Insights from archaeological analysis and interpretation of marine data sets to inform marine cultural heritage management and planning of wave and tidal energy development for Orkney Waters and the Pentland Firth, NE Scotland
Pollard, Edward; Robertson, Philip; Littlewood, Mark Eric; Geddes, George

Published in:
Ocean & Coastal Management
Publication date:
2014
Publisher rights:
Copyright © 2015 Elsevier Ltd. All rights reserved
The re-use license for this item is:
CC BY-NC-ND
The Document Version you have downloaded here is:
Peer reviewed version

The final published version is available direct from the publisher website at:
10.1016/j.ocecoaman.2014.05.012

Link to author version on UHI Research Database

Citation for published version (APA):

General rights
Copyright and moral rights for the publications made accessible in the UHI Research Database are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights:

1) Users may download and print one copy of any publication from the UHI Research Database for the purpose of private study or research.
2) You may not further distribute the material or use it for any profit-making activity or commercial gain
3) You may freely distribute the URL identifying the publication in the UHI Research Database

Take down policy
If you believe that this document breaches copyright please contact us at RO@uhi.ac.uk providing details; we will remove access to the work immediately and investigate your claim.

Download date: 18. Dec. 2018
Insights from archaeological analysis and interpretation of marine data sets to inform marine cultural heritage management and planning of wave and tidal energy development for Orkney Waters and the Pentland Firth, NE Scotland

Edward Pollard a,*, Philip Robertson b, Mark Littlewood c, George Geddes d

a British Institute in Eastern Africa (formerly Orkney College UHI), Laikipia Road, Kileleshwa, P.O. Box 30710, GPO Nairobi, Kenya
b Historic Scotland, Longmore House, Salisbury Place, Edinburgh EH9 1SH, Scotland, UK
c Orkney Research Centre for Archaeology (ORCA Marine), Orkney College UHI, Kirkwall KW15 1LX, Scotland, UK
d Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS) John Sinclair House, 16 Bernard Terrace, Edinburgh EH8 9NX, Scotland, UK

ABSTRACT

The Orkney archipelago has a rich heritage that includes the Heart of Neolithic Orkney World Heritage Site, Viking settlements, harbours supplying Hudson’s Bay Company ships, and the wartime naval base of Scapa Flow. This rich history has left its mark on the seabed but accurate maps showing the location and character of surviving seabed archaeology do not exist to the same extent as for archaeology on land. ORCA Marine was commissioned by Historic Scotland to work with the Royal Commission on the Ancient and Historical Monuments of Scotland in interrogating marine data sets to enhance historic environment records of Orkney Waters and the Pentland Firth. These waters were prioritised for their history of maritime activity and to help guide planning and developments in an area highlighted by the Scottish Government for marine renewable energy.

A variety of recent and legacy datasets, including wreck databases; sonar data gathered by public sector bodies; aerial photography; seabed cores; Admiralty charts; and local knowledge, were examined for their effectiveness in discovering and interpreting marine cultural heritage cost-effectively. A methodology was developed that enabled marine cultural heritage information to be quickly assimilated within the national and regional inventories for dissemination online. Polygonisation of records resulted in GIS-based shapefiles identifying site extents, and areas of archaeological potential in relation to wrecks, submerged prehistoric landscapes, anchorages and fishing areas.

Substantial gaps in data coverage were identified and areas of the seabed have been surveyed at resolutions that are sufficient to detect large upstanding remains such as iron shipwrecks but insufficient to identify smaller archaeological features. Other geophysical datasets have been created at a resolution detailed enough to allow the recognition of smaller anomalies but in some cases processing of the data has removed small anomalies of interest to archaeologists. Intensively used marine areas often contain the most artefactual remains such as historic ports being developed to service the marine renewable industry. Zones of high wave and tidal energy favourd for renewable energy devices include navigation channels and hazards where a large number of wrecks are documented. Transmission cable routes cross deep water where 20th-century wartime losses occurred. Planning and development of infrastructure relating to renewables may also interact with significant built heritage and archaeology on the foreshore and coast edge.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

The coasts and seas around the UK have long provided a source of subsistence and energy, security from invasion, and a springboard for trade and communication between neighbouring
communities and across oceans. As a result the seabed preserves a rich heritage. Lighthouses, harbours, coastal settlements and the wrecks of ships enhance the distinctiveness of maritime areas, attracting visitors to Scotland.

Over the last 40 years there has been a growing recognition that this heritage merits responsible stewardship in much the same way as heritage on land. The UK’s international commitments to this effect followed ratification in 2000 of the European Convention on the Protection of the Archaeological Heritage, commonly known as ‘The Valletta Convention’. EC Directives transposed into UK and Scottish legislation impose obligations to consider significant impacts on cultural heritage on land and underwater arising from plans, programmes and strategies through a process of ‘strategic environmental assessment’; developers must undertake ‘environmental impact assessment’ when planning individual developments and marine works above a certain threshold. The Marine (Scotland) Act 2010, introduced a statutory marine planning system with national and regional tiers, and a streamlined marine licensing system administered by Marine Scotland, a directorate of Scottish Government. In developing marine plans and issuing marine licenses, Marine Scotland is obliged to consider cultural heritage and sites of historical or archaeological interest. The 2010 Act also includes powers for Scottish Ministers to designate Historic Marine Protected Areas where they consider this desirable to preserve marine historic assets of national importance. These powers are administered by Historic Scotland, an executive agency of Scottish Government.

The Marine (Scotland) Act 2010 was seen by the Scottish Government as providing the tools to help deliver increased sustainable economic growth and a vision for ‘clean, healthy, safe, productive, biologically diverse marine and coastal environments, managed to meet the long-term needs of people and nature’ (Scottish Government, 2010a). As part of this vision, the Scottish Government’s stated priorities included to ‘take advantage of opportunities for developments in marine renewables and offshore wind energy to contribute towards both ambitious climate change targets and socio-economic benefits for Scotland’.

The waters surrounding the Orkney archipelago (Fig. 1) have high potential for wave and tidal energy. There are strong tidal streams, particularly where water is forced through constrained channels such as along the 10 km-wide Pentland Firth, and around headlands such as War Ness on Eday. Wave conditions are most severe in the exposed coastal areas on the west side of the islands. Building on initiatives such as the 2001 establishment of Orkney’s European Marine Energy Centre, the Scottish Government identified Orkney Waters and Pentland Firth as a priority area for marine renewable energy (Scottish Government, 2010b). Working with partners, including the Crown Estate, Marine Scotland has since progressed a range of enabling actions from research and seabed surveys, to the establishment of the Saltire Prize, and preparation of regional locational guidance for developments in an area recognised for its outstanding marine environment. Pentland Firth and Orkney Waters were classified as a Marine Energy Park in July 2012.

Orkney and Caithness are also rich in archaeology and built heritage. Survival of prehistoric archaeological sites indicates that the area has been inhabited since at least the Mesolithic (c. 12,000 to 6,000 Before Present [BP]). The rich heritage of the area since that period is best illustrated by appreciation of the Heart of Neolithic Orkney World Heritage Site (WHS), comprising monuments of outstanding cultural value at Ness of Brodgar and Skara Brae on west Mainland Orkney. Since 2009, marine geophysics, diving and intertidal survey by the Rising Tide Project is resulting in a much more systematic investigation into the character of submerged landscapes and the possibility of submerged prehistoric sites within the Bay of Firth and Loch of Stenness near the Ness of Brodgar. This research may transform our understanding of the landscape around the WHS and offer fresh insights for Orkney as a whole (Bates et al., 2011, 2012).

In the Medieval period, Caithness and Orkney were important areas of Pictish and then Viking or Norse settlement. The islands and channels of Orkney have long been associated with trade and exploration and the Vikings used their maritime superiority to dominate the seaways. From the early 18th century, Stromness benefited most from the north Atlantic trade with its sheltered harbour and easy access to the sea for the Hudson’s Bay Company ships and whalers (Thomson, 2008). Commercial herring fishing developed rapidly in the 19th century at ports such as Stromness and Whitehall on Stronsay. Evidence of Scapa Flow’s use as a Royal Navy base (Hewison, 2005) is very apparent with numerous wartime wrecks surviving in the harbour and surrounding waters (Forbes, 2002, 2006). Scapa Flow was the scene of the internment and subsequent scuttling in 1919 of 74 ships of the German High Seas Fleet and the infamous sinking at anchor of the battleship HMS Royal Oak, torpedoed in 1939 by the German submarine U-47. To prevent further U-boat attacks and to provide a road joining the islands between Mainland and South Ronaldsay Winston Churchill ordered the construction of fixed barriers, known today as ‘the Churchill Barriers’. Lyness on Hoy was a Royal Navy base in the 20th century and along with Copland’s Dock in Stromness Harbour they are presently being developed to service the new marine renewable industry.

Effective development planning that takes account of cultural heritage in decision-making benefits from reliable, up-to-date information on the historic environment. Historic Scotland and the Built Environment Forum Scotland (BEFS) (2009) observed that inventories of archaeological sites on the seabed around Scotland were at an early stage of development and that steps needed to be taken to improve the quality of information available to support new marine planning and licensing systems. There was particular recognition of the potential benefits of interrogation by archaeologists of the wide range of marine survey data being gathered by public sector organisations and industry (Wessex Archaeology, 2011). Historic Scotland and the Royal Commission on the Ancient and Historical Monuments of Scotland (RCAHMS) established Project Adair in July 2011 to improve the information held about Scotland’s marine archaeological sites within the ‘Canmore’ national database (www.rcahms.gov.uk) which included about 24,000 maritime records at that time. Project Adair was completed in May 2013 (RCAHMS, 2012; 2013). The integration of information from two key national datasets has resulted in large numbers of new records and improved locations for existing records of archaeological sites around the Scottish coast (Table 1).

Further work included the creation of a wreck density map for Scotland, the cataloguing and digitisation of all maritime reports submitted to RCAHMS in recent years, and the digital archiving of Dr Colin Martin’s collection of photographs and drawings from key Scottish shipwreck excavations.

As part of Project Adair, in October 2011 Historic Scotland commissioned Orkney Research Centre for Archaeology (ORCA) to carry out a desk-based assessment for Orkney Waters and the Pentland Firth. The brief required ORCA to work with RCAHMS and the Local Authority Archaeology Services for Orkney and Highland Councils to ensure that an improved record for this area could swiftly be made available to inform marine planning and developments, particularly those associated with the rapid expansion of marine renewable energy in Orkney Waters and the Pentland Firth (Pollard et al., 2012). The project also set out to evaluate the benefits of interrogation by archaeologists of a wide range of marine data sets as sources of information to improve knowledge of the survival of cultural heritage on the seabed. This paper discusses
Fig. 1. Orkney and the Pentland Firth showing places mentioned in text (Contains SeaZone Solutions Limited, 2005, [SZ 112011.016] and Ordnance Survey data © Crown copyright and database right 2010).
the methods and results of the Orkney Waters and Pentland Firth investigation, completed in March 2012.

2. Material and methods

An ArcGIS project was established for the project area (0–12 nautical miles from the high water mark [HWM]) with Ordnance Survey (OS) OpenData and SeaZone Hydrospatial being used as base maps. Various databases provide information on located archaeological sites in the intertidal zone and offshore and the following baseline datasets were obtained:

- Maritime archaeological sites curated by RCAHMS (1,620 records of located sites);
- RCAHMS documented losses of ships and aircraft without specific location (1,286 records of unlocated sites);
- The Highland Council’s Historic Environment Record (HER) (825 maritime records);
- Orkney Councils Sites and Monuments Record (SMR) (113 wreck records);
- Wrecks data from the UK Hydrographic Office (UKHO) available through SeaZone Hydrospatial.

SeaZone Hydrospatial marine mapping data in shapefile format was supplied in both WGS1984 and OSGB1936 coordinate systems. Most of these wrecks or suspected wreck sites had two sets of source data, provided as two distinct points in the shapefile. The original sources were usually S-57 Electronic Navigation Chart data and UKHO wrecks and obstruction data. The attribute data for these points name any identified wrecks, give details on dimensions, depth, the nature of the seabed, when the wreck was identified, any subsequent surveys and how the wreck was located. The latter attribute was especially useful as it enabled the project team to ascertain the accuracy of the plotted point data.

A variety of non-geophysical datasets were gathered for analysis. These included:

- Vertical and oblique aerial photography coverage supplied by RCAHMS;
- Admiralty and historic charts from the National Library of Scotland and the UKHO;
- Summary of cores from British Geological Survey (BGS) website [http://www.bgs.ac.uk/GeoIndex/] and comparison of six sample cores were obtained from the BGS;
- Local knowledge from commercial and research projects, websites, government officials, harbour authorities, fisheries, dive clubs along with dive and boat operators.

Table 2 shows the geophysical datasets acquired. Marine geophysical survey involved multi-beam echo sounder (MBES), side-scan sonar (SSS) and sub-bottom profiler (SBP). MBES covers larger areas of the seabed producing a 3D digital terrain model (DTM). Depending on the data resolution it is possible to make out shipwrecks and natural features such as sediment waves, bedrock outcrops, and submerged palaeochannels and wave-cut notches from when sea level was lower (Westley et al., 2011; Plets et al., 2011). SBP generates sound waves that reflect off boundaries or objects within the seabed such as sediment, peat, bedrock or wood. This produces a two-dimensional dataset showing a cross-section of the seabed (Bowens, 2009). SSS provides images of the sea

### Table 2

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Database size</th>
<th>New records added to Canmore</th>
<th>Updated records added to Canmore</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Kingdom Hydrographic Office (UKHO) wrecks database</td>
<td>Over 5200 entries</td>
<td>3680</td>
<td>1572</td>
</tr>
<tr>
<td>Ian Whittaker (1998) work on maritime losses</td>
<td>Over 18,000</td>
<td>5434</td>
<td>4000</td>
</tr>
</tbody>
</table>

### Table 1

Scottish maritime datasets added to Canmore.

<table>
<thead>
<tr>
<th>Data source</th>
<th>Data type</th>
<th>Data date</th>
<th>Area covered (km²)</th>
<th>Data quality</th>
<th>How analysed</th>
<th>Anomalies</th>
<th>Shipwrecks</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crown Estate</td>
<td>SSS</td>
<td>2011</td>
<td>13.86471</td>
<td>Possible to discriminate aspects of the seabed such as areas of loose sediment (including sand, gravel and boulders) from bedrock. This makes it possible to determine the potential for survival of cultural material.</td>
<td>Viewed in DeepView FV 3.0</td>
<td>39</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Crown Estate</td>
<td>MBES</td>
<td>2011</td>
<td>13.86471</td>
<td>The resolution of the data was always less than 0.2 –0.3 m and often less than 0.1 m. The 2 m-resolution of the data is sufficient to make out gullies, gorges, basins, areas of bedrock and sediment waves.</td>
<td>Viewed in Fledermaus 7.2.2e</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Marine Scotland</td>
<td>MBES</td>
<td>2011</td>
<td>230.967</td>
<td>Resolution of varying quality from 20 m to 3 m. Only possible to identify large features such as iron shipwrecks and palaeochannels on lower resolution.</td>
<td>Viewed in Fledermaus 7.2.2e</td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>UKHO</td>
<td>MBES</td>
<td>1994 to 2012</td>
<td>5745.370634</td>
<td>Resolution of varying quality from 20 m to 3 m. Only possible to identify large features such as iron shipwrecks and palaeochannels on lower resolution.</td>
<td>Viewed in Fledermaus 7.2.2e</td>
<td></td>
<td>54</td>
<td>40</td>
</tr>
<tr>
<td>SeaZone</td>
<td>TruDepth Points</td>
<td>2011</td>
<td>22.698348</td>
<td>The resolution of the data revealed features of approximately 25 m or larger but was of insufficient resolution to support identification of smaller features.</td>
<td>Viewed in Fledermaus 7.2.2e</td>
<td></td>
<td>30</td>
<td>7</td>
</tr>
<tr>
<td>SeaZone Hydrospatial Survey</td>
<td>Shapefile</td>
<td>2011</td>
<td></td>
<td></td>
<td>ArcGIS 10</td>
<td>3</td>
<td>47</td>
<td>10</td>
</tr>
</tbody>
</table>
floor, which show aspects of seabed geomorphology and objects exposed on the seabed (ibid.).

Samples of SeaZone's TruDepth Points were obtained for evaluation purposes. This data provides a geo-referenced digital elevation model of the seabed, made up, preferentially, of high density, recent MBES data. However, as this is not always available the next best available bathymetry data is used, which could be less recent MBES data, high-density single beam data, or charted bathymetry data (SeaZone, 2011).

2.1. Data analysis

All data sets were interrogated for the presence of archaeological sites and potential for submerged landscapes. Where information was identified, polygons were created in ArcGIS to define in plan, the location and extent of the sites, following methodology established by RCAHMS under its Defining Scotland’s Places (DSP) Project (Middleton, 2010).

How the different types of data were analysed is shown in Table 3. To enable comparison of bathymetric data alongside GIS data, high resolution georeferenced images of each DTM were exported into ArcGIS. Geophysical anomalies were categorised by level of importance based on the criteria in Table 4.

Site and landscape information derived from data interrogation was entered into two Microsoft Access databases supplied by RCAHMS following liaison with the Local Authority Archaeologists for Orkney and Highland. Each record has a Project Unique Identifier (PUID) with a Polygon Identifier (PID). The first database included a consistent record for each site, using a RCAHMS monument-type thesaurus available online (http://orcaweb.rcahms.gov.uk/apex/f?p=210:1:0), a descriptive note with information on sources consulted, a record of location, and a concordance with existing site record numbers at council and national level. The second database is linked to the shapefile and was used to supply metadata with regard to:

- the nature of the source data e.g. MBES data;
- the accuracy of the above source data used to create the polygon;
- any extra buffering applied to compensate for any inaccuracies in the source data.

The DSP shapefile gave the assessor a choice of two different classes of polygon to use when creating the boundary for each new/ amended record:

a) Discovery polygons — used when there is no actual direct evidence for the existence of remains on the seabed. For example, in 1981 the steam trawler Celerity ‘disappeared in a force 8 to 9 westerly gale while heading in an easterly direction through Pentland Firth. No Survivors.’ The polygon in this case has a radius of 1000 m to cover an approximate area where the vessel was lost;

b) Known Site Extent polygons — used where there are known features on the seabed. For example, the wreck of the WW1 German destroyer SMS V83 off Rysa Little in Scapa Flow was digitised from observed geophysical data.

An assessment was made in drawing the boundary of any MBES anomaly to ensure that the entire feature lay within the boundary of its polygon.

Where there was no accompanying marine geophysics data a circular buffered point was created, centred on the appropriate record. The dimensions of such a feature depended on the dimensions of the feature or the historical length of the lost vessel, if known, and the accuracy of the recorded point.

2.2. Assimilation within the RCAHMS Canmore database and onward dissemination

Each site created during the project was assigned a unique identifier within the Canmore database which allows it be linked with individuals, bibliographic sources, collection items and events, such as survey or excavation. The site-area polygons clarify the extent of the feature, and give an indication of the accuracy of the recorded location. This information is now publicly available through the RCAHMS website (www.rcahms.gov.uk) and through related web sites such as PastMap (www.pastmap.org). Highland and Orkney Council Archaeology Services automatically receive copies of this data to support local heritage management and planning matters. Public users are able to submit comments and images to site records. The data is also published through the Scottish Government’s ‘National Marine Plan Interactive’ (http://marinescotland.atkinsgeospatial.com/nmpi/).

3. Results

The project resulted in the creation of 577 Canmore site descriptions describing 462 new sites, and updated information including more accurate locations for 115 previously recorded sites. These records can be characterised as follows.

3.1. Submerged palaeolandscapes and terrestrial archaeological sites

Submerged palaeolandscapes are previous terrestrial landscapes that have been inundated due to rising sea levels. These are features primarily of natural origin but which may contain evidence

<table>
<thead>
<tr>
<th>Table 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Methodologies used to analyse the data.</strong></td>
</tr>
<tr>
<td><strong>Type of data</strong></td>
</tr>
<tr>
<td>Bathymetry</td>
</tr>
<tr>
<td>Side-scan sonar</td>
</tr>
<tr>
<td>Sub-bottom profile</td>
</tr>
<tr>
<td>SeaZone Hydrospatial DTM</td>
</tr>
<tr>
<td>Charts</td>
</tr>
<tr>
<td>Aerial photographs</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definitions of importance of geophysical anomalies.</strong></td>
</tr>
<tr>
<td><strong>Level of geophysical importance</strong></td>
</tr>
<tr>
<td>High</td>
</tr>
<tr>
<td>Medium</td>
</tr>
<tr>
<td>Low</td>
</tr>
</tbody>
</table>
relating to past environmental conditions and human settlement. The submerged landscape around Scotland is still little understood due to land displacement and rebound caused by the pressure of ice sheets and glaciers. The time of maximum thickness and extent of the ice sheet over Scotland is not precisely known, but is presumed to have coincided with the coldest phase of the last glacial period at c. 20,000 to 18,000 BP (Boulton et al., 1991). Since the Ice Age, however, around Orkney the melting of the global ice sheets has caused rising sea levels (Wickham-Jones, 2010). An understanding of sea-level change is crucial to our knowledge of the evolution of coastal areas during early settlement of the Northern Isles. Models suggest that by 18,000 BP there was dry land from Caithness to Shetland (Flemming, 2003, 2004). The lithic artefact discovered off the Viking Bank (to the east of Shetland) from a depth of 145 m indicates these environments were being exploited (Long et al., 1986). In 1990, a serpentinite axe was also discovered amongst peat during dredging in Bressay Sound, Shetland (Hall and Fraser, 2004).

The Rising Tide project’s mid-late Holocene sea level curve for Orkney exhibits a very rapid rise from c. −45 m at 10,000 BP to −6 m around 6,000 BP (Bates et al., 2012). This means that there is potential for once-terrestrial sites dating from the Neolithic and earlier, to presently be situated below the HWL. Wickham-Jones (2010) has said that the reason Orkney has yielded few Mesolithic sites is due to submergence of the ancient coastal areas that would have formed the preferred locations for Mesolithic settlement.

The data gathered by the Project Adair team is of sufficient quality to enable some degree of submerged landscape reconstruction, with the existence of possible palaeochannels from periods of lower sea levels evident in the sample interrogated (Figs. 2 and 3). However, targeted coring would be needed to confirm this. West of Mainland the submerged bathymetry varies from around 100−240 m depth. The seabed topography could be the remains of submerged glacial valleys during the Pleistocene. The till recorded in the core data indicates that glaciers and ice sheets were previously active in this area.

Some BGS cores and grab samples contain sediments of terrestrial origin, suggestive of land submergence including weathered rock at depths of around 70−80 m off North Ronaldsay and rounded pebbles at a depth of 70 m off Sanday. The predominant seabed sediments from the cores and grab samples to the north, east and west of Orkney are shelly sand and gravel. The pebbles could be evidence of a still stand beach. In the sheltered area of Dunnet Bay in Caithness, at water depths of around 30 m, shell sand lies over fine sand, which could be aeolian or again related to a now submerged beach. Deep cores have revealed till or boulder clay lying below this marine sediment on the western and eastern side of the islands. The boulder clay off the coast is found at water depths of at least 60−70 m. This is of archaeological interest as it indicates sea level when the ice sheets were retreating and there is the potential for early humans to have exploited this environment prior to inundation. Finer sands and mud have been recorded in more sheltered areas such as Sanday Sound and within Scapa Flow. These finer grained sediments are more likely to retain in-situ archaeological deposits as opposed to the higher-energy exposed coasts where sediments could have been re-deposited.

### 3.2. Wrecks of ships and aircraft

The project recorded evidence for 133 shipwrecks and six aircraft crash sites. The wreck density map for Orkney Waters and Pentland Firth delineates high concentrations of shipping losses within Scapa Flow, reflecting its importance as a harbour since at least Norse times (Fig. 4). A key factor in this statistical weighting is the scuttling of 74 vessels of the German High Seas Fleet in 1919 and the sinking of blockships at the eastern and western entrances to Scapa Flow to defend the harbour in WWI and WWII. There are other high concentrations of losses around Thurso, Kirkwall and Stromness, reflecting the historic use of these harbours; and around Stroma in the Pentland Firth, Sanday and North Ronaldsay, all well-known dangers to shipping in transit between the Atlantic and the North Sea through Orkney. This is especially true of North Ronaldsay, as any ship attempting to cut through here runs the risk of being blown onto surrounding navigational hazards such as the Reef Dyke. Losses are evident throughout the inshore coastal zone of Orkney and Caithness, albeit at much lower concentrations. In the case of ‘a brig reported foundered on the Cuthe Bank in North Sound’, reference to a vessel’s loss has been delineated on 19th-century Admiralty charts (see Thomas, 1848).

Given the extent of maritime activity around Orkney waters since prehistoric times, numerous losses of early vessels will have occurred. For example, the Orkneyinga Saga (written in Iceland in the 13th century), records a sea battle off North Ronaldsay during which losses are likely (Thomson, 2008). However, most of the wrecks reported in documentary sources relate to the 18th to 19th century or later periods when the more or less systematic recording of wrecking incidents began. The locations of earlier shipwrecks often come to light through local knowledge following chance discoveries, for example by divers or local fishermen. Local information has included reports of an amphora wreck at the Grinds in Scapa Flow and the location of possible Spanish Armada wrecks off Gairsay and South Ronaldsay. Community tales abound throughout Scotland of wrecks from the 1588 Spanish Armada and are not always correct. A shipwreck off Shapinsay thought by locals to be from the Spanish Armada, was revealed by investigation to be that of the Spanish Armada.
of a Spanish ship carrying fish oil and wrecked in 1862 (Kevin Heath, personal communication). However, local knowledge was instrumental in recording the fate of the crew of the 18th-century Swedish Indiaman *Svecia* wrecked off North Ronaldsay and subsequently investigated by archaeologists (Cowan, 1980). Local knowledge proved particularly helpful to Project Adair in verifying the identification of geophysics anomalies around Lyness and in relation to aircraft crash sites. For example, in December 2011, a local diver looking for lost creels discovered and reported a Seafire aircraft, which crashed in 1943 in Eynhallow Sound (ARGOS, 2010). Most wrecks identifiable from geophysics data are of 20th-century date. Key elements of the surviving shipwreck resource include the complex of wartime remains within Scapa Flow, particularly the seven remaining intact wrecks of the German Fleet and debris fields associated with the salvage of the fleet, located close to the island of Cava. These have been surveyed in detail by the ScapaMap project (Forbes, 2002, 2006). Analysis of SeaZone TruDepths data for the area around Lyness confirms that there is a high degree of debris survival extending into Gutter Sound reflecting the extent of losses and the intensive salvage operations of the German High Seas Fleet (Fig. 5). Blockship graveyards are visible to the eye at Churchill Barriers 2, 3 and 4. UKHO MBES data confirms extensive surviving subtidal blockship remains at Churchill Barriers 1 and 3, as well as across Burra Sound. Conversely, the density of wreck sites in the SMR around Stromness and Stroma did not show up on the MBES surveys despite their high resolution. This may be because these surveys did not extend very close inshore where most of the wrecks are likely to have occurred.

In the deeper waters off the east coast fifteen wartime shipwrecks are identified on SeaZone Hydrospatial data, compared to three off the west coast. The site losses have been previously charted but the project has provided more accurate Canmore locations for wrecks such as the Norwegian steamship *Vestfoss* bombed by German aircraft in 1940 to the east of Copinsay. This was shown on the MBES data and identified from SeaZone Hydrospatial to be 18.5 km NE of Copinsay. The concentration of wrecks probably accords with most Royal Navy/merchant activity traversing the east side of Orkney and into Kirkwall Harbour where neutral/impounded ships would be taken for inspection, and other patterns of wartime shipping. The activity of the German High Seas Fleet was concentrated to the east of Orkney during WWI (Stell, 2011). During WWII, the Royal Navy would deploy from the south side of Scapa Flow heading east into the North Sea to patrol the Denmark Strait or north for Shetland to defend the Arctic convoys (Hewison, 2005). Returning Arctic convoys gathered on the west coast of Scotland where they would then steer NE from the NW point of Scotland for Shetland and beyond (Woodman, 2004).

The wreck of the Norwegian steel sailing barque *Urania* (built in 1891 and sunk by a torpedo from UC-42 on 28 March 1917) and German submarine *U-27* are good examples of how the UKHO MBES data compares with other datasets (Fig. 6) and how inaccuracies in historic environment records can usefully be resolved.

The *Urania* was already recorded in Canmore (ID 102375) at an approximate location east of Stronsay, the source of which is Whittaker (1998) who records the loss by a mine. Within the current project a geophysical anomaly was identified as the *Urania*...
from UC-42’s Kriegstagebücher (U-boat war diaries), which records torpedoing the ship in this area and has been confirmed by recent high-resolution MBES survey and divers (Kevin Heath, personal communication).

This identified wreck may be associated with the previously assumed wreck site of the German submarine U-27 where no geophysical anomaly can be seen. Canmore, using UKHO information, recorded the loss location as approximate, while another UKHO source note that U-27 was lost off Lewis. It is possible that the wreck of the Urania was mistakenly thought to have been the U-27 by the Royal Navy on echo-sounding patrols to find submarines in September to October 1939 and a target was depth charged in this area. This has led to an approximate location for the U-27 to be in the vicinity of the Urania wreck. There is another visible anomaly present in the MBES data (PUID20) but there is no identification at present.

3.3. Geophysical anomalies

Interrogation of geophysics data identified 146 anomalies, of which 23 are of low, 47 medium and 76 high archaeological potential. Further investigations would be required to understand these features more fully.

Crown Estate SSS from the exposed NW inshore coast of Mainland Orkney revealed features more easily on sand than bedrock, which may explain identification of a concentration of anomalies located 600–1200 m from the west Mainland coast from Marwick to Yesnaby (Fig. 7). This is due to the presence of light coloured sand seaward of the shallower bedrock subrate. The Crown Estate MBES data also revealed anomalies (Fig. 8) but divulged less information on the seabed environment than the SSS data. Fig. 7 shows a possible shipwreck anomaly on the seabed in around 18 m of water, c.116 km from the entrance to the Bay of Skail. It is 13.4 m by 5 m on sand and gravel seabed. Another feature of medium potential is 37 m away, and is identified by an acoustic shadow 10 m by 14 m and 5 m high, suggesting presence of further upstanding wreckage.

3.4. Harbours, anchorage areas, fishing grounds and other features of a maritime cultural landscape

Marine charts proved useful for identifying aspects of the historic character of the coastal zone such as harbour systems, anchorages, ferry routes and fishing grounds used at specific periods. RCAHMS aerial photographs revealed individual features such as fish traps, piers, tidal fords, causeways, and landing places.

Built features such as piers and causeways can be of significance in their own right. By virtue of their intensive use over time, the seabed surrounding harbours, anchorage areas and fishing grounds can also be of high archaeological potential, as is evidenced from artefacts that have come up in dredging operations and fishermen’s nets, for example finds recovered from sediment disturbed by propeller wash in Stromness Harbour and a lost anchor left on the Corn Slip after dredging around Kirkwall Harbour in 2011 (Fig. 9).

At Stromness, an Admiralty Chart (1813) depicts the 19th-century waterfront and anchorage, and aerial photographs reveal port features at the Outer Holm relating to the herring industry, demonstrating the evolution of Stromness Harbour since its origins in the 16th century (Figs. 10 to 11). Smaller harbours are commonplace. For example, a previously unrecorded small harbour was identified at Sand Wick, South Ronaldsay following a report by local people of ship’s ballast on the beach. Beach clearings are also widespread where larger rocks have been removed to allow a boat to land safely. Many of these will not be recorded but a boat landing and boat clearings on Fara are marked on a 1923 Admiralty Chart (Fig. 5). A landing place observed in aerial photographs at Quindry, Widewall Bay is probably associated with the 18th-century herring fishery at Herston; while the port of Brims on the Caithness coast appears associated with the nearby 16th-century Brims Castle. Other examples of enhancing natural features include a possible fishtrap or landing place at the Rough of Rerwick that appears to have been constructed by enhancing a natural 200 m-long spit, known as an ‘ayre’ enclosing a tidal pool.

Many parts of the coast show tidal fords or causeways built to facilitate access between tidal islands. Examples include the Outer and Inner Holm and Mainland on Stromness, and the Holm of Grombister in the Bay of Firth. Causeways are often found near associated archaeological sites of contemporary date, such as an Iron Age midden on Copinsay (Canmore ID3252) and a farmstead on the Inner Holm (Canmore ID173922). Admiralty charts (1900, Chart 2581) depict a ferry crossing of Water Sound between Burray and South Ronaldsay that pre-dates the WW2 construction of the Churchill Barriers.
Admiralty charts depict 25 anchorages during the 17th century. In the 18th century, there were around 90 anchorages, including Thurso Bay and Scapa Bay but some earlier anchorages such as east North Ronaldsay no longer appear on charts. By the early 20th century, anchoring was prohibited in large areas of Scapa Flow, including entrances to the harbour in order to manage access to the naval base. The anchorages for the fleet were north of Flotta and south of Scapa Bay and there was a torpedo range south of Smoogro Bay in Scapa Flow (Admiralty chart, 1923: 3729). Anchorage sites may still retain the mooring points and rubbish thrown overboard where the British fleet was stationed to the north of Flotta during the World Wars. Some of the geophysical anomalies recorded on the seabed in this area are likely to relate to the remains of the extensive network of boom defences deployed to defend the Grand Fleet. Of particular note is regard is the surviving site of the Clestrain Hurdles (Stell, 2011), a fixed defence across Clestrain Sound constructed during WW1 (Fig. 12).

Fishing areas for cod and ling were important enough commercially to be marked on the 17th- and 18th-century charts especially along the west coast from the mouth of the Westray Firth to the western Pentland Firth. In 1794, the fishery at South Walls was catching 50,000 to 70,000 fish each year (Thomson, 2008) and many of the port developments including slipways, piers and beach clearings recorded around Widewall Bay, Whitehall and Stromness probably date to the boom in the 19th-century herring fisheries. The settlements, the havens, the route to the fishing grounds and the fishing grounds themselves are all part of a maritime cultural landscape. The artefact traces of this ‘tradition of usage’ as defined by Westerdahl (1992) could be ephemeral due to the biodegradable nature of the materials used and the relatively smaller size of craft.
to the cargo vessels. However, in the right conditions traces of net weights and shipwrecks could be found, providing evidence for time period and intensity of use of a fishing area.

4. Discussion

4.1. Data quality and effectiveness for enhancing historic environment records

The quality and coverage of the geophysical data varied considerably (Table 2). The Crown Estate provided high resolution SSS and unprocessed MBES data at the highest resolution (0.2–0.3 m) from surveys along the north and west coasts of Mainland Orkney. Obtaining data at this resolution allows archaeologists to build up a detailed picture of cultural material on the seabed, as well as making it possible to determine the potential for survival of cultural material by identifying gullies, areas of bedrock, sediment and marine bedforms. Although lots of ‘spikes’ or possible ‘bad data’ were present, possibly caused by natural and physical phenomena such as ship turns or fish, this is preferable to gridding of MBES data by an inexperienced data processor in such a way as to remove spikes that may actually depict cultural material. By contrast, the UKHO MBES data varied in quality from 3 m-resolution in some cases, to 20 m in others depending on the purpose for which the data was gathered and how it has been stored. While data at 20 m resolution might be sufficient for mapping deep water areas and can still detect wrecks of large ships of metal construction in some instances, there is generally insufficient information to confirm identification of anomalies as wrecks without corroborating from other data sources, such as wreck point data supplied by SeaZone, RCAHMS or the Local Authority SMR/HERs.

Most of the shipwrecks recorded in the geophysical data were less than c. 100 years old and no pre 17th-century wrecks were recorded. This position reflects that of Plets et al. (2011) examination of MBES data off the north coast of Ireland. It is likely that remains of earlier wrecks of mostly small, wooden vessels will survive within the project area, either buried in sediment, or as scattered sites consisting of artefacts that are less prone to degradation (for example anchors and cannons). However, detection by MBES or SSS alone will be impossible in the case of buried material; higher data resolution is needed to discover artefacts scattered on the seabed. The resolution of the Marine Scotland MBES data was capable of detecting sediment scours on the seabed arising from tidal current fluctuations in moderate to high-energy environments around anomalies that were probably shipwrecks. The presence of bedforms and scours features provides evidence of the local seabed conditions. Understanding this is useful for predicting the extent of survival of archaeological sites as structures such as shipwrecks will both affect and be affected by natural environmental factors including currents, waves, sedimentary processes, metal corrosion and boring of organisms (Ward et al., 1999).

Stone and wood-built fish traps have previously been identified from aerial photographs of the intertidal zone at locations around Britain (Dawson, 2004). RCAHMS aerial photographs proved to be a useful resource for studying foreshore and shallow inshore sites across Orkney Waters and Pentland Firth. Marine fauna growth on a stone man-made dyke or pier situated below the HWL made such features stand out on an aerial image amongst sand or mud substrate. Other satellite and aerial photograph images from websites such as Google Earth were found to have higher quality, albeit more recent, images than that available from the RCAHMS. All available imagery should be studied for intertidal and shallow water investigations as there are big differences in the height of image taken above the earth’s surface, resolution of the image, time of day taken, whether black and white or colour image, cloud cover, the stage of the tide, and sea state. For example, the aerial photographs studied for the Caithness coast around Thurso were taken at a time when the sea was rough and the tide high. As a result, fewer sites could be identified.

4.2. Data gaps

Gaps in data coverage can be identified that limit efforts to improve knowledge about the marine archaeology of Orkney and Pentland Firth waters. With the possible exception of waters close to ports and harbours, there is less survey data available for the shallower, sheltered, sediment-rich nearshore areas than for areas further offshore, possibly because of the difficulties for survey vessels of navigating close inshore. This data gap is significant because shallow coastal areas are precisely the types of locations where the majority of archaeological features are likely to survive. A shortage of BGS SBP data for water depths shallower than 25 m around Orkney limits our understanding of past sea level change and submerged landscapes. BGS core and grab samples are much more evenly dispersed than the SBP tracks and they cover areas between the islands of Orkney and the Pentland Firth. However, the samples generally decrease in density northwards and there are fewer in the channels around the Westray and Stronsay Firths. The cores and grab samples rarely penetrate deeper into the substrate than 1 m. They have also been taken at water depths greater than around 10 m, a factor which may explain why no evidence of peat was observed in any of the cores; even though peat has been recorded on the intertidal zone since the 19th century around Orkney and Caithness (Denniss, 1999; Sharman, 2008).

Most MBES surveys are too far away from the coast to locate shipwrecks lost close to navigational hazards. Marine Scotland’s data covers the area of the Pentland Firth but extends only up to 500–700 m from the coast. Large unsurveyed areas include waters up to 2 km off the north coast of Caithness from Dunnet Head to Duncansby Head, the surrounding waters of Stroma and Swona, south of Hoy and South Walls, and south and west of South Ronalday. Even within harbours such as Lyness, the SeaZone Tru-Depth data did not cover depths less than approximately 10 m. Recent initiatives are beginning to fill these gaps such as The Crown Estate’s high-resolution surveys along NW Orkney Mainland where wave-energy devices are to be located. UKHO MBES survey data has also reached close inshore with depths of less than 1 m around Eday, where the EMEC tidal-energy test centre is located. Some marine energy projects still in the development and exploration stage are protected from the information being released to the public by confidentiality or non-disclosure agreements (NDA). It is important to realise that some information held by developers on seabed geomorphology, currents and archaeology is not yet in the public domain.

4.3. Archaeological potential of areas identified for marine renewables developments

A variety of complex natural and man-made factors dictate the extent to which archaeological material is preserved on the seabed (Historic Scotland, 2012). As such it can be difficult to make reliable predictions on the archaeological potential of specific locations. However, the results of this project allow some observations to be made in relation to areas where planning for renewables developments is underway. Lyness, Kirkwall and Copland’s Dock (Stromness) are actively being developed to service the marine renewable industry. These are historic ports used intensively over long periods. Reports of finds recovered from sediment disturbed by the ferry’s propeller
wash in Stromness Harbour, as well as dredging in Kirkwall Harbour and Lyness (Kevin Heath, personal communication) illustrate the potential for archaeology to be discovered during dredging works and the construction of new piers.

Marine renewables installations are located in high wave or tidal energy zones, for example off exposed coastlines (in the case of wave energy) or within tidal channels between islands (tidal stream). Nearby reefs, headlands and channels may have been located on historic sea routes and close to traditional fishing grounds where shipping losses are documented and where evidence relating to past human exploitation of coastal and marine resources, transport, naval history and trade may survive. For example, the Pictish and Norse settlement at the Brough of Birsay benefited from easy access to marine resources and control of sea routes. While preservation potential in high-energy areas is likely to be lower than more sheltered locations, high-energy environments are seldom uniform; they often contain niches within which low-energy conditions prevail, such as gullies and behind boulders. Within such niches, fine grained and delicate deposits can survive, preserving stratigraphic relationships and organic remains (Firth, 2013). For example, the Palaeolithic site of La Mondrée in Normandy, France, lies at 20 m depth in an area of coastal erosion (Cliquet et al., 2011). In Scotland, archaeologically stable levels were discovered in a gully off Fair Isle during excavations of the 1588 Spanish Armada wreck El Gran Grifon (Martin, 1998).

Fig. 13 shows known wreck sites and geophysical anomalies within expansive areas of exposed bedrock and occasional sediment-filled gullies in a wave-energy renewable area at Mar Wick on west Mainland Orkney. Nearby at Skail Bay, adjacent to the Neolithic settlement of Skara Brae, there are gullies in the bedrock outcrops and some areas of loose sediment overlying bedrock at depths of less than 10 m. Exposed intertidal peats are reported to survive within the intertidal zone providing evidence of past sea-level change, despite an apparently high-energy coastal location.

The Pentland Firth has been a major shipping channel linking the North Sea and the Atlantic Ocean. A large number of wrecks are recorded in this area. However, the geophysical data does not support identification of a correspondingly high concentration of wreck sites or even geophysical anomalies. This could be due to the MBES data not covering seabed close to the coast where shipwrecks are likely to have occurred. Alternatively, the high-energy environment characteristic of the Pentland Firth may explain poor survival. It is however notable that the SS Avra (lost 1941) survives in one piece on bedrock substrate (Fig. 14).

The Churchill Barriers that block Orkney’s inter-island channels east of Scapa Flow, have been recognised as potential tidal stream development objectives. Together with the rusting blockships, they provide visitors to Orkney with an important and highly visible reminder of the significance of the naval harbour of Scapa Flow. Before the construction of causeways, these and other narrow inter-island channels throughout the Orkney archipelago were used as ferry routes. Where losses occurred, it is possible that buried evidence may survive although vessels would have been small and remains difficult to locate.

To transfer energy from Orkney and Pentland Firth waters to mainland Scotland, there are requirements for transmission cables from individual developments to onshore substations, and a reinforced subsea cable AC link connecting Orkney to Caithness. Numerous wartime losses have occurred in deeper waters and
surviving sites are likely to be relatively easy to detect by pre-development cable-route hydrographic surveys. Where cable-laying projects transit areas of high-sedimentary cover, archaeological potential may be expected, particularly where sediments remain largely undisturbed close inshore, on the foreshore and at the coast edge. Such locations have the potential to conceal isolated finds, deposits and structures relating to all periods from prehistory to the recent past.

Scapa Flow is particularly rich in intact submerged sites, particularly around the islands of Cava, Flotta and in Hoxa and Burra Sounds. This sheltered harbour may also retain evidence of inundation by rising sea levels after the Ice Age: accumulated sediment and low-energy currents away from the harbour entrances provide a burial environment conducive to the long-term preservation of submerged archaeological remains. For example a worked plank of oak was discovered in 2013 in intertidal peat at Cummi Ness in the Bay of Ireland, a sea route from Scapa Flow into the Loch of Stennis and the Neolithic World Heritage Site near an ancient fording point called the Bridge of Waith. Evidence of submerged landscapes in the form of intertidal peat has been recorded in shallow embayments such as Sunday, Thurso Bay, Sidewall Bay and Skail Bay. Such sites have the potential to reveal in-situ evidence of submerged prehistoric settlement due to the lower-energy tidal regime and other factors supporting long-term in-situ preservation. More underwater survey work would be needed together with gathering and dating of marine core samples to identify possible areas of habitation and exploitation and submerged terrestrial features such as caves, peat and palaeochannels.

When addressing interactions between marine renewable developments and archaeology in Orkney Waters and Pentland Firth, there is a particular need to consider indirect effects on coastal processes. For example, given the coastal erosion problem experienced at Skara Brae, it would be useful to investigate the possible effects of wave developments west of Skara Brae on sediment transportation, erosion and accretion. At sites such as the Churchill Barriers, there will be a need to learn lessons from the Minas Passage of the Bay of Fundy (Karsten et al., 2007) and to consider indirect effects on the block-ships that might arise from changes in tidal currents and tidal range if the barriers are replaced with tidal-stream generating causeways.

5. Conclusion

RCAHMS and Historic Scotland accept that a basic and current maritime record now exists for the Scottish seas that can be updated as knowledge continues to improve. The Orkney Waters and Pentland Firth desk-based project was particularly valuable in testing an area, as opposed to an archaeological site investigation; and in evaluating the wide range of marine data now being gathered across Scottish seas in respect of its potential to answer questions about cultural heritage.

The original dataset supplied to ORCA included 9,986 located records for the project area (of which 1620 were maritime). Information on 1,286 unlocated records (i.e. those assigned a map sheet but not a grid reference) was also supplied. The 462 new records presented a significant increase in the overall maritime dataset. By March 2013, assimilation of this information within Canmore was completed. While the project benefited greatly from local contact with divers who were able to clarify the specific character of many otherwise unknown obstructions, over 344 remain classified as ‘Unidentified Object’. It is therefore difficult to verify the value of the numerical increase in records and the character and origin of these objects, without identification by higher resolution marine geophysics, intertidal field walking, diver investigation or use of a remotely operated underwater vehicle. Characterisation of areas as historic anchorages and fishing grounds raises a number of questions about how aspects of the historic character of sea areas are recorded in future projects and about how their cultural significance can be reflected in regional marine planning policy.

The large area approach to maritime record upgrade has also been tested and, although it was possible to study available survey data, it was not possible to undertake a complete ‘record revision’ of the dataset of c.2800 maritime records (unlocated and located) in the available timescale. Record revision on that scale is something that takes many years and has, in the past, been undertaken by national organisations such as the UKHO and the Ordnance Survey Archaeology Division.

The lessons learned from this project are being incorporated into the Orkney Waters and the Pentland Firth marine planning process, which in turn will feed into the decision making process on marine licenses by Marine Scotland, Orkney Islands Council’s works licensing and other relevant consenting mechanisms. The information may also be used in the future to inform consideration by Historic Scotland of a possible Historic Marine Protected Area for Scapa Flow. All Project Adair data is now available on Canmore and National Marine Plan interactive (NMP) and is automatically available to the Local Authority Archaeology Services. Dissemination by these mechanisms ensures that all stakeholders in marine energy developments, from heritage curators, planners, to developers and their consultants, as well as the public can access useful knowledge resources to aid research into our marine and maritime heritage and improve public appreciation and understanding of it.

When considering further priorities for Orkney Waters and Pentland Firth, there is a need for early integration of archaeological considerations where renewables and associated infrastructure developments are planned, both under EIA and consenting procedures and as part of any future enabling actions. The key data gaps identified by Project Adair are high resolution geophysical and geotechnical core surveys in sheltered, shallower inshore areas. Early integration of archaeological consideration can result in multiple positive outcomes. Data-gathering will be cost effective as archaeological and biological objectives can often co-exist where there are shared interests. Archaeologists will benefit from access to the highest quality survey data to address archaeological questions. Planners and developers will gain greater certainty and minimise ‘risk’ during planning and consenting processes. Important archaeological sites are avoided during development, and where this is not possible, such sites can be recorded before they are lost. Finally, improving the archiving of information derived from these investigations by following the guidelines of RCAHMS and the Marine Data Information Network (MEDIN), will ensure that knowledge gained can efficiently be fed back into the system, for the benefit of future planning and sustainable development within Orkney and Pentland Firth waters.

Acknowledgements

The authors are grateful to the editor and two unnamed referees for their comments, and to the following who provided data and advice: British Geological Survey — Paul H. Henni, Alan G. Steven-son; Crown Estate — John Robertson; Highland Council — Sylvia Tilbury; Marine Scotland — Peter Hayes; Maritime Coastalguard Agency — Helen Croxson, Richard Dean; Orkney College UHI — Jane Downnes; Paul Sharman; Orkney Islands Council — Julie Gibson; Rising Tides Project — Caroline Wickham-Jones, Richard Bates; SULA Diving — Kevin Heath, Robert Forbes; UK Hydrographic Office — Sam Harper.
References


