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Climate change impact assessment on shipwreck sites in Ireland

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Abstract: In Ireland, the CHERISH project has investigated the impacts of climate change on wreck sites exposed to different environmental conditions. Remote sensing and archaeological recording methodologies created substantive site records, baseline and monitoring datasets. Maritime archaeologists, geologists, divers, surveyors and geophysicists worked together, providing a range of expertise for data collection, analysis and appraisal. The incorporation of previous site records made it possible to assess change and site formation processes for periods longer than the six-year course of the project. The CHERISH project looked at a number of wrecks from three different locations and environments, including unidentified wooden intertidal wreck sites at North Bull Island, Dublin, which are being impacted and damaged by storm activity on an annual basis; the schooner *Sunbeam* located at Rossbeigh Strand, County Kerry, which has suffered severe damage due to storms in recent years; and SS *Manchester Merchant*, which is located a few kilometres offshore from the *Sunbeam* in Dingle Bay and has been reported by local divers as deteriorating due to storm damage. This chapter presents the gathered data, how data can help increase the understanding of these cultural heritage assets and how climate hazards associated with climate change are impacting the coastal and underwater cultural heritage resource.

Introduction

CHERISH (Climate, Heritage and Environments of Reefs, ISlands, and Headlands) investigated how changes to the physical climate of Wales and Ireland are impacting archaeological heritage along the coastal zone and underwater. This cross-nation multidisciplinary European-funded project (Ireland-Wales 2014–2020 Programme) was undertaken by four project partners: the Royal Commission on the Ancient and Historical Monuments of Wales; the Discovery Programme: Centre for Archaeology and Innovation Ireland; Aberystwyth University: Department of Geography and Earth Sciences; and the Geological Survey Ireland. The project ran for a period of six years from 2017 to 2023 and raised awareness of climate change for Irish Sea communities through outreach events such as talks and community excavations.

Anthropogenic climate change is accelerating and intensifying environmental impacts acting on the cultural heritage resource (Cassar 2005; Colette 2007; Jigyasu *et al.* 2013; Fatóric and Seekamp 2017; ICOMOS 2019; Dawson *et al.* 2020). Physical wreck-site change is caused by climate hazards such as coastal erosion and flooding, increased storminess, drought and seabed erosion, phenomena which are increasing in frequency and intensity due to climate change. CHERISH mapped, monitored and assessed potential climate change impacts on shipwreck sites by establishing new metrically accurate baseline and monitoring datasets. A number of the survey methods were able to be repeated during the course of the project, and the results were subsequently compared to the initial baseline or/and other pre-existing surveys to analyse degradation and change at the wreck sites. The research and survey work presented within this chapter produced important information on the overall archaeological context and impacts of climate change on shipwrecks.

The debilitating effects of sea-level rise include more extreme and frequent flooding events, increased impacts of storm surge and accelerated rates of coastal erosion. These are projected to alter the natural and built environments, and therefore, understanding the impacts to heritage is crucial (Curran *et al.* 2016: 23; Horowitz 2016: 40). The relationship between rising sea levels and flood events is clear; this means an uncertain future for heritage assets situated on the coast. Sea level rise is seen as a pressing issue, as coastal heritage and communities were dealt with in the subject matter of 23% of publications on climate impacts and cultural heritage in the five-year period 2015–2020 (Orr *et al.* 2021: 12). In Ireland, sea levels are forecast to increase for all coastal areas, with satellite observations indicating the sea level around Ireland has risen by approximately 2–3 millimetres per year since the early 1990s (Cámaro García and Dwyer 2021). Increasing wave heights have been observed over the last 70 years in the North Atlantic (Cámaro García and Dwyer 2021), and projected changes in sea level will magnify the impacts of changing storm surge. Alteration to storm patterns has the potential to impact wave strength and direction (see Woolf and Wolf 2013), potentially increasing seabed and coastal erosion, which in turn results in the degradation of underwater and coastal archaeological heritage. Erosion is one of the greatest threats to coastal archaeological resources, as wave and tide action cause the loss of invaluable and unrecoverable information (Westley *et al.* 2011: 352). Coastal erosion may destroy heritage sites gradually over decades or cause catastrophic loss during single events (Dawson *et al.* 2020, 2021).

The CHERISH project focussed on wreck sites located in three different locations and environments, including Dublin Bay, which is relatively enclosed and sheltered from the prevailing winds, and Dingle Bay, which is exposed to the full forces of Atlantic weather systems. The main aim was to monitor site condition and change, in order to understand how climatic changes are physically impacting wreck sites located in these exposed coastal and underwater environments. Overall sea-level rise for Dublin Bay is in line with expected trends, but higher rates of rise occurred in recent years (Shoari Nejad *et al.* 2022: 511). Higher sea levels amplify coastal flooding and erosion, which directly impacts the coastal archaeological resource of intertidal wreck sites at North Bull Island. The erosion of the dunes at Rossbeigh, Dingle Bay, where the wreck of the *Sunbeam* is located, has been of particular concern; erosion and flooding events in this area are predicted to intensify in the context of climate change, sea level rise and more intense and frequent storms (Tubridy *et al.* 2022: 7; also see Devoy 2015). SS *Manchester Merchant* is located in 15 m of water in Dingle Bay. Climate change will cause increased storminess for Ireland, which means more frequent storm surges. Seabed sediments are affected by storm surges; during storms, wave–current interaction may result in seabed damage (Zhang *et al.* 2015). From this, it can be ascertained such events may damage archaeological material located in impacted areas, whilst stronger currents will increase scouring around wreck sites during storm periods.

North Bull Island, Dublin Bay

In Dublin Bay, on the intertidal sand flats seaward of North Bull Island storms, shifting sand bars and channels occasionally expose shipwrecks and loose timbers. This island developed after the completion of the North Bull Wall, built to protect the entrance to Dublin Port in 1824 (Gilligan 1988: 89–95). The harbour wall blocked sand movement around the Bay, causing an area of sand dunes to grow to become the island known today as North Bull Island. Over 800 shipwrecking events in Dublin Bay are recorded in the Wreck Inventory of Ireland Database (WIID) held by the Underwater Archaeology Unit (UAU) of the National Monuments Service (NMS) (Brady 2008; WIID 2023). These are compiled from historical records, archaeological investigations by the NMS and development projects such as the Dublin Bay pipeline project in 2001 and 2002. The earliest documented record for a wrecking incident in the Bay dates to 1562, when the Vice-Treasurer of Ireland reported a ship with artillery and munitions wrecked on Dublin Bar. No doubt, many ships were lost in earlier times, and some evidence for this has emerged with keels from clinker-style vessels dating to the eleventh to thirteenth centuries recovered from the 2001 pipeline project (Brady 2008: 268, 322; Dunne 2008: 295–298).

Surveys over the last 30 years have found six wooden wrecks, recorded in the WIID, on North Bull Island strand, though there are approximately 150 historical wrecking events (Brady 2008). The number of vessels recorded as being wrecked on the North Bull, Dublin Bar and North Wall area every decade falls from 35 in the 1790s when the Great South Wall was built to only eight wrecks in the 1830s after the North Bull Wall was built. This not only highlights the effectiveness of the building of the seawalls, but it also suggests many shipwrecks found today could be from the late eighteenth century or earlier. Historical sources also record episodes of plundering wrecks lost on the North Bull; one such occurrence took place in 1745, when Lord Howth jailed tenants for looting recently wrecked ships (wreck no. W01071). This and other historical accounts of the protection of wrecks from plundering by various authorities may explain why the wrecks which are exposed on North Bull were not completely salvaged for their wood at the time of wrecking.

CHERISH undertook seasonal and post-storm site monitoring visits of intertidal shipwrecks, from September 2019 to February 2020 when, unfortunately, the Covid-19 pandemic prevented fieldwork. Fieldwork involved archaeological survey, beach profiles and magnetometer survey to ascertain if significant changes could be detected over time, particularly after storms. Earlier commercial and UAU surveys were incorporated into the site analysis to further the understanding of the archaeological context alongside rates and patterns of change at each wreck site. As well as the usual tidal and seasonal changes, a series of storm events occurred during CHERISH fieldwork in early 2020 which impacted the wrecks, including Storm Brendan (13 January 2020) and Storm Ciara (9 February 2020). Due to the dynamic tidal nature of the environment, weather conditions and the varying levels of wreck exposure, a variety of equipment and techniques were required to record the sites, including GPS (particularly Global Navigation Satellite System (GNSS)), beach profiling and magnetometry (using a Sensys MAGNETO MXPDA 5 sensor channel push-cart magnetometer). Three wrecks were monitored during the CHERISH surveys.

Prior to CHERISH, the UAU surveyed Wreck 1 (W01131 in the WIID) between 2004 and 2006; the vessel was recorded as exposed for 9.30 m by 3.35 m with clinker overlapping planks and 14 oak futtocks (Brady 2008: 236–237). Photographs showed a wreck on the sand flat in a pool larger than the extent of the exposed wooden futtocks. Further images from March 2015 held by the UAU show a wreck in a smaller pool, as there are three futtocks above

Figure 17.1. North Bull Island Wreck 1. Clockwise from top left: 2 September 2019; 8 January 2020; 20 January 2020 (after Storm Brendan, which occurred on 13 January 2020); and 11 March 2020. Photographs taken looking northeast. Copyright Discovery programme/CHERISH project.

water level in the pool on the surrounding sand ripples of the sand flat. The sand level must have been higher, as only two timbers were exposed on the northern side, as opposed to at least nine in the earlier survey. The largest extent during CHERISH surveys was 7.92 m with only one side of exposed futtocks visible. However, the magnetometer survey showed a magnetic disturbance around Wreck 1 of about 12 m long and 5 m wide. Wreck 1 (Figure 17.1) was recorded in September 2019 on the sand flat around 20–30 m seaward from the sloping beach which leads from the sand flats to the sand dunes. Ten timbers were recorded initially, although after the storms in January, this number had reduced to six, and by the last visit in March, there was only one timber visible. The beach profile from the sand cliff at the HWM across the sloping beach and over the wreck in January shows the wreck only 7 m from the sloping beach and the smoothing of the sloping profile of the beach. Wreck 1's length of around 12 m suggests a sloop- or yawl-sized vessel.

Wreck 2 (the Sutton Wreck) is a section of carvel planking covered by sea lettuce (*Ulva lactuca*) near the northern end of the sand flats. The archives at the UAU have photographs of this being recorded in October 2015. CHERISH recorded planking lying on a sand bar 3.49 m long, 0.27 m high and 0.60 m wide. The section consists of two layers of perpendicular planking joined by tree nails 4 cm in diameter. Compared to the 2015 photographs, the CHERISH surveys found the section to be covered more by carragheen (*Chondrus crispus*) and sea lettuce, though similarly surrounded by a shallow pool and sand ripples. This may be a part of the hull section of UAU wreck W01142 (also known as the Sutton Wreck), which is located about 750 m seaward of Wreck 2. A section of hull from the Sutton Wreck floated free and settled on the sand when discovered during archaeologically monitored dredging operations for a pipeline (Dunne 2008: 298). The pipeline route was diverted around the wreck, which was covered over by sandbags and sand and thought to be a trading vessel with a beam of 6.5 m and length of about 23 m.

Substrate changes resulted in Wreck 2 disappearing by January 2020 with a 30 m-wide intertidal drainage channel recorded in its location. GNSS measurements indicated a 3–4 cm drop in sand levels between September and January in the Wreck 2 position, indicating the wreck had not been buried, with the new channel up to 23 cm deeper. It is also possible two loose timbers (Timber 1 and 2) found in the northern area of the beach also came from the Sutton

Wreck. Ship timbers have been intermittently recorded as washing up on the beach (*e.g.* Brady 2002: 475; Dunne 2002: 474), and more recently in March 2021, five ship timbers were reported by the public to have washed onto the southwestern area of beach. Timber 1, recorded by CHERISH, was a plank broken at both ends, found on 8 January 2020 in a shallow drainage channel 350 m west–southwest. It was 3.41 m long, 0.35 m wide and 0.04 m thick, with traces of 21 dowel holes 38 mm in diameter. Timber 2, found 250 m north–northwest of Wreck 2 on 10 March 2020, was 1.5 m long and 0.2 m wide, with dowel holes and one unbroken end exposed.

The primary locus of the Sutton Wreck was inspected during a low spring tide in February 2020, but nothing was visible. A working hypothesis is that the bulk of the wreck remains buried; otherwise, if the wreck structure had been destroyed, larger quantities of timbers would likely have washed ashore since its 2001 discovery. However, Wreck 2 and the timbers found landward probably represent the concentration of wrecks recorded in the WIID around Sutton Creek mouth. Two wooden wrecks were found in the area of Sutton Creek, 150 m apart, during the course of dredging works for the Dublin Bay Pipeline Project (Brady 2008: 239–240). The WIID records 23 wrecked brigs and 10 schooners on the North Bull, some of which would be about the same size of vessel as those recorded around Sutton Creek. A couple of examples include *Lively* (W01025), a brig from London stranded 2 January 1788 on North Bull with cargo of sugar, tea and hops, and *Olive* (W01038), a 97-tonne schooner travelling from Liverpool to Cork wrecked on the North Bull, near Sutton, in a gale on 15 February 1828.

Wreck 3 was a previously unrecorded, *in situ* single timber on the sand flats whose height above the sand varied from 0.36 m to 0.59 m. It lay further seaward on the sand flats than Wreck 1. The single-angled timber is orientated northeast–southwest, reaching 0.41 m high above the sand, with a width of 0.13 m. The magnetometer survey over Wreck 3 indicated a wreck around 35 m long from a similar positive anomaly that same distance to the west–southwest. The angle of the timber in the sand suggested it may be the stern or bow of a vessel. Wreck 3 GNSS beach profiles showed a drop of 9 cm in the sand level over an area of about 3 m between September and January, indicating clear pooling around the single timber. There was a further 20 cm drop in sand height after Storm Ciara in February, which contrasts with the silting over of the more landward Wreck 1. The end of the timber was thinner at the end of the CHERISH surveys, compared to when it was first recorded, suggesting abrasion due to wave action. Similar to the wrecks around Sutton Creek, it could be the remains of a schooner or brig type vessel, due to the 35 m length suggested by the magnetometer data.

Tidal and wave forces continually affected these Bull Island wrecks over the monitoring period, causing changing sand ripples, scour pools, drainage channels and sand bars. The growth of sea lettuce, barnacles (*Semibalanus balanoides*) and carragheen (found only on Wreck 2) on the wooden wrecks contrasted with loose timbers which had no growth, suggesting the latter had been recently exposed above sand level. The colonisation of these wrecks with marine life indicates that wreck site exposure from the time of initial recording by CHERISH probably lasted years, though further biological studies need to be done to further determine the age. The carragheen growth on Wreck 2 suggested it had been exposed for the longest amount of time. The evidence from Bull Island shows seasonal environmental changes, but it also reveals the effects of storms with the silting of Wreck 1 closest to the HWM, attributed to redeposition of sand from an eroded sand cliff. The disappearance of Wreck 2 from wave action powerful enough to remove this section of timbers, and the exposure and deterioration of Wreck 3 from reduction of the height of the sand flats, shows the effects of further seaward and wave abrasion.

Sunbeam, Rossbeigh Beach, County Kerry

The *Sunbeam*, a 99-tonne wooden schooner around 24 m long and 6 m wide, was built in Exmouth in 1860. Bought by Richard Kearon of Arklow, Wicklow in 1874, it had a regular run between Galway, Cork and the Bristol Channel. In January 1904, the schooner departed Kinvara, Galway in ballast for Cork to load timber for transport to the Bristol Channel. Soon after the ship left Galway Bay, the weather deteriorated, with storm conditions intensifying to a force 8–9 gale. The schooner's foresail ripped, and she took shelter in Dingle Bay. The second evening of the storm led to the vessel breaking anchor, and it was driven ashore. The crew walked away unscathed, whilst all salvageable material was shipped to Arklow (Dunne 2014; WIID). With no hope of refloating the largely intact vessel, it was subsequently abandoned on Rossbeigh Beach, County Kerry. It became a popular attraction, remaining as such as the vessel broke down and became partially buried over time. Its lower hull remained intact, and the wreck was a local landmark.

The eastern side of Dingle Bay is bounded by beach-dune barrier systems of the Inch and Rossbeigh Spits orientated approximately north–south (Devoy 2015: 141–142). These dune systems are special areas of conservation in their own right. Given the open and exposed nature of Dingle Bay, the dominant Atlantic southwest–west prevailing winds, swell waves and storm surges result in wave heights reaching 2.8 meters (Devoy 2015: 146). This continuous high-energy wave environment—high winds in tandem with the increased occurrence and intensity of storms—has resulted in the spit suffering significant erosion, with the dune system being breached in a number of areas.

Severe winter storms in 2013/2014 resulted in direct, damaging impact to the *Sunbeam*. The UAU responded to this by commissioning a local archaeological consultancy, Laurence Dunne Archaeology Ltd., to undertake rapid assessment, wreck remains defence works and rescue of over 50 ship timbers, including a large articulated section of the bow (Dunne 2014). As a means to protect the impacted wreck remains on the beach, a temporary defence was put in place using large 1-tonne sandbags to form a protected structure around the articulated hull remains. Large disarticulated timbers recovered were placed within the hull remains, along with iron fixings, to ensure they too were protected. These defensive works were subsequently destroyed by further storms in February 2014, which also destroyed the stern of the vessel. The remaining coherent wreck was also lifted and moved 200 m along the beach, where it lodged up against the dune system, which had also been breached (Dunne 2014). The Google Earth historical images from 2003 to 2012 show the outline of the wreck of the *Sunbeam* orientated northwest to southeast and lying partially buried 16–19 m seaward of the sand dunes on Rossbeigh Beach. In order to preserve the remaining intact wreck structure after the 2014 storm events, it was reburied in this general area. The southern spit, Rossbeigh, was about 4 km long prior to its breaching and the erosion of its distal end by a storm surge in 2008. The satellite data shows a 661 m wide breach had appeared 3.4 km along the length of the spit by 2010.

CHERISH began monitoring the site of the *Sunbeam* from the outset of the project in 2017 in order to record seasonal and storm impacts on the wreck site. On 26 July 2017, a photographic and photogrammetric survey of the *Sunbeam* wreck (Figure 17.2) was carried out, resulting in a Structure for Motion (SfM) 3D model of the site and its immediate surroundings. At this point in time, the majority of the wreck site was buried with only its framing elements exposed. On 19 September 2017, a monitoring inspection of the site recorded the wreck and surrounding sand levels as relatively stable. Only the sides of the vessel remained above the sand, as most of the stern and bow sections had been destroyed in earlier storm events. During the autumn/winter period of 2017 into 2018, several storms hit Ireland, including Ophelia (16 October), Eleanor (2 January) and Fionn (16 January). Following these storms, the site was revisited in April 2018, but no remains of the wreck were located. A further visit on 26 June 2018 involved a snorkel survey; from the results of the survey, the site was presumed either to have been reburied or to have moved again.

A wider search on 10 October 2018, which involved a walkover survey of the entire extent of the spit, found a portion of the lower hull of the *Sunbeam* (Figure 17.3) at the northern tip of Rossbeigh Spit, at the entrance to Castlemaine Harbour. This is 2.4 km northeast of its last recorded position, and it had therefore moved farther north along the spit for at least 2 km and was washed about 700 m into the mouth of the channel. Not surprisingly, the wreck had been badly damaged and was now in poor condition, with only about 10 m of one side remaining and 2 m in height of hull structure surviving above the seabed. The full extent of this remaining part of the hull section could not be fully surveyed due to being submerged within the channel. It lay just beyond the low water mark in an area of sand with patches of pebbles. Marine growth

Figure 17.2. Image of wreck taken during recording works in 2017. Copyright Discovery programme/CHERISH project.

Figure 17.3. CHERISH project staff recording *Sunbeam* in 2019. Copyright Discovery programme/CHERISH project.

(barnacles, mussels and sea lettuce) flourished on the wreck in its new location; this indicated the wreck was exposed near the low water mark for some time. Following another inspection in April 2019, marine growth on the ship timbers was observed to have decreased to mostly barnacles and sea lettuce, possibly indicating continuous levels of sand abrasion was limiting marine growth. The wreck had continued to deteriorate; copper alloy nails and wooden dowels which originally held the hull planks together were very exposed. A beach profile was carried out; this procedure was repeated in May 2022 when the substrate was found to be sandy again, probably indicating longshore drift and accretion of sand. Only five ribs remained above the water line, with six of the previously recorded ribs impacted and lowered to the remaining planking height. Sea lettuce growth had increased to cover the protruding ribs, along with bladder wrack on lower parts more permanently underwater. Beach profiling was undertaken at the northern end of Rossbeigh Spit in 2019 and 2022, revealing several metres of erosion of the island towards landward.

The *Sunbeam* illustrated the destructive and catastrophic nature of singular climatic episodes such as storm events on shipwreck sites. The work undertaken by the UAU, Laurence Dunne Archaeology and the CHERISH project created a timeline, mapped and monitored wreck site change and recorded the impact of storms. This site demonstrated how storm events can occur in tandem with each other, acting as a continual force against an archaeological resource leading to significant deterioration and loss which will eventually result in the complete breakdown and loss of the archaeological site. The reshaping and relocation of this wreck site does not solely result in the loss of the archaeological context and structural integrity of the site, for it also impacts local communities and visitors' sense of place, as the *Sunbeam* was a popular attraction and marker on the beach.

SS Manchester Merchant

SS *Manchester Merchant* was a 5600-gross tonne cargo vessel en route from New Orleans to Manchester. The vessel was 400 km off the southwest coast of Ireland when its cargo of cotton bales spontaneously ignited. The vessel sought refuge in Dingle Bay, Kerry on 15 January 1903, but after attempts to quench the fire failed, most of the crew took to the lifeboats, leaving the master and a handful of crew to scuttle the ship in shallow water with the hope of salvaging the vessel at a later stage. The wreck lies in approximately 12 m of water and is orientated northeast–southwest. The upper works of the steamer are largely destroyed and have fallen onto the surrounding seabed, with the boilers and bow now forming the highest part of the wreck. Local divers have reported structural collapse and change to the wreck site in recent years; this was attributed to storm damage after the worsening condition of the wreck was correlated with storm events.

The CHERISH project aimed to identify physical change occurring at the wreck of the *Manchester Merchant*. Accordingly, a programme of work was initiated to produce individual and combined 3D models using point cloud data captured from methods such as multibeam echosounder (MBES) survey, remotely operated vehicle (ROV) and diver videography and photography, from which 3D SfM models are derived. This programme of work required elements of the survey operation to be repeated over the course of the project to create baseline, monitoring and comparison datasets. MBES data capture was undertaken as part of the CHERISH project in 2019. The acoustic wreck survey used a Kongsberg EM2040D single-swath multibeam echosounder operating at 400 kHz in tracking mode. Multiple survey lines were run at the lowest speed at which adequate control of the vessel and heading could be maintained, ensuring maximum along-track data density (generally 2–3 knots). A 10° overlap between swaths was maintained, and angular coverage of each swath varied between 30° and 70° to maintain coverage within a 10 cm grid over the wreck. The quality of the data was also checked in the field. Sound velocity profiles were taken before and after the wreck survey. The site has been mapped a number of times over the previous 15 years as part of the seabed mapping programme undertaken by Geological Survey Ireland and the Marine Institute (Irish National Seabed Survey (INSS), later Integrated Mapping for the sustainable development of Ireland's marine resource (INFOMAR)).

The image on the top left (Figure 17.4) shows the INFOMAR MBES survey from 2009. This data was compared to the CHERISH 2019 survey results using cloud compare software, and this showed degradation of the shipwreck site over a ten-year period. We can see particular changes in the condition of the wreck site at a number of areas, such as the bow, stern and amidships from this comparison dataset. This change is denoted by the colour green on the main image (Figure 17.4). A repeat survey of the wreck was undertaken in 2021 in conjunction with an ROV survey. It was conducted with a Kongsberg EM2040 D dual head multibeam echosounder using the same survey methodology as the 2019 survey. As MBES data provides structural information only to a certain level of accuracy, it was decided to supplement the MBES data with SfM data which would be captured through ROV and diver photogrammetric surveys. As it was not feasible to record the entirety of the wreck site in this manner due to time constraints, target areas were therefore identified

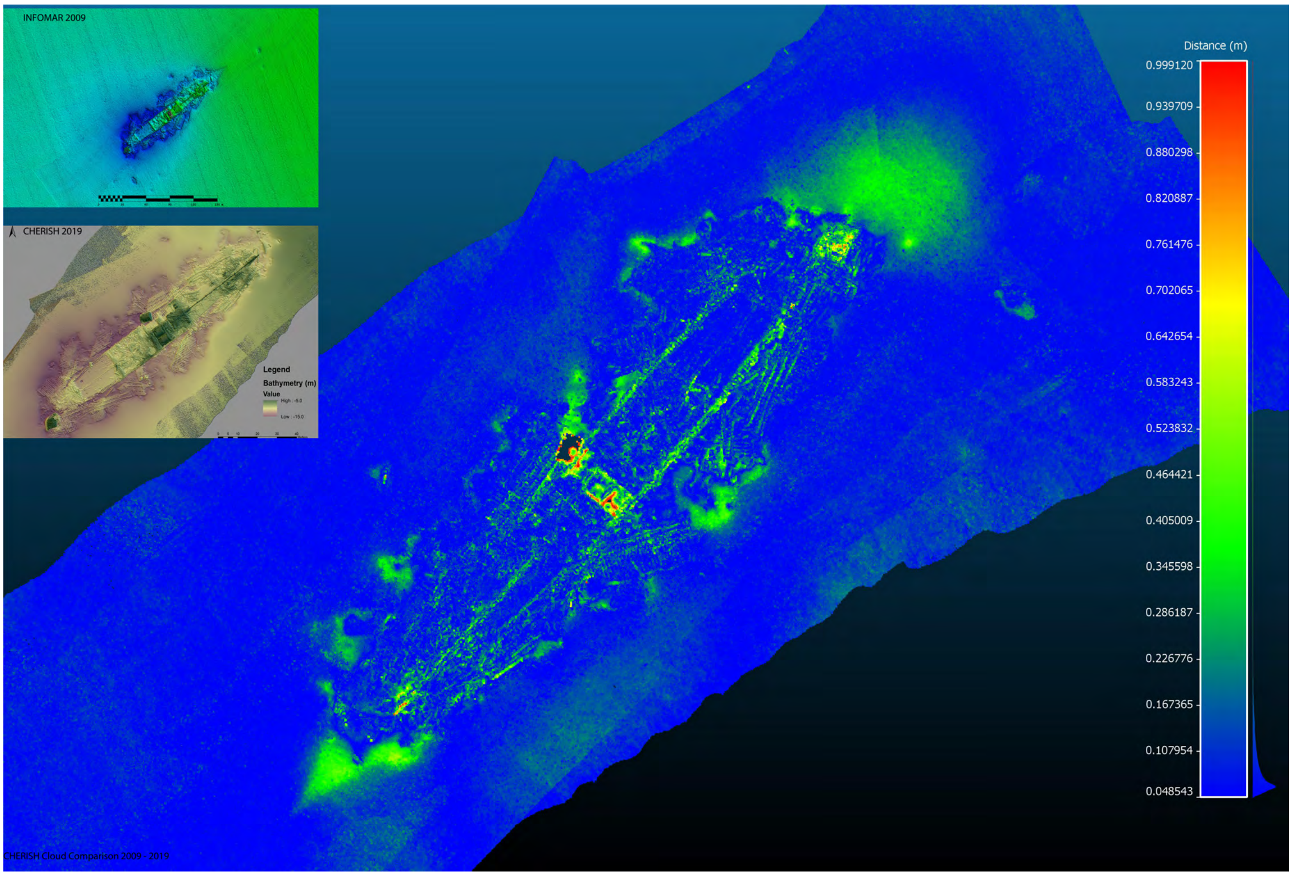

Figure 17.4. (a) INFOMAR 2009 survey (copyright INFOMAR, 2009). (b) CHERISH 2019 survey. (c) CloudCompare results; areas of structural change are denoted by green colouring. Copyright Geological Survey of Ireland/CHERISH project.

from the MBES comparison dataset. These areas were the ones observed to be suffering the most from structural collapse and change. CHERISH initiated the data capture and detailed visual survey of the wreck site with ROV and camera systems to augment the sonar data of the site captured; the MBES and ROV survey were undertaken over a two-day period during June 2021, aboard the RV *Keary*.

The ROV survey of the wreck was conducted by the Centre for Robotics and Intelligent Systems (CRIS), University of Limerick (UL) using the I-ROV system, an inspection-class ROV designed and built at CRIS, UL. It is a smart advanced system, not typically found in the commercial world, driven by a smart navigation and control suite known as OceanRINGS. This system moves away from manual piloting to automated piloting and control. To achieve a higher survey-grade platform, the IROV system facilitates an onboard inertial navigation system (INS), which is utilised by OceanRINGS to provide autonomous navigation and control. The INS is coupled with a doppler velocity log (DVL) for speed estimation, and a submersible GPS gives last known position prior to dive. The INS couples all sensor inputs, including 3-axis accelerometers and 3-axis fibre gyros, to provide a very accurate dead reckoning position over time from last known GPS. These platforms enable more accurate survey trajectories subsea, which can be critical in capturing close-quarter data.

The photogrammetry system utilises a camera system from SubC imaging, which is operated in a continuous shooting mode and triggers two onboard strobe LED lights when a picture is taken. The camera and strobes are positioned in such a way as to minimise backscatter. In terms of execution of the survey itself, the system utilises GPS positioning to manage the navigation of the ROV and ensure photos with overlaps of about 80% between camera frames are achieved. There are many operational issues on shipwreck sites, and it can be challenging to acquire high-quality photogrammetry datasets underwater. The conditions onsite were somewhat challenging, particularly in terms of strong tidal currents and poor visibility. The ROV system completed a number of surveys of target areas (Figure 17.5). The first area surveyed was the boiler section. The survey was designed to ensure good coverage and effective frame/path overlap, and a photogrammetric survey was completed with five passes on one axis and then seven passes on the second axis. The second target area surveyed was the bow section located to the southwest, one of the highest points on the wreck site. The ROV system undertook passes of this section in a less systematic manner. This was due to its height off the seabed and the entanglement hazards presented by this section of wreckage, which were even more prevalent due to the strength of the currents around the wreck site. A photogrammetric survey of this section of the wreckage was completed in roughly 15 minutes, which provided a consistent overlap and full coverage of the upper section of this part of the vessel.

The third survey area focussed on the propeller shaft, which runs half the length of the vessel, starting from the triple expansion engine just behind the boilers to the stern of the vessel. For this survey, three passes were completed along the length of the shaft, with additional data collected from passes made either side of the shaft. An inspection

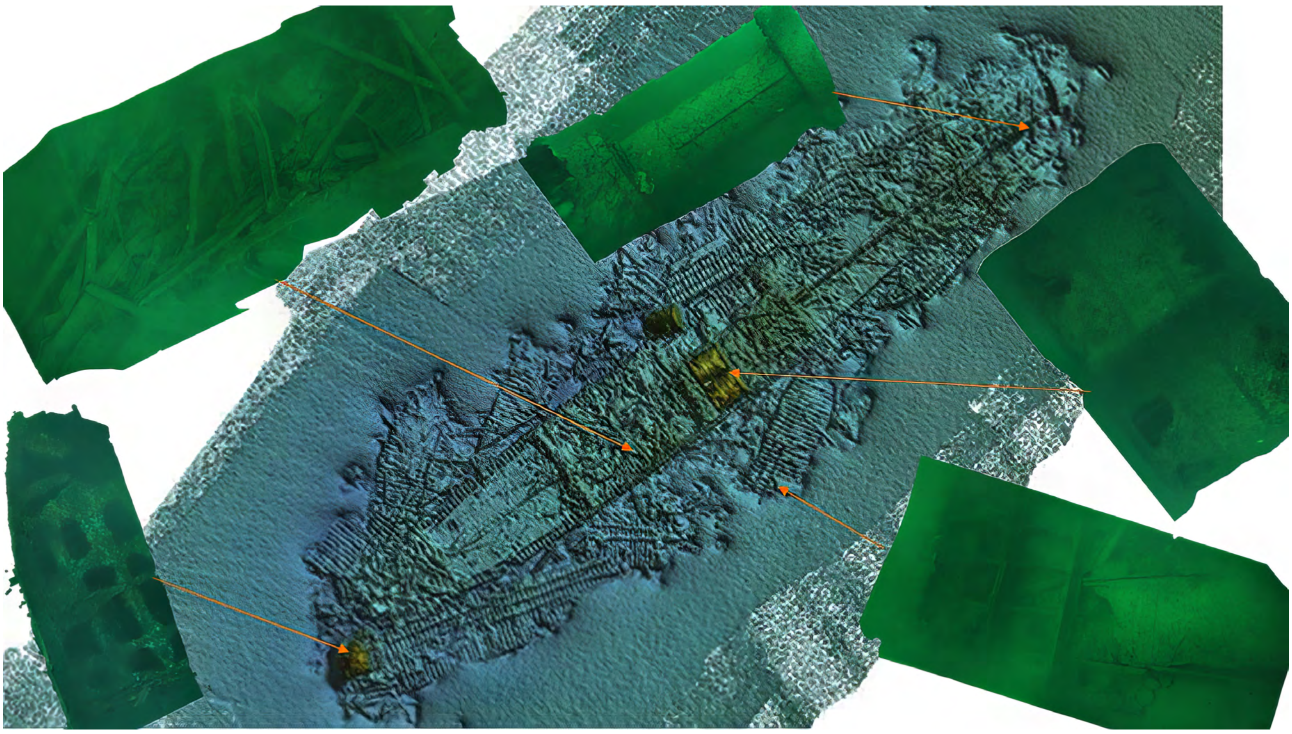

Figure 17.5. SS *Manchester Merchant* with ROV images from the targeted survey areas of the wreck site. Copyright Centre for Robotics and Intelligent Systems, UL/CHERISH project.

survey of the final target area focussed on the stern of the vessel, where the rudder can be seen lying flat on the seabed. The diver surveys were undertaken in August 2022 by Indepth Technical Diving, whose crew collected photographic and video survey of the same areas targeted by the ROV survey. This ensured extensive datasets were gathered for the areas of wreck identified as suffering the most from structural degradation and wreck site change, and the imagery gathered was also used to produce 3D models (Figure 17.6).

The condition of the wreck was assessed through the collected data from the ROV and diver survey. Degradation of the structural integrity of the wreck was identified at all the target areas including the bow, stern and amidships around the boilers along with various other parts of the wreck. The hull plating has fallen away from the main body of the hull structure. This has led to the interior of the wreck being fully exposed and more susceptible to deterioration. The interior of the wreck is a collapsed jumble of various steel structural components, with sections of hull plating mixed with interior piping and other sections of wreckage, highlighting the structural collapse and decay which has occurred on the wreck site over the hundred plus years since its wrecking. SS *Manchester Merchant* is located in an area of strong tidal currents; increased storminess will mean increased current speeds acting on underwater wrecks, and greater potential for seabed damage due to storm related tidal, wave and current action, which inevitably results in damage to underwater cultural heritage located in impact areas. The addition of these forces to an already highly dynamic environment means that sites such as SS *Manchester Merchant* are significantly threatened with rates of deterioration fast-tracked by environmental impacts being intensified by climate change.

This work highlights the importance of mapping and monitoring change, and the importance and significant contribution of visual inspections by the diving community. The project has shown the capability of ROV survey for visual inspection of these important sites. The visibility posed a significant challenge for visual camera survey; however, this was mitigated to a large degree through the use of a smart ROV platform. The divers collected complementary datasets which enabled the production of high-quality 3D models and further material for wreck site condition assessment. The datasets are rich and supplement datasets acquired from ship-based sonar imagery. The SfM models provide dimensional information and data outputs, including point clouds and orthomosaics. These models can be overlain on the 2021 MBES data to provide higher-resolution data which complement the point clouds produced from the MBES survey. This survey established a high-quality baseline which can be utilised to continue to assess and map the deterioration of the wreck site in the future.

Discussion

Climate impacts on coastal and underwater heritage are relatively poorly understood (Gregory *et al.* 2022: 1396). Increases in intense storm events and rising sea level

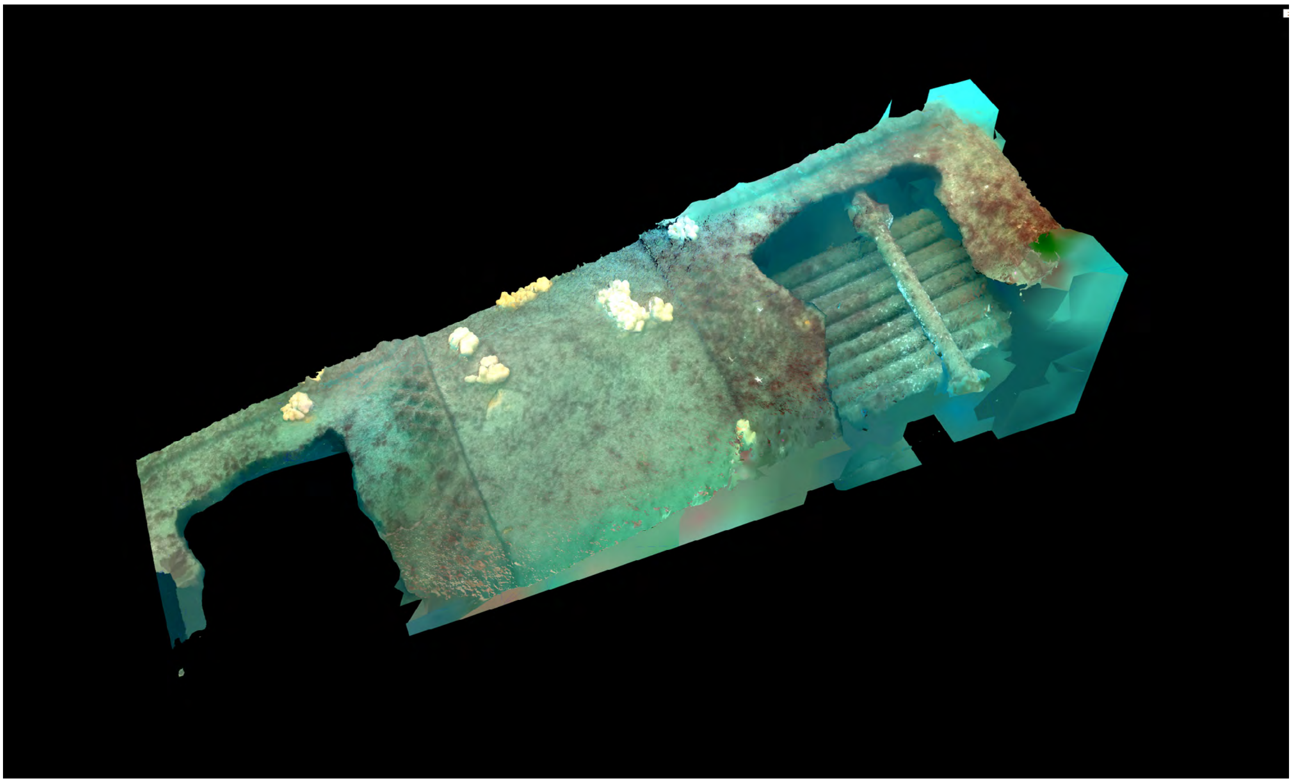

Figure 17.6. Photogrammetric model of the boiler, diver survey Go-Pro images. Copyright Discovery programme/CHERISH project.

accelerate coastal erosion and flooding. As recorded on Bull Island and Rossbeigh, these factors are impacting intertidal archaeology in the form of uncovering, moving, breaking apart, redepositing and reburying sites and artefacts. At Bull Island, shifting sand is regularly revealing evidence in the form of shipwrecks, artefacts and loose timbers. Beach profiling shows the erosion at the HWM of the island during storms and sediment transfer to the sand flats. The environment is less active during calmer periods, resulting in formation of continuously moving sand bars separated by channels which expose and cover over wrecks and timbers. While these conditions are and have been ongoing events over time, climate change is resulting in heightened and increased impact. Beach profiling at Rossbeigh showed extensive erosion of the northern end of the island and sand spit where the *Sunbeam* came to rest following its initial impact during a series of extensive storm events. The dynamic nature of sediments outlines the extensive erosion occurring in the area of the wreck. This intertidal work has highlighted the need to undertake repeat intertidal surveys, not only around low spring tides but seasonally and following storms when sediment is most likely to be in flux. Many shipwrecks are in danger of being damaged and lost before confirming identification through available historical and artefactual evidence, and creating substantive site records.

Remote sensing techniques such as magnetometry have proven successful in identifying potential archaeological anomalies, alongside locating and determining the extent of wreck sites. This enables archaeologists to be prepared for the uncovering of high-potential areas after storms, seasonal changes or the continual movement of sand bars and channels. The results gained at Bull Island from surveys in areas immediately surrounding exposed timbers are promising, and this method needs to be expanded to assess the full length of the beach to test its value further. This is logistically challenging as the tidal window at low water can be limited, and other techniques would be required to cover larger areas quickly. The geophysical data provided an indication of approximate size of the buried remains of the wrecks, but it would be useful to confirm these results with test excavation or probing. The site records and information created for Bull Island and Rossbeigh are useful as a baseline study for any future surveys which can provide further information of the nature and cause of deterioration, stability, new processes and biological factors affecting the wreck.

Over the past decade or so, equipment and methodological advances have resulted in MBES surveys presenting strong capabilities for identifying and mapping condition change on wreck sites. The results obtained through comparing datasets of the SS *Manchester Merchant* allowed the identification of changes in the condition of the wreck site over a 10-year period, and across smaller timeframes such as two years. This allowed the collection of data in target areas where the wreck site suffered the most change, such as the bow, stern and amidships. The ROV survey showcased the ability of such systems to undertake the visual inspection of these important sites and produce high-resolution 3D models, even under adverse survey conditions. The ROV and diver datasets are rich and can supplement datasets acquired from ship-based MBES imagery with higher-resolution models. The datasets can be utilised to estimate the degradation of the sites over time, given the results of this survey as an established baseline.

It is also worth noting that through the invaluable input of diver engagement with underwater cultural heritage, verbal and visual records of change are produced, and these were critical to the development of this study. This work can be used to further the understanding of and feed into wider studies on the impacts of climate change on Irish underwater cultural heritage. This work also informs the use of efficient and state-of-the-art underwater cultural heritage monitoring and recording methodologies. The collection of rich, metrically accurate datasets allows for the development of strong visualisations and representations of underwater cultural heritage. Mapping this change and visualising it are hugely beneficial in bringing this underwater resource into the public domain. The outputs of the work by CHERISH, such as 3D models, can be used as a tool to communicate change to the wider public, who normally do not have the opportunity to engage directly with underwater resources.

The understanding of natural systems is pivotal for assessing the sites at greatest risk from climate change, and allow for informed decisions concerning future risks faced at sites, the understanding of past processes and the sustainability and timescale of preservation actions (Howard 2013: 654). The identification of climate hazards which are known to be intensified and accelerated by climate change provided information on how Irish wreck sites are being and will continue to be impacted due to climate change. The development of such studies provides insights on other at-risk sites and enables the assessment of future impacts for sites. In nearly all instances, the breakdown and deterioration of the wreck was recorded, with instances of extreme loss recorded. Episodes of loss have the ability to negatively impact the value and significance of an archaeological site. Future projections due to the currently observed impacts and in consideration of climate projections suggest significant loss is occurring and will continue to occur to shipwrecks. The *Sunbeam* provided thought-provoking and surprising insights on the application of preservation measures, such as the building of defensive structures and the reburying of sites. The work described in this chapter presents the adaptation measure of management of loss through the creation of the archaeological record. In the face of climate change, this adaptation measure is likely to become the most commonly employed method in the management and implementation of adaptation strategies for at-risk coastal and underwater heritage, assisting in the preservation of these resources for future generations through the creation of site records.

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18

Blending WW2 history with the present in an interactive virtual heritage experience

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Abstract: We have developed ‘Exercise Smash’, a virtual heritage experience which allows audiences to take part in a 1944 military exercise originally held in preparation of the D-Day landings in Normandy. Several participating amphibious tanks sank during the exercise, and our experience allows audiences to explore the present-day tank wrecks in a virtual dive to the seafloor.

The interpretation and presentation of archaeological artefacts frequently revolves around the two fundamental questions: ‘what happened here?’, and ‘who did it happen to?’. Addressing these, we propose a mode of cultural heritage presentation using an interactive virtual environment, our ‘Snapshot in History’ time-travel paradigm for Virtual Heritage, which provides an innovative synthesis of tangible and intangible cultural heritage.

Audiences engage in a two-step interactive virtual experience which is ideally suited for the public presentation and dissemination of maritime archaeology, *e.g.* as an interactive museum exhibit. First, they experience the snapshot in history, taking part in the historical event which resulted in the submerged archaeology. The underlying story is conveyed through an interactive narrative, after which the audience are given the opportunity to explore the present-day archaeological site in an extension of the virtual dive trail concept.

‘Exercise Smash’ proves our concept, engaging audiences with this WW2 heritage. The audience first experience the story, then they are tasked with landing one of the swimming tanks on the beach without sinking it, and finally they explore the present-day wrecks within a detailed virtual environment populated with simulations of local marine life, which in the real world would be accessible only to divers.

Introduction

The public presentation of archaeology is a complex issue (Moshenka 2017) and of increasing importance, not the least because engagement with the public plays a major role in the dissemination of the results of research findings. With the rise of digital media over the past three decades, in recent years Virtual Heritage approaches—the use of interactive virtual environments for the presentation of cultural heritage—have become a popular medium for engaging the public.

The presentation of archaeology can involve different types of cultural heritage. Obvious among these is the ‘tangible cultural heritage’ which consist of archaeological finds and remains or their reconstructions; these tend to be (more or less) visible, and approaches to their presentation—after preservation—can be straightforwards, *e.g.* in museums. Requiring a much more complex approach for public presentation is the far less obvious and often invisible ‘intangible cultural heritage’ (UNESCO 2003), which encompasses oral traditions, performing arts, rituals and social practices but can also include personal stories such as memories of war (Jansen-Verbeke and George 2012) or memories by witnesses or survivors of a—potentially traumatic—historical event. Intangible cultural heritage frequently requires a means for interaction of the audience with dynamic objects in the virtual environment and sometimes also with virtual characters.

Our proposed approach towards the public presentation of archaeology aims to combine both tangible and intangible heritage to create a more holistic virtual heritage experience with the intention of improving audience engagement with the archaeology.

Related work

There exist many different types of Virtual Heritage applications for the presentation of cultural heritage, each providing their own sets of challenges. They are often concerned with the interactive visualisation of heritage sites which provide a means for exploration of digital reconstruction of lost or decayed objects and places, sometimes in museums (Deggim *et al.* 2017), requiring the provision of necessary infrastructure or hardware, or online (Firth *et al.* 2019), which can limit the extent of user interaction with the heritage artefacts. Sometimes