; Robinson et al. 2010). Whether or not there is a single ‘right’ approach is an open question and, more likely, the most appropriate response will depend on the nature and magnitude of the threat locally, the nature of the local archaeological record, the available baseline data (both archaeological and environmental) and available personnel, whether they be trained specialists or a willing and concerned local community.

Nevertheless, whatever approach is adopted, decision-making should be based on the best-available evidence. This places the onus on heritage managers and archaeologists to understand both the nature of the archaeological record in their area of responsibility (e.g. site location, site and landscape types, preservation potential) and the pattern of coastal change rather than being guided by anecdotal accounts of erosion or perhaps media reports of single high profile incidents.

This is made easier where there is secure knowledge of coastal archaeology gained from systematic survey coupled with extant and up-to-date information on shoreline change, for instance, derived from regional to national-level management programs which quantify coastal hazards. Good examples of such practice can be found in the British Isles. In Scotland, Coastal Zone Assessment Surveys (CZAS) conducted between 1996-2011 covered 40% of the country’s coastline and combined historic environment record enhancement with assessment of erosion from both desk-based and field survey (Dawson 2015a; SCHARP 2017). Survey results allowed prioritization of sites based on their vulnerability (Dawson 2013) while a
successful community-based program (Shorewatch, now superseded by SCHARP) has made possible long-term monitoring and site discovery (Dawson 2015b; SCHARP 2017). Vulnerability assessment will probably also be enhanced in the immediate term with the recent completion of a National Coastal Change Assessment (NCCA) covering the entire county (NCCA 2017). England has a similar program of Rapid Coastal Zone Assessment Surveys (RCZAS) ongoing since 2000 which also use a two-phase approach of initial desk-based assessment followed by field survey (Heathcote et al. 2017; Murphy et al. 2009). Estimates of vulnerability are then primarily obtained by examining RCZAS results in the context of national-level Shoreline Management Plans (SMP2) which include estimates of erosion from the Environment Agency’s National Coastal Erosion Risk Map (NCERM) (Environment Agency 2017). This has recently been supplemented by the CITiZAN community-based monitoring and recording project (CITiZAN 2017). Wales completed systematic archaeological surveys of its coastline by the late 1990s (Davidson 2002), and is included within the SMP2 and NCERM programs that also cover England. The recently initiated CHERISH project, which covers the Irish Sea region and aims to assess, locate and monitor coastal and submerged heritage assets, will also further enhance understanding of vulnerability in Wales (CHERISH 2017).

The situation is different for the island of Ireland, including both the Republic of Ireland (ROI) and UK devolved administration of Northern Ireland. Broad systematic survey of the coastal historic environment has not taken place in either region. Instead, the emphasis has been on focused in-depth studies of selected high potential regions, namely the Shannon Estuary (O’Sullivan 2001), Strangford Lough (McErlean et al. 2002) and Rathlin Island (Forsythe and McConkey 2012). In the Republic of Ireland, this will be partly redressed by the aforementioned CHERISH project which spans the Irish Sea and covers Ireland’s south and east coasts (CHERISH 2017). Additional supporting data for the Republic of Ireland also comes from
the Irish Coastal Protection Strategy Study (ICPSS) which has assessed coastal erosion hazard at a national level (OPW 2017). In contrast, Northern Ireland has been hampered by a lack of strategic coastal management (Cooper et al. in press) and consequently, has no up-to-date national-level overview of coastal erosion. Research into coastal change has been focused on specific study areas (e.g., Carter and Bartlett 1990) and the only extant province-wide assessment of vulnerability was done at a relatively low resolution and has not been updated since the early 2000s (McLaughlin 2001; McLaughlin and Cooper 2010).

The lack of an up-to-date and uniform baseline for both coastal erosion and the historic environment in Northern Ireland was therefore the impetus to design a broad-scale first-pass assessment of coastal archaeological vulnerability from scratch (Westley and McNeary 2014). This was based on examination of oblique aerial photographs and, while it did provide a measure of generalized risk levels across the Northern Ireland coastline, there remained uncertainties in its accuracy. More specifically, the broad-scale approach took no account of local variation in erosion rates, the resilience of a given site to erosion or the accuracy of the recorded site location. Consequently, a pilot study focussing on a small study area was commissioned by the provincial historic environment manager (Historic Environment Division, Department for Communities) to assess and improve on the accuracy of the broad-scale assessment and thus allow for development of locally appropriate mitigation.

This paper will discuss the approach and results of this pilot study. In so doing, it will provide an example of how baseline information on the archaeology and coastal environment of a given area can be successively acquired and enhanced. In keeping with work done elsewhere in the British Isles, the approach is an integrated one using both desk-based assessment and field survey. The key difference with previous work (e.g. Scottish CZAS, English RCZAS) is that the desk-based assessment incorporates additional quantification of coastal
change via analysis of historic maps and recent aerial orthophotos. Although these data sources have been used in previous CZAS and RCZAS, this has been in a qualitative rather than quantitative fashion (e.g., Hambly et al. 2010; Pink 2016). In the context of Northern Ireland, quantification was necessary given the absence of up-to-date baseline data on shoreline change.

**STUDY AREA BACKGROUND**

The study area is a 10km-long stretch of coastline between the Roe Estuary and Magilligan Point on the eastern shoreline of Lough Foyle, a semi-enclosed marine embayment straddling the border between the Republic of Ireland and Northern Ireland (UK) (Figure 1). This forms the western side of Magilligan Foreland, a triangular beach ridge and dune plain which accumulated between c. 7000-600 BP (Wilson 2002; Wilson and Farrington 1989). The studied shoreline comprises a sandy beach or intertidal flat generally backed by an unconsolidated sand cliff between 3-5m high. The cliff top is grassed over, while the vertical face backing the beach is often un-vegetated and exposed. The cliff itself comprises the remains of mid-late Holocene (c. 5000-2500 BP) beach ridges which were subsequently covered by dunes from c. 1200 BP onwards (Wilson 2002). The shoreline is linear and broken only by a handful of small southeast-northwest-aligned streams. Shore defences are absent apart from a seawall at Magilligan Point.

The study area was chosen because the aforementioned Northern Ireland-wide broad-scale vulnerability assessment identified it as having the highest level of coastal erosion in the province (Westley and McNeary 2014). This was based on interpretation of oblique aerial photographs which showed an exposed and unvegetated backshore along almost the entire study area, often with slumped deposits suggestive of active, or at least former, erosion
(Figure 2). The first-pass assessment also identified from the extant provincial Historic Environment Records (HERs) that 16 archaeological sites were at risk of erosion (Figure 3; summary in Supplemental Table 1). These comprise seven Second World War (WW2) sites (recorded in the Defence Heritage Record [DHR]), one industrial-era site (recorded in the Industrial Heritage Record [IHR]), and eight older archaeological sites (recorded in the Sites and Monuments Record [SMR]). This latter group included four Iron Age-Early Christian (c. 2500BP-800 AD) shell middens found eroding out of the backshore sand cliff during the 1980s (Mallory et al. 1984, 1988) and three burials/findspots of human remains.

Using the first-pass assessment methodology, all 16 sites were judged to be risk of erosion within the next 50 years, based on crude extrapolation from averaged provincial erosion rates (Westley and McNeary 2014). Given the uncertainties in the method (see above), this gave no further guidance beyond identifying that the erosion risk was higher than elsewhere in Northern Ireland and that proportionally many sites were at risk.

**METHODOLOGY**

The additional work took the form of an integrated project incorporating both new desk-based assessment (DBA) and systematic field survey.

**DSAS Desk-Based Assessment**

The aim of the new DBA was to quantify local shoreline change and thus more accurately characterize present-day patterns of erosion and, if possible, allow prediction of future trends and likely impact on sites inland of the present shoreline. This was done digitally in a Geographical Information System (GIS) environment (ESRI ArcMap 10.3.1) using the freely available Digital Shoreline Analysis System tool (DSAS: Thieler et al. 2009). DSAS is a software
extension for ESRI ArcGIS v. 10 developed by the United States Geological Survey (USGS) and allows calculation of rate-of-change statistics using historic shoreline positions identified from georeferenced datasets such as historic maps, aerial photos and digital elevation models. The core method involves casting a series of regularly-spaced transects from a user-generated baseline. These transects intersect digitised representations of historic shorelines and, given knowledge of the date of these shorelines, intersection positions can be used to calculate rates and magnitudes of shoreline change (Thieler et al. 2009). Further details on the calculated statistics are presented below. Based on the published literature, DSAS has seen extensive use for coastal management purposes over the past 2 decades (e.g., Ford 2013; Hapke et al. 2006; Kabuth et al. 2014; Theiler and Danforth 1994) and, in more recent years, has been applied to vulnerability assessments of the coastal historic environment (e.g., Maio et al. 2012; O’Rourke et al. 2017; Radosavljevic et al. 2016).

Historic shorelines for the study area were compiled from two sources: historic maps and vertical orthophotos. Historic maps comprised Ordnance Survey (OS) County Series 6-inch-to-the-mile maps (equivalent to 1:10,560 scale) which were periodically re-surveyed at irregular intervals during the 19th and early 20th Centuries. Although, the entire study area is covered by the 1st (dated 1830) and 4th Editions (dated 1923) maps, only the 4th Edition is used here owing to uncertainty regarding the depiction of the shoreline on the 1st Edition, specifically whether it represents the coastal edge or High Water Mark. The feature chosen as representative of the historic shoreline on the 4th Edition was the High Water Mark (HWM). Vertical orthophotos were collected by the Ordnance Survey of Northern Ireland (OSNI) as part of a countrywide mapping programme (NI Direct 2017a). The orthophotos covering the study areas comprise 4 rounds of repeat imagery taken on a 3-year cycle from 2003-2013 (Table 1). The feature chosen as representative of the digitized shoreline was the vegetation
line separating the beach from the vegetated backshore. An additional modern shoreline proxy – the 1:2500 High Water Mark – was also used for comparison with the historic maps. This is derived from the continually updated OSNI Large Scale Vector dataset (NI Direct 2017b).

Shorelines digitized from these sources were input into a GIS project and, using DSAS, rate-of-change statistics were calculated along virtual transects spaced every 20m. This spacing ensured even coverage along the study area and broadly perpendicular intersection with all digitized shorelines.

The following comparisons were made:

1) Fourth Edition historic map versus modern High Water Mark: This provides an estimate of 20th Century shoreline change from 1923 to 2017, and hence the long-term trend for the study area.

2) Orthophoto V1 versus V4: This provides an estimate of shoreline change within the last 15 years. Note that individual successive shorelines were compared (e.g. V1 vs. V2, V2 vs. V3 etc.) as well as a comparison which included data from all 4 shorelines (i.e. V1 to V4).

In each comparison, both Net Shoreline Movement (NSM) and End Point Rate (EPR) were calculated. NSM represents the distance between the oldest and youngest shoreline while EPR represents the rate of shoreline movement as calculated from the oldest and youngest shorelines. An additional Linear Regression Rate (LRR) was calculated for the comparison that included all 4 orthophoto shorelines. This latter calculation uses all shorelines (regardless of accuracy), not just the oldest and youngest to estimate a rate of movement. Since it needs at least 3 shorelines to work, it could only be used for the orthophoto-based comparison (Himmelstoss et al. 2009).
Mapping shorelines from cartographic and photographic sources involves a degree of uncertainty. This encompasses a range of variables including the accuracy of the source data, the resolution of the source data (pixel error), rectification errors relating to geo-referencing and the precision of the shoreline digitizing process (Anders and Byrnes 1991; Moore 2000; Radosavljevic et al. 2016; Romine et al. 2009). Uncertainties relating to the source data used here were estimated as follows.

The orthophotos were supplied ready-to-use as georeferenced digital data with distortions caused by camera tilt and topographic relief removed (NI Direct 2017a). Since these data represent the base layer for the GIS project (i.e. effectively the baseline map), they do not need to be rectified and hence have no rectification error. There is however a minor pixel error: the orthophotos have a resolution of 0.25m and therefore features smaller than this cannot be resolved. Similarly, the 1:2500 High Water mark was supplied already georeferenced and, since it represents part of the countrywide base mapping, has no rectification error. Moreover, as these data were supplied in vector format, there is no pixel or resolution error.

The historic maps were also supplied as geo-referenced raster data. However, on inclusion into the GIS project it was found that there were positional errors in comparison to the orthophotos. This required a bulk shift of the entire map tiles of c. 6.8m, based on the position of two base towers depicted on the maps that were used by the original OS surveyors and which are still visible on the orthophotos. Once shifted, correspondence with the base orthophotos was good, with rare variation of up to 5m between common features visible on the orthophotos and depicted on the maps (e.g. road and rail intersections, bridges). This value encompasses an estimate made by Carter and Bartlett (1990) who noted that shoreline features on the OS 6-inch maps could not be located to within 2-3m due to inaccuracies in the
original survey. A resolution error is also present in this data due to the thickness of the line depicting the historic HWM. At the scale of the maps, it equates to c. 5m. Therefore, for this study, a value of 10m was used as an estimate of the positional error inherent in the historic maps encompassing both resolution and georeferencing errors.

To overcome digitization errors, shoreline digitization was done at large spatial scales (1:500) to follow the chosen shoreline proxy as closely as possible. In addition, 3 shorelines were digitized over the same sample area of coastline (chosen to encompass both linear and more convoluted shorelines types). The distance between these digitized shorelines was measured along perpendicular transects spaced every 2m and the average distance used as an estimate of the digitizing error (see Radosavljevic et al. 2016 and Romine et al. 2009 for similar approaches). This resulted in an additional digitization error of 0.7m for the orthophotos and 0.6m for the historic maps (see Table 1). The higher value for the orthophotos is because there are occasional areas where the coastal edge is in shadow thus making the vegetation line hard to discern. As the modern HWM was supplied in vector format, no digitization was necessary. The sum of the errors then provided the total uncertainty which was in turn used by DSAS to calculate confidence intervals for the EPR estimates.

**Field survey**

Fieldwork comprised a comprehensive walkover survey conducted by a team of 2, and timed to coincide with low tide. Given the remit of the project to investigate coastal erosion, the focus of the survey was on the eroding backshore and adjacent beach close to high water mark. While some features were noted on the intertidal sandflats which form the lower part of the intertidal zone (see results section), these extensive areas were not systematically
walked in contrast to the upper part of the beach and backshore. Observations of coastal
gemorphology, erosion and any anthropogenic/archaeological material were noted on
proforma sheets and positions recorded using a handheld GPS. The condition of all
archaeological sites/material encountered, including both previously- and newly-recorded
ones, was also noted. Geotagged photographs of archaeological features and representative
coastal geomorphology were also taken. All the above data was then incorporated into the
GIS project to allow direct comparison with the desk-based assessment.

RESULTS

DSAS Desk-Based-Assessment

The DSAS statistics are summarized in Table 2 and confirm both historic and ongoing coastal
retreat. However, they also show that some areas appear to be advancing rather than
retreating.

Long-term retreat was the norm during the past Century (c. 1923-2017) with 94% of transects indicating retreat of the HWM. The exception is the most southerly part of the study area at the mouth of the Roe Estuary (Figure 4a). Rates of retreat are significant, with most areas apparently showing retreat of more than a few tens of centimetres per year with localized increases up to -1.6m/yr. These values are generally greater that the Estimated Confidence Intervals calculated by DSAS (ECI: Table 2) based on the total error estimates shown in Table 1. This suggests the identified patterns are genuine and are not entirely the product of uncertainties in mapped shoreline position.

Recent comparisons between vertical orthophotos (V1 to V4 comparison) taken within the last decade indicate a general trend of retreat with 75% of transects suggesting erosion (Table 2 and Figure 4b). Rate-of-change statistics accounting for all 4 rounds of orthophotos
(LRR calculation: Table 2) suggest average rate of retreat of a few tens of centimetres per year, increasing locally up to -4.6m/yr, but also with localized advances up to c. 3.4m/yr. These orthophotos also reveal a more complex pattern of change than suggested by the long-term 20th Century trend in that zones of erosion are interspersed with zones of advance. Comparison between individual orthophoto rounds (i.e. at 3-year intervals) substantiate this in that average EPRs fall between -0.3 to -1m/yr and between 63—77% of transects show erosion (Supplemental Figure 1). As with the historic map comparison, the majority of EPR values are greater than the calculated ECI values (Table 2) substantiating the view that the identified patterns are genuine.

The orthophoto-based comparisons also highlight the episodic and variable nature of shoreline change in that maximum retreat rates of -4 to -21.1m/yr can be observed along with advance of up to 8.6m/yr (Table 2). These largest values have been checked and found to be genuine movement of the vegetation line. Areas of largest advance seem to result mainly from re-vegetation of talus accumulated in front of eroded scarps. The area of largest retreat, seen between the V3 and V4 orthophotos, involves an area of marsh at the southernmost end of the study area. Field survey suggests that this could be the result of the seasonal dieback/reduced growth of vegetation rather than actual retreat. Significantly though, there are other areas where the backshore scarp has clearly retreated by tens of metres within the past decade (Figure 5).

To give further confidence in the DSAS estimates, they were compared with previous published measurements of shoreline change from this area. Carter and Bartlett (1990) estimated average movement of -0.75m/yr (varying alongshore by -0.57-0.93m/yr) from 1833-1966 from historic maps and -0.84m/yr (varying alongshore from -2.1 to +1.7 m/yr) between 1949-80 based on aerial photos and ground surveys. Carter and Stone (1989), based
on aerial photos alone, estimated persistent and spatially consistent retreat of c. -1.2 m/yr since 1949. These values compare reasonably well with the DSAS historic to recent EPR and recent EPRs (Table 2). Overall, together with the ECI values, this general correspondence with previous research gives confidence that the DSAS estimates are reasonably accurate or at least represent the best-available estimate of local shoreline change.

Field survey results

Clear evidence of recent erosion was observed by the field survey in the form of exposed backshore faces showing mid-late Holocene peat and palaeosol deposits and topsoil blocks, fence posts or concrete slabs toppled from the cliff top (Supplemental Figure 2a-c). Although these features were relatively common, they were interspersed with areas of apparent stability, typified by a vegetated backshore slope or accumulation of sand talus deposits up to 3m high at the cliff base (Supplemental Figure 2d).

Field survey also recorded 50 new findspots of anthropogenic material (Figure 6; Supplemental Table 2). Much of the material is described as anthropogenic because there is doubt regarding its archaeological significance. For instance, the most common find types were spreads of concrete, brick, building stone and metal rubble distributed along the foreshore or backshore (Supplemental Figure 3a). All of the constituent material appeared to be 20th Century in date. Their position along the shoreline, particularly in areas of apparent erosion, suggests that they were created as unauthorized attempts to halt coastal retreat. However, the quantity of dumped building material, including features such as large concrete slabs, metal-reinforced concrete and large concrete posts, is at odds with the sparsely populated rural landscape, and it is possible that at least some of it comprises dismantled structures dating from the Second World War. This is suggested by the fact there is clear
evidence of WW2 defences along this stretch of foreshore (Supplemental Table 1), and that there was significant military activity in the form of four presently disused military airfields (Limavady, Ballykelly, Eglinton, Maydown) and a military base (Magilligan Point) within the general environs of the study area (Blake 2000; Figure 1).

Other relatively recent structures or features include rubble dykes (which first appear on the OS 3rd Edition [1904] map and may be related to 19th Century land reclamation south of the Roe Estuary) (Supplemental Figure 3b), paths/roads, various wooden posts and possible concrete structures (Supplemental Figure 3c). These include extensive alignments of regularly-spaced wooden posts embedded in the intertidal sandflats (Supplemental 3d; e). These are not previously recorded and, based on their appearance and arrangement, they are likely the remains of Second World War defences, placed to prevent landing of troops either by sea or glider. This is substantiated by the fact that the wide sandy beaches of the north coast of Northern Ireland were regarded as vulnerable locations for landing when the threat of German invasion was at its height in 1940 (Blake 2000). Similar features have been recorded elsewhere in the UK by the Defence of Britain Project (Council for British Archaeology 2007) and three other sites are known elsewhere in Northern Ireland (McErlean et al. 2002; NI SMR 2017). Though cut down from their original height, the individual posts are present in sufficient numbers such that the overall shape and extent of the defensive alignment remains clear.

At the other end of the archaeological timescale are 13 lithic findspots of between 1-4 individual flints either eroding out of the sand cliff or lying loose on the foreshore (Supplemental 3f; Supplemental Table 2). None are diagnostic and can only be attributed to the general prehistoric period (c. 9800-2500 BP). However, they suggest a hitherto unrecognised prehistoric use of this landscape given that the extant HER comprises only two
standing stones on Magilligan Foreland and a single Bronze Age flint scatter located c. 3km inland of the eroding shoreline. Therefore, the lithics located by this survey clearly indicate prehistoric use/occupation of the area around the modern shoreline. Other than the four previously recorded shell middens (Supplemental Table 1), the only other findspot of predating the modern era comprises a few small ceramic sherds, of Early Medieval appearance (c. 400-1100AD), which are supplemented by an unpublished collection of 40 similar sherds found by amateur collectors, from broadly the same location. The likely age of these supports the previously documented use of this landscape during this period (Mallory et al. 1984, 1988).

The field survey also described the condition of each newly discovered site and provided updated condition assessments for 9 of the previously recorded HER sites (Supplemental Table 1). The majority of the newly recorded sites (45) are rated as being in poor condition given that they are heavily broken up, or eroded out and no longer in situ (Supplemental Table 2). Sites in moderate condition include the possible World War 2 anti-landing poles on the intertidal sandflats which though cut down and exposed, are still in situ. Other exceptions include the possible reclamation dykes (immediately north of the Roe Estuary), the reason being that their original shape and alignment (based on the historic maps) still appears to be preserved.

Of the previously recorded HER sites, at least seven appear to be destroyed. These comprise four shell middens, two burials and one pillbox. No evidence fitting the description of either the middens or burials was observed during the field survey. This is unsurprising given that the sites were already at risk when originally documented (Supplemental Table 1) and, based on the DSAS analysis, are situated in areas which have suffered recent and historic erosion (Figure 4). However, deposits of shells were exposed by erosion in two locations close
to the recorded middens, roughly 2-4m up within the backshore sand cliff. These lacked clear evidence of human action (e.g. artefacts, charcoal concentrations) but were sufficiently elevated to question whether they were deposited by natural processes such as storms. Therefore, it is possible that they are an expression of human activity, perhaps from the same period as the now-destroyed middens. One of the remaining two sites is in poor condition; defensive beach scaffolding visibly eroding out and broken up by waves and tides. However, the other is in good condition. This is a recorded pillbox at Magilligan Point (Supplemental Table 1). This latter site is almost totally intact and has survived due to its position amid rock armour protecting a modern ferry terminal.

**DISCUSSION**

The intention of this study was to demonstrate an example of 1) how baseline information on historic assets and coastal change can be successively acquired and enhanced and 2) how this in turn alters the assessment of vulnerability. Therefore, the following discussion will first examine each approach in turn, with particular reference made to improvements on the original first-pass assessment (Westley and McNeary 2014). Then the new data derived from each approach will be used to produce a revised vulnerability assessment which prioritizes sites for attention.

**DSAS Desk-Based Assessment**

Use of the DSAS tool directly addresses one of the main disadvantages of the original first-pass assessment; namely that it comprised only a snapshot of the situation at the time of survey and could not quantify shoreline change. In doing so, it also highlights the complexity
of change along the study area and allows identification of particularly sensitive zones of high retreat.

This was expressed clearly by recent shoreline movement rates which showed both advance and retreat within the study area (Figure 4b; Supplemental Figure 1). This complexity mirrors patterns elsewhere in Ireland with examples of steady regression (particularly on the Irish Sea coast) versus cyclic patterns of erosion/accretion in response to fluctuations in sediment supply and energy level (particularly on the Atlantic coast) (Cooper 2013). Marine embayments such as Lough Foyle are regarded as having particularly site-specific patterns of shoreline change which are influenced by local sediment availability, pre-existing topography and exposure to waves and tides (Cooper 2013). In this case, the observed variation can be attributed to protective features such as drapes of toppled vegetation or sand talus deposits which temporarily halt erosion (Supplemental Figure 2a; 2cCarter and Stone 1989), resulting in spatio-temporal variation in shoreline movement within an overall trend of progressive retreat (Cooper and Gault 2002). Importantly, from the standpoint of assessing the vulnerability of the coastal historic environment, there are clear zones of significant and consistent retreat, as shown by both the recent LRR and EPR results (Table 2; Figure 4; Supplemental Figure 1). For instance, areas of particularly severe retreat coincide with the previously recorded midden sites (Figures 5 and 6; areas 1 and 2; Mallory et al. 1984; 1988). This strongly supports the premise that these assets are now completely destroyed.

Quantification of shoreline retreat also allows an estimate of likely time until destruction for sites located inland of the backshore edge. However, this should be taken with the caveat that it is simply extrapolation of presently-observed retreat rates rather than a predictive model incorporating applicable local variables (e.g. wave and sediment characteristics: Splinter et al. 2014). In this case for example, the previously-recorded WW2 lookout post (DHR
481: Supplemental Table 1) is presently situated c. 30m inland of an eroding shoreline. The closest DSAS transects show retreat rates of -1.2 to -1.5m/yr. If this trend continues, then the asset will be at risk of destruction in 20-25 years. Conversely, the previously recorded pillbox (DHR 77: Supplemental Table 1) despite its location directly on the shore, is not presently at risk due to the surrounding rock armour, and unless conditions change, is probably not at future risk given that the DSAS statistics indicate that this area is very stable (LRR = 0.01m/yr).

**Field survey**

Like the first-pass assessment, a single field survey in isolation will provide little predictive ability or quantification of change over time. However, it still remains the best means of gaining accurate and up-to-date observations of site condition and potential threat (Daire et al. 2012), identifying previously unrecorded sites including ones revealed by erosion (Dawson 2015a) and, in some instances, confirming site locations which are not always accurately recorded in HERs (Westley et al. 2011).

The first two aspects were true of this study. For instance, a more up-to-date assessment of previously-recorded sites’ condition was possible and included confirmation that 7 sites were now probably destroyed (4 middens, 2 burials/findspots of human remains, 1 pillbox: Supplemental Table 1). With respect to the identification of new sites, many were not detectable by desk-based/remote sensing assessment because of the small size of the artefactual evidence. This is most apparent for the lithic and ceramic findspots, but even the extensive Second World War anti-landing poles are not visible on most of the orthophotos either due to high tide or sand cover, or the inability to distinguish a wooden post from a natural feature. Thus, the only way these could be identified and recorded was by field survey. Overall, the provision of up-to-date data improved considerably on the first-pass assessment.
which was based on HER records that, in some cases, had not been updated for at least 30 years.

**Revised vulnerability assessment**

One conclusion drawn from existing research on the impact of climate change, coastal erosion and sea-level rise on the historic environment is that not all sites can be saved (Heathcote et al. 2017; Murphy et al. 2009). Therefore, it is important that vulnerability assessments provide a means for historic environment managers to prioritize attention towards certain sites, landscapes or regions (e.g. Dawson 2013; 2015a; Reeder-Myers 2015; Robinson et al. 2010; Westley et al. 2011). In this study, the DSAS and field survey results were combined to provide an estimate of vulnerability, which could in turn be used for prioritization. This was based around 3 categories: significance, condition and risk.

Significance was judged on the basis of the historic asset’s rarity, period, potential to contribute to knowledge and group value, for instance whether it is an isolated example or part of a wider grouping. This encompasses several criteria used when considering legal protection for the UK historic environment (Dawson 2013; DCMS 2013). Condition was based on the physical appearance of the site as assessed by the field survey. For inland sites which were not surveyed, their physical appearance was based on the orthophoto evidence (if visible) and extant HER records. Sites regarded to be in good condition appear largely intact and undamaged. Conversely, sites in poor condition are broken up, damaged or eroded out of context. Finally, risk was based on the field survey combined with DSAS results. High risk sites are those which are 1) exposed in the intertidal zone (i.e. continuously impacted by waves and tides); or 2) located in exposed backshore sections where DSAS results indicate ongoing erosion; or 3) located inland of the backshore edge, but based on DSAS results are predicted
to erode in <5 years. Moderate risk sites are those located inland of the backshore edge, but based on DSAS results are predicted to erode in 5-10 years; while low risk sites are similar but predicted to erode in >10 years. Similar application of coastal change rates based on a DSAS-style methodology have been used for prioritization by Robinson et al. (2010) for coastal Georgia (USA), though the precise categories differ from those adopted here.

Sites were accordingly ranked on a scale of 1 to 3 (effectively low, moderate and high respectively) in each category and the cumulative value used to provide the final vulnerability estimate. Effectively, the highest priority sites are high significance sites in good condition but at high risk from erosion. Conversely, the lowest priority sites are low significance sites in poor condition, and at low risk from erosion. Based on the results here it is suggested that any site scoring ≤5 would be regarded as low priority, given that this could include a low significance site in poor condition but at high risk. Anything scoring ≥8 would be regarded as high priority given that it must have a score composed of at least 2 high and 1 moderate categories. It must be stressed that this is a subjective classification, and different researchers might classify each individual site differently or indeed develop classification schemes more applicable to their own study area and/or approach (e.g. Daire et al. 2012; Dawson 2015; Hutchings 2017).

Based on this ranking, out of the total of 67 sites in the area (including new and previously recorded ones), the majority are at high risk (84%), but are of low to moderate significance (54% and 42% respectively) and are mainly in poor condition (87%) (Table 3). This results in a final vulnerability assessment which identifies a majority of low priority sites (60%) and only a handful of high priority sites (3%). This contrasts with the first pass assessment which simply identified 16 sites which were of equal priority (Westley and McNeary 2014).

Sites which are regarded as high priority are the WW2 anti landing defences because they relatively rare (in a provincial context), are good examples of formerly extensive
defences, remain *in situ* (albeit cut down) and are at high risk due to their position in the intertidal zone (Figure 7). Moderate priority sites are dominated by the findspots of prehistoric to early Medieval material situated primarily towards the northern and southern parts of the study area (Figure 7), which are at risk considering their position in eroding backshore sections or the intertidal zone, and while in poor condition (e.g. single isolated findspots), do have moderate significance through their group value. In this case, the multiple findspots of similar age provide evidence of the human use and occupation of this landscape which is otherwise invisible due to a relative lack of recorded upstanding monuments or excavated sites. Finally, the large numbers of low priority sites reflects the fact that much of the material documented on this coastline is in poor condition, broken up and, while at risk due to its location, has probably been dumped in the recent past.

**Synthesis**

The research presented here shows that the original broad-scale first pass assessment (Westley and McNeary 2014) was only partly correct. The original interpretation was one of total erosion across the study area. However, new field observations and desk-based assessment indicate a more complex mosaic of shoreline advance and retreat; including areas which are apparently stable, within a general trend of long-term 20th Century erosion (Figure 4). Therefore, while the first-pass assessment captured the general situation, the new approaches have added a greater degree of nuance and detail.

The general picture is now of a coastal landscape which is highly sensitive to erosion. From a historic environment standpoint it is clear that there are more archaeological sites within the study area than previously recorded, and that many of them are at risk. However, the overall vulnerability of the area is generally low to moderate due to the poor condition
and/or low significance of the most of the recorded assets (Figure 7; Table 3). This is not to say that as-yet undiscovered significant sites are not present in the study area. The possibility that such material could be revealed by future erosion cannot be excluded, therefore the identification of particularly sensitive areas (e.g. Figure 4: areas 1 to 6) by the DSAS analysis could help pinpoint locations where repeat monitoring surveys can be focussed.

In terms of the relative merits of the methods used here, while the DSAS assessment was capable of improving on the first-pass assessment, field survey was still found to be essential. First, it was the only means of obtaining up-to-date information at a site-scale and second, was the only means of identifying new sites revealed by erosion. Therefore, while it might be tempting to advocate desk-based assessment as a rapid and cost-effective method of managing the impact of coastal erosion on archaeological sites (e.g., Westley et al 2011; Reeder et al. 2012), this study and the first-pass assessment have shown that there is often much uncertainty in the extant archaeological (location, condition, numbers of sites) and environmental data (e.g. locally applicable erosion rates) which limit its effectiveness. This is not to say that desk-based assessment has no part to play, but it is perhaps most effectively used as part of an integrated approach. In any case, both the desk- and field-based methods described here are relatively straightforward and could be readily incorporated into broader programs of coastal research. In particular, use of the DSAS-type methodology would be applicable in areas lacking baseline data on shoreline movement, and would also take advantage of the increasing availability of high-resolution aerial or satellite imagery from global providers such as Google Earth or national-level mapping agencies. Moreover, as identified by O’Rourke (2017), use of recent imagery taken over shorter time intervals, as done here, would allow increased ability to assess the impact of short-term high impact events (e.g.
storms) whose effect might be otherwise underestimated if using historic imagery and longer (e.g. decadal) time intervals.

CONCLUSION

This study set out to demonstrate the refinement which could be made to a broad-scale first pass archaeological vulnerability assessment using a combination of new desk-based assessment and field survey. The evidence above indicates that, for the study area, the first-pass assessment provided a basic, but not totally accurate, vulnerability assessment. The level of accuracy was sufficient to prioritize work on a provincial level and to provide a baseline on which more detailed assessments can build (as done here; see also Dawson 2015a), but it was insufficient to allow site-level prioritization or mitigation. From this standpoint, the first-pass assessment works as intended, and provides a good example of how broad-scale overviews can provide the initial basis for managing the impacts of climate change and coastal erosion and creating a foundation for more detailed follow-up work (see also Reeder-Myers 2015).

The integrated desk- and field-based approaches used here have built on this foundation. The DSAS analysis highlighted that spatio-temporal variability in shoreline change with identifiable zones of significant retreat characterizes the study area. The field survey provided condition assessments for existing sites, and also identified numerous unrecorded assets. Combining the two approaches has resulted in a new vulnerability assessment for the study area which uses significance, condition and risk to prioritize sites for attention. Ultimately, greater understanding of the level of detail or data provided by different approaches to coastal vulnerability assessment can help historic environment managers to refine their knowledge of risks to coastal heritage and in turn direct resources appropriately, sustainably and effectively.
ACKNOWLEDGEMENTS

All research presented here was supported by the Historic Environment Division, Department for Communities (formerly the Northern Ireland Environment Agency: Historic Environment Division); thanks in particular to Rhonda Robinson, Claire Foley and Rory McNeary. Thanks also to Sandra Henry for assistance with the field survey and Brian McNaught for information on the unpublished assemblage of pottery sherds. All mapping data and aerial orthophotos were provided by Land and Property Services for research purposes under the Northern Ireland Mapping Agreement; this Intellectual Property is Crown Copyright and is reproduced with the permission of Land and Property Services under Delegated Authority from the Controller of Her Majesty’s Stationery Office, © Crown Copyright and database right (2017). Finally, thanks to two anonymous reviewers whose comments improved the original draft.

REFERENCES


Dawson, T. 2015a. Eroding archaeology at the coast: how a global problem is being managed in Scotland, with examples from the Western Isles. Journal of the North Atlantic Special Issue no. 9:83-93.


O’Rourke, M.J.E. 2017. Archaeological site vulnerability modelling: the influence of high impact storm events on models of shoreline erosion in the Western Canadian Arctic. Open Archaeology 3:1-16.


<table>
<thead>
<tr>
<th>Data source</th>
<th>Date</th>
<th>Pixel/Resolution Error (m)</th>
<th>Positional Error (m)</th>
<th>Digitization Error (m)</th>
<th>Total error (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4th Edition OS map HWM</td>
<td>1923</td>
<td>5</td>
<td>5</td>
<td>0.6</td>
<td>10.6</td>
</tr>
<tr>
<td>V1 Orthophoto</td>
<td>August 2003</td>
<td>0.25</td>
<td>-</td>
<td>0.7</td>
<td>0.95</td>
</tr>
<tr>
<td>V2 Orthophoto</td>
<td>September 2006</td>
<td>0.25</td>
<td>-</td>
<td>0.7</td>
<td>0.95</td>
</tr>
<tr>
<td>V3 Orthophoto</td>
<td>August 2010</td>
<td>0.25</td>
<td>-</td>
<td>0.7</td>
<td>0.95</td>
</tr>
<tr>
<td>V4 Orthophoto</td>
<td>June 2013</td>
<td>0.25</td>
<td>-</td>
<td>0.7</td>
<td>0.95</td>
</tr>
<tr>
<td>1:2500 HWM</td>
<td>Jan 2017</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 1. Summary of historic and recent shoreline data sources used in the DSAS analysis including dates and uncertainties/errors.
<table>
<thead>
<tr>
<th>Comparison</th>
<th>Dates</th>
<th>Min. NSM (m)</th>
<th>Max. NSM (m)</th>
<th>Mean NSM (m) [1σ]</th>
<th>Min. EPR (m/yr)</th>
<th>Max. EPR (m/yr) [1σ]</th>
<th>ECI (m/yr)</th>
<th>Min. LRR (m)</th>
<th>Max. LRR (m)</th>
<th>Mean. LRR (m) [1σ]</th>
<th>Retreating transects (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Historic to recent (HWM)</td>
<td>1923-2017</td>
<td>-146.8</td>
<td>90</td>
<td>-50.7 [34]</td>
<td>-1.6</td>
<td>1.0</td>
<td>-0.5 [0.4]</td>
<td>-</td>
<td>-</td>
<td>0.12</td>
<td>94</td>
</tr>
<tr>
<td>Recent 1 V1 to V2)</td>
<td>Aug 2003-Sept 2006</td>
<td>-14.5</td>
<td>19.5</td>
<td>-1.9 [3.6]</td>
<td>-4.7</td>
<td>6.3</td>
<td>-0.6 [1.2]</td>
<td>0.43</td>
<td>-</td>
<td>-</td>
<td>77</td>
</tr>
<tr>
<td>Recent 2 (V2 to V3)</td>
<td>Sept 2006-Aug 2010</td>
<td>-22.5</td>
<td>13.8</td>
<td>-1 [4.5]</td>
<td>-5.7</td>
<td>3.5</td>
<td>-0.3 [1.1]</td>
<td>0.34</td>
<td>-</td>
<td>-</td>
<td>63</td>
</tr>
<tr>
<td>Recent 3 V3 to V4)</td>
<td>Aug 2010-Sept 2013</td>
<td>-59.7</td>
<td>23.9</td>
<td>-2.8 [6.8]</td>
<td>-21.1</td>
<td>8.6</td>
<td>-1 [2.4]</td>
<td>0.43</td>
<td>-</td>
<td>-</td>
<td>76</td>
</tr>
<tr>
<td>Recent 4 (V1 to V4)</td>
<td>Aug 2003-Sept 2013</td>
<td>-54.2</td>
<td>41.4</td>
<td>-5.7 [9.3]</td>
<td>-5.5</td>
<td>4.2</td>
<td>-0.6 [0.9]</td>
<td>0.13</td>
<td>-3.4</td>
<td>0.43</td>
<td>75</td>
</tr>
<tr>
<td>Carter and Bartlett (1990)</td>
<td>1949-1980</td>
<td>-</td>
<td>-</td>
<td>-2.1</td>
<td>+1.7</td>
<td>0.84</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Carter and Bartlett (1990)</td>
<td>1833-1966</td>
<td>-</td>
<td>-</td>
<td>-0.57</td>
<td>0.93</td>
<td>-0.75</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Carter and Stone (1989)</td>
<td>Post-1949</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-1.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2. Summary of DSAS calculations for the shoreline comparisons. Negative values indicate retreat, positive values indicate advance. Net Shoreline Movement (NSM): measurement of the distance between the oldest and youngest shoreline per transect; End Point Rate (EPR): measurement of the rate of change between the oldest and youngest shoreline per transect; Estimated Confidence Interval (ECI): confidence interval for EPR calculated from total uncertainty provided in Table 1; Linear Regression Rate (LRR): measurement of the rate of change taking into account all shorelines on a given transect. Also shown are summary rates of local shoreline movement from the literature.
<table>
<thead>
<tr>
<th>Category</th>
<th>Uncertain/ N/A</th>
<th>High/Good [priority ≥8]</th>
<th>Moderate [priority 6-7]</th>
<th>Low/Poor [priority ≤5]</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significance</td>
<td>-</td>
<td>3</td>
<td>28</td>
<td>36</td>
<td>67</td>
</tr>
<tr>
<td>Condition</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>58</td>
<td>67</td>
</tr>
<tr>
<td>Risk</td>
<td>1</td>
<td>56</td>
<td>-</td>
<td>10</td>
<td>67</td>
</tr>
<tr>
<td>Final priority classification</td>
<td>-</td>
<td>2</td>
<td>25</td>
<td>40</td>
<td>67</td>
</tr>
</tbody>
</table>

Table 3. Summary table showing breakdown of individual categories and final vulnerability assessment.
Figure 1. Map showing the location of the study area (dashed polygon on main map). Inset map shows general location on the island of Ireland. Coordinates are in Irish National Grid. Numbered sites are major Second World War installations mentioned in the text: 1. Maydown Airfield; 2. Eglinton Airfield; 3. Ballykelly Airfield; 4. Limavady Airfield; 5. Magilligan Camp and coastal gun batteries.
Figure 2. Example of coastal erosion (exposed faces in backshore sand cliff) as imaged by oblique aerial photograph (AP) along Magilligan Foreland. See Figures 1 or 3 for location.

46x20mm (300 x 300 DPI)
Figure 3. Extant HER sites within the study area that were identified as being at risk of erosion by the broad-scale first pass assessment. Erosion by photo refers to whether backshore erosion was visible in oblique aerial photographs of the shoreline (Y = yes, N = no) (see Westley and McNeary 2014 for a full description of the approach) (Orthophoto © Crown Copyright 2017).
Figure 4. Rates of shoreline change as measured by each DSAS transect for a) historic and recent High Water Mark (1923-2017) and b) the past decade (2003-2013). Transect colour indicates End Point Rate (EPR) for 4a or Linear Regression Rate (LRR) for 4b (green, blue = advance; yellow, orange, red = retreat), transect length is indicative of the Net Shoreline Movement (NSM). Numbered dashed black lines indicate zones of particularly severe retreat. (Orthophoto © Crown Copyright 2017).
Figure 5. Orthophoto examples showing zone of major retreat (c. 20-30m) within the past 10 years. Base image is the V4 orthophoto, digitized shorelines for all 4 orthophotos rounds are superimposed along with transects showing the DSAS calculated LRR (Orthophoto © Crown Copyright 2017).

37x19mm (300 x 300 DPI)
Figure 6. Distribution map of new sites recorded, or extant HER sites examined, by the 2014 field survey. Study area has been split into northern (left) and southern (right) zones in order to better show the distribution of assets. Map also shows location of previously recorded HER sites identified as being at risk from the original first pass assessment. Numbered dashed black lines indicate zones of particularly severe retreat (Orthophoto © Crown Copyright 2017).

51x43mm (300 x 300 DPI)
Figure 7. Distribution map of all historic assets in the study area, including newly recorded and extant HER sites, prioritized as per the classification scheme described in the text. Study area has been split into northern (left) and southern (right) zones in order to better show the distribution of assets. Numbered dashed white lines indicate zones of particularly severe retreat (Orthophoto © Crown Copyright 2017).
Supplemental material captions

Supplemental Table 1. Recorded HER sites between the Roe Estuary and Magilligan Point which were identified as at risk by the broad-scale first pass assessment (Westley and McNeary 2014). HER observations refers to information provided in the extant HER entry (NI SMR 2017), 2014 observations refers to relevant information generated by the new survey work discussed in this paper.

Supplemental Table 2. Summary table of key features for sites newly recorded by the 2014 survey. Note that this includes an additional unpublished findspot of pottery sherds made by amateur collectors.

Supplemental Figure 1. Rates of coastal advance/retreat as measured by each DSAS transects at c. 3 year intervals: a) 2003-2006; b) 2006-2010; c) 2010-2013). Transect colour indicates End Point Rate (EPR) (green, blue = advance; yellow, orange, red = retreat), transect length is indicative of the Net Shoreline Movement (NSM). Numbered dashed black lines indicate zones of particularly severe retreat. (Orthophoto © Crown Copyright 2017).

Supplemental Figure 2. Survey photographs, Magilligan Foreland. A) 2-3m high sand cliff exposed by recent erosion. B) 1.5m high section showing toppled fence posts. Exposed section shows Holocene palaeo-sols layered with sand. C) 6m high sand cliff showing recent erosion at the cliff top (toppled blocks of vegetation) creating an extensive talus deposit which covers the cliff toe. A layer of compact dark Holocene peat occurs at the base of the section; recently separated chunks are visible scattered on the foreshore. D) Relatively stable backshore, 1.5m high with vegetation growing over the backshore and extending onto the foreshore.

Supplemental Figure 3. Representative photos of anthropogenic material recorded by the 2014 field survey. A) example of dumped rubble spread on the foreshore; B) smaller of the 2 rubble dykes north of the Roe estuary, probably reclamation related; C) unknown isolated concrete structure located on the foreshore c. 20m from an eroding backshore; D) example of intertidal wooden post; probable WW2 anti-landing pole; E) view across intertidal sandflats showing alignment of probable WW2 anti-landing poles; F) prehistoric flint flake eroding out the backshore sand cliff.
<table>
<thead>
<tr>
<th>HER Ref.</th>
<th>Site type</th>
<th>Period</th>
<th>Observations (HER)</th>
<th>Observations (2014 survey)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IHR 01334:000</td>
<td>Ferry</td>
<td>Modern</td>
<td>N/A</td>
<td>Position is 300m offshore, marks ferry route shown on historic map.</td>
</tr>
<tr>
<td>DHR 77</td>
<td>Pillbox</td>
<td>Modern (WW2)</td>
<td>Reported condition: fair</td>
<td>Condition: good. Intact and undamaged. Located directly on shoreline surrounded by rock armour</td>
</tr>
<tr>
<td>DHR 351</td>
<td>Coastal battery</td>
<td>Modern (WW2)</td>
<td>Reported condition: poor</td>
<td>Not visited. Partly visible on orthophotos (vegetation-covered). Located c. 90m from rock-armoured shoreline</td>
</tr>
<tr>
<td>DHR 381</td>
<td>Coastal gun position</td>
<td>Modern (WW2)</td>
<td>Reported condition: poor</td>
<td>Not visited. Partly visible on orthophotos (vegetation-covered). Located c. 70m from rock-armoured shoreline</td>
</tr>
<tr>
<td>DHR 382</td>
<td>Coastal gun position</td>
<td>Modern (WW2)</td>
<td>Reported condition: poor</td>
<td>Not visited. Partly visible on orthophotos (vegetation-covered). Located c. 100m from rock-armoured shoreline</td>
</tr>
<tr>
<td>DHR 359</td>
<td>Beach defences (scaffolding)</td>
<td>Modern (WW2)</td>
<td>Reported condition: poor</td>
<td>Condition: poor. Visible but scattered across foreshore, eroding out of backshore. Individual scaffolds damaged to varying degrees</td>
</tr>
<tr>
<td>DHR 481</td>
<td>Lookout (?)</td>
<td>Modern (WW2)</td>
<td>Reported condition: fair</td>
<td>Condition: moderate. Intact and upstanding though unroofed. Located c. 30m inland from eroding shoreline</td>
</tr>
<tr>
<td>DHR 482</td>
<td>Pillbox (possible)</td>
<td>Modern (WW2)</td>
<td>Reported condition: unknown/likely poor</td>
<td>Condition: poor. Localized scatter of concrete slabs and rubble. Uncertain if actually a pillbox</td>
</tr>
<tr>
<td>SMR LDY001:009</td>
<td>Findspot (human remains)</td>
<td>Uncertain</td>
<td>Bones, exposed in dunes by trackway cutting. Remains removed for analysis</td>
<td>Not visited. Located c. 100m from eroding shoreline</td>
</tr>
<tr>
<td>SMR LDY001:002</td>
<td>Shell midden</td>
<td>Early Christian</td>
<td>Exposed in sand cliff face. Material inc. bone, shellfish, pottery, charcoal</td>
<td>Condition: poor; prob. destroyed. No material visible in exposed cliff face. Reported position is seaward of current backshore.</td>
</tr>
<tr>
<td>SMR LDY001:008</td>
<td>Burial</td>
<td>Uncertain</td>
<td>Bones exposed in sand dune face backing beach. No associated finds.</td>
<td>Condition: poor; prob. destroyed. No material visible in exposed cliff face. Reported position is seaward of current backshore</td>
</tr>
<tr>
<td>SMR LDY001:004</td>
<td>Shell midden</td>
<td>Early Christian</td>
<td>Exposed in sand cliff face. Material inc. bone, shellfish, pottery, charcoal</td>
<td>Condition: poor; prob. destroyed. No material visible in exposed cliff face. Reported position is seaward of current backshore</td>
</tr>
<tr>
<td>SMR LDY001:003</td>
<td>Shell midden</td>
<td>Iron Age</td>
<td>Exposed in sand cliff face. Material inc. bone, shellfish, post holes, slag, charcoal</td>
<td>Condition: poor; prob. destroyed. No material visible in exposed cliff face. Reported position is seaward of current backshore</td>
</tr>
<tr>
<td>SMR LDY001:005</td>
<td>Shell midden</td>
<td>Early Christian</td>
<td>Exposed in sand cliff face. Material inc. bone, shellfish</td>
<td>Condition: poor; prob. destroyed. No material visible in exposed cliff face. Reported position is seaward of current backshore</td>
</tr>
<tr>
<td>SMR LDY001:010</td>
<td>Findspot (human remains)</td>
<td>SMR</td>
<td>Cranium and bone fragments. Located within exposed dune section.</td>
<td>Condition: poor; prob. destroyed. No material visible in exposed cliff face. Reported position is seaward of current backshore</td>
</tr>
<tr>
<td>SMR LDY005:007</td>
<td>Non antiquity: Giant’s Grave</td>
<td>Uncertain</td>
<td>Holocene raised beach ridge rather than anthropogenic feature</td>
<td>Condition: poor. No indication of ridge at shoreline though there is an indication of it further inland.</td>
</tr>
</tbody>
</table>

Supplemental Table 1. Recorded HER sites between the Roe Estuary and Magilligan Point which were identified as at risk by the broad-scale first pass assessment (Westley and McNeary 2014). HER observations refers to information provided in the extant HER entry (NI SMR 2017), 2014 observations refers to relevant information generated by the new survey work discussed in this paper.
## Supplemental Table 2. Summary table of key features for sites newly recorded by the 2014 survey.

Note that this includes an additional unpublished findspot of pottery sherds made by amateur collectors.

<table>
<thead>
<tr>
<th>Site types</th>
<th>no. sites</th>
<th>Periods</th>
<th>no. sites</th>
<th>Condition</th>
<th>no. sites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete structure</td>
<td>2</td>
<td>C19th</td>
<td>2</td>
<td>Good</td>
<td>1</td>
</tr>
<tr>
<td>Findspot: flint</td>
<td>13</td>
<td>C19th/20th</td>
<td>2</td>
<td>Moderate</td>
<td>5</td>
</tr>
<tr>
<td>Findspot: metal</td>
<td>2</td>
<td>C20th</td>
<td>26</td>
<td>Poor</td>
<td>45</td>
</tr>
<tr>
<td>Findspot: pottery</td>
<td>2</td>
<td>C20th?</td>
<td>2</td>
<td>TOTAL</td>
<td>51</td>
</tr>
<tr>
<td>Metal post</td>
<td>1</td>
<td>E. Medieval</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Path/road</td>
<td>3</td>
<td>Prehistoric</td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rubble dyke</td>
<td>2</td>
<td>Uncertain</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rubble spread</td>
<td>20</td>
<td>TOTAL</td>
<td>51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shell deposit</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wooden posts</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>51</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>