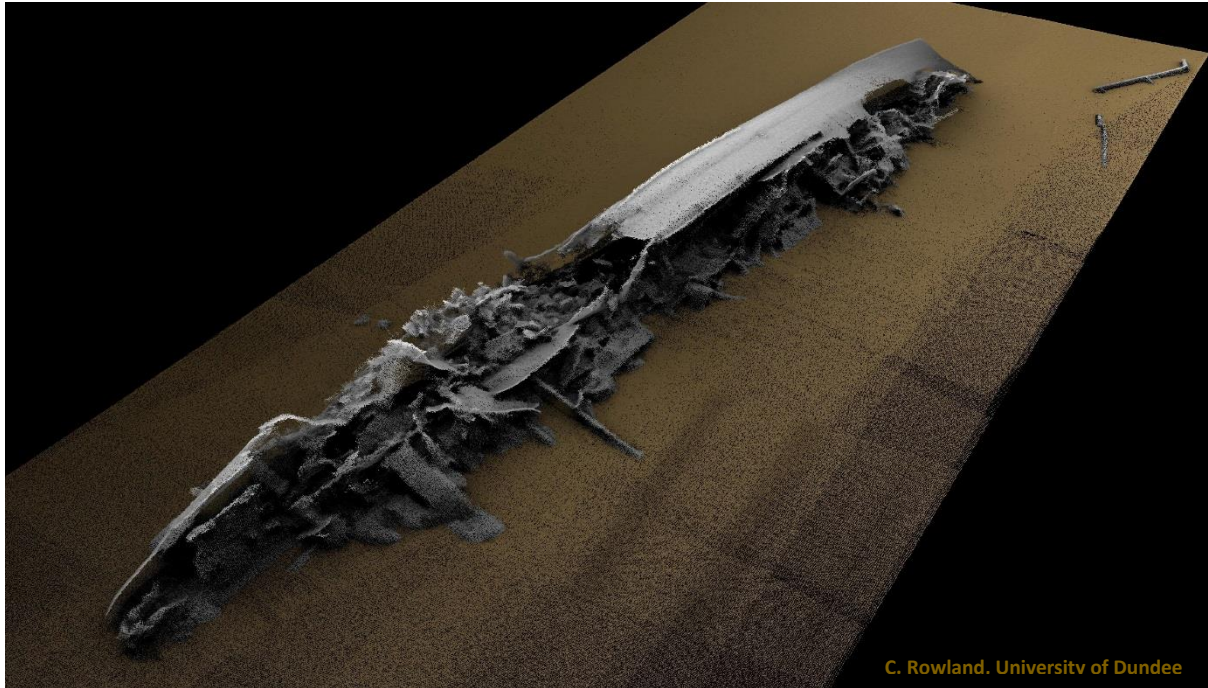


Scapa Flow Ship Time Project
A Collaborative Multidisciplinary Remote Sensing Survey,
Orkney



This report was written and compiled by Sandra Henry, The Discovery Programme and Kevin Heath, SULA Diving, on behalf of Historic Environment Scotland

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Executive Summary

This report outlines the data gathering phase of survey work undertaken in Scapa Flow Orkney on the wrecks of the High Seas Fleet and the Royal Navy vessels HMS *Hampshire*, HMS *Vanguard*, HMS *Pheasant* and HMS *Royal Oak*. This project involved a consortium of organisations that aimed to gather new data to further understanding of the extent, survival and character of submerged cultural heritage remains located on the Orcadian seafloor.

The report describes the fieldwork phase of the project only. It is anticipated that project partners will further process data gathered during this survey.

The survey project was conducted aboard the Marine Scotland vessel MV *Scotia*. MV *Scotia* provided the work platform for MBES, drop camera and Remotely Operated Vehicle (ROV) survey operations. MBES surveys used the drop keel mounted Teledyne Reson MBES system and were conducted by a Marine Scotland surveyor. Marine archaeologists from University of the Highlands and Islands and Ulster University provided input on data acquisition techniques for imaging wreck sites.

ROV surveys were conducted by a freelance pilot on behalf of Seatronics_An Acteon Company. Heriot-Watt University provided input into the specifications for data acquisition for the ROV survey and undertook marine biological studies on the submerged cultural heritage assets. The Ministry of Defence (MoD) provided input into the specifications for data acquisition for the geophysical and ROV surveys, specialist knowledge and environmental studies of the wreck sites. MV *Challenger* was the work platform for diver survey, side scan sonar (SSS) survey and interferometric bathymetry survey. SULA Diving led dive operations, side scan sonar surveys and provided vessel transfers. Triscom Marine Ltd undertook interferometric surveys. Funding support and advice was provided by Historic Environment Scotland (HES), and appropriate licences were granted by the MoD.

This survey successfully collected various forms of data that will inform monitoring of wreck sites, creating a detailed account of the sites for 2017, visualisations and the data will form the basis for furthering maritime archaeological research. The SSS and MBES surveys produced highly detailed pictures of the wreck sites, which combined with the ROV and diver surveys, documented the wrecks nearly one hundred years after sinking, mapping the extent of the wreck sites and their current condition.

The surveys and evaluations established the identity, extent, character and condition of the remains in support of Scotland's Archaeology Strategy (HES 2015; <http://archaeologystrategy.scot/>). The aims of this strategy are to help deliver archaeology, to enhance the understanding of our past, to help care for, value and protect our historic environment, to encourage greater engagement with our past, and to provide opportunities for innovation and development of skills. While it is not within the remit of this survey project to address management issues, the evidence from this project (and the outcomes of previous surveys) should contribute to HES and stakeholders' formulation of appropriate management and monitoring strategies for heritage assets within Scapa Flow and at a national level. This project provides baseline data for long-term monitoring of the sites, aiding promotion and protection of this submerged cultural heritage resource.

Acknowledgements

Sandra Henry and Kevin Heath authored this report. This project was a multi-disciplinary project that involved many individuals. Thanks are extended to the project team: Malcolm Thomson, Brett Green, Wayne Allen, Barry Kenyon, Joanne Porter, Kieran Westley, Matt Skelhorn, Polly Hill, Keith Rendall, Chris Rowland, Tris Thorne, Eric Armstrong, Neil Collie, Iain Gibbs, Michael Copeland, Eric Malcolm, Paul Sharman, Mark Littlewood, Sean Page and the crew of MV *Scotia*.

Thanks are extended to Philip Robertson and Andrew Fulton for their guidance and input throughout the project.

This project could not have happened without the support of the partner organisations, especially Historic Environment Scotland, which provided funding support; Marine Scotland, which provided the use of the MV *Scotia* and crew; and the Ministry of Defence, which granted the licences to undertake the work on protected wrecks.

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1. INTRODUCTION

This report outlines and summarises surveys undertaken on the wrecks of the High Seas Fleet and the wrecks of the Royal Navy vessels HMS *Hampshire*, HMS *Vanguard*, HMS *Pheasant* and HMS *Royal Oak*. This project gathered data to further knowledge and understanding of the extent, survival and character of submerged cultural heritage remains located on the Orcadian seafloor. This report outlines the data capture through marine geophysical survey, remote archaeological evaluation, and diver survey. This report does not go beyond the data capture to discuss processing or data interpretation. Further projects conducted by the partner institutions are ongoing or currently in development to utilise the data captured during this project.

The centenary of the scuttling of the High Seas Fleet is 21st June 2019. The High Seas Fleet was interned at the Royal Navy base Scapa Flow, Orkney at the end of the First World War (WW1). Admiral Ludwig Von Reuter ordered the fleet to be scuttled resulting in the sinking of 52 of the 74 interned vessels. Today, the seven wrecks that were not salvaged constitute one of the most famous wreck diving sites in the world. These wreck sites share the Orcadian seafloor with the structural remains and components of many of the salvaged vessels along with the evidence of the associated salvage activities.

The war graves HMS *Royal Oak* and HMS *Vanguard* are located within Scapa Flow, whilst HMS *Hampshire* and HMS *Pheasant* lie to the western seaboard of the Orkney Islands. Together with the numerous other forms of submerged wartime cultural heritage in Scapa Flow such as aircraft, drifters and torpedoes, Orkney offer an unparalleled collection of submerged wartime heritage within a confined area, due to Scapa Flow's function as a naval base in both World Wars. Indeed, the sheltered waters of the natural harbour of Scapa Flow could be regarded as an underwater museum.

The submerged heritage of Orkney is a complex collection of assets that require monitoring, management and protection to ensure their survival for as long as possible. These sites individually and in combination tell the story of many nationally and internationally significant events in the 20th century that have directly contributed to and moulded society and culture into the 21st century. These historical assets directly feed into the Orcadian and Scottish blue economy, acting as a stimulus for tourism. The wreck sites offer insights into engineering and technological advancements of their time. Data from these wreck sites help further understanding, knowledge and techniques in many fields of research and public interest, including maritime heritage management, wreck site formation processes, marine geophysics, wartime and naval research, and the wildlife colonisation of artificial reefs.

2. PROJECT BACKGROUND

This project builds on and complements previous projects undertaken and conducted in Orkney. The ScapaMap Project (2001-2006) and Scapa Flow Marine Archaeology Survey (2013) previously imaged the remains of the High Seas Fleet and wrecks of the Royal Navy. Previous projects have produced baseline and monitoring data for the submerged heritage resource, recording the extent and condition of submerged historic assets in the area. These projects have cumulatively helped to map and record large extents of the cultural heritage resource situated on the seabed throughout Scapa Flow, and within the wider context of Orkney. Projects include:

- High Seas Fleet Salvage Sites, Orkney by ORCA Marine and SULA Diving in 2017 funded by Historic Environment Scotland (HES) (Henry et al. 2018);
- Lost Aircraft of Scapa Flow, Orkney by ORCA Marine and SULA Diving in 2016, funded by HES (Henry et al. 2016a and 2016b);

- Geophysical survey of the HMS *Hampshire* in 2016, by ORCA Marine, Seatronics & Teledyne Reson (Henry and Littlewood 2017);
- Roan Head Boom Buoy Vessel Project conducted by ORCA Marine and SULA Diving in 2015 as part of the HES funded project to undertake archaeological assessment of submerged wartime defences off Roan Head, Flotta (Christie et al. 2015; Christie et al. 2016);
- Side scan sonar (SSS) and diving surveys of the blockships at the Churchill Barriers and lesser known wartime wrecks around Scapa Flow conducted by ORCA Marine and SULA Diving in 2013 as part of the HES funded Scapa Flow 2013 Marine Archaeology Survey (Christie et al. 2014);
- HES-funded multibeam echosounder (MBES) surveys completed by Wessex Archaeology (WA) in 2011 to map the blockships in Burra Sound and other wartime wrecks (HMS *Strathgarry*; *UB116*; the *F2* and *YC21 barge*; *S54*; *V83*; and *Dewey Eve*) (Dresch and McCarthy 2012);
- Desk-based assessment (DBA) work to improve the record of the marine historic environment conducted as part of H[E]S and the Royal Commission for Ancient and Historic Monuments of Scotland (RCAHMS) Project Adair (Pollard et al. 2012; Pollard et al. 2014);
- MBES surveys in 2001 and 2006 by ADUS (Archaeological Diving Unit Scotland) as part of the HS funded ScapaMap project to map the remains of the scuttled German High Seas Fleet and the area of the Royal Navy Anchorage including the dispersed remains of the HMS *Vanguard* (Forbes 2002; Forbes 2006); and
- Ministry of Defence (MoD) surveys of the HMS *Royal Oak*.

3. THE PROJECT PARTNERSHIP

The project involves a consortium of organisations, led by ORCA Marine, University of the Highlands and Islands Archaeology Institute. The partners include universities (UHI, Ulster University, Dundee University, Heriot Watt), commercial companies (SULA Diving, Seatronics – an Acteon company, and Triscom Marine Ltd), government and public bodies (Marine Scotland, HES and the MoD) and community volunteers.

4. AIMS AND OBJECTIVES

This project aimed to collect up-to-date survey data in order to:

- monitor the submerged wartime heritage sites of the High Seas Fleet in Scapa Flow, Orkney;
- help to establish the extent of the submerged cultural heritage resource;
- locate, record and assess the condition of various war ships in Scapa Flow, Orkney;
- provide information to aid HES in monitoring protected wartime heritage assets;
- create a dataset to inform the Pentland Firth and Orkney Waters Marine Spatial Plan; and
- create a data source for dissemination, academic and public study, appreciation and enjoyment.

5. METHODOLOGY

The intended suite of methodologies to be used and trialled in this project, as described in the Project Proposal (Henry 2017), are outlined in the subsections below.

The survey project was conducted aboard the Marine Scotland vessel *MV Scotia*. *MV Scotia* provided the work platform for MBES, drop camera and Remotely Operated Vehicle (ROV) survey operations. MBES surveys used the drop keel mounted Teledyne Reson MBES system and were conducted by a Marine Scotland surveyor. Marine archaeologists from University of the Highlands and Islands and Ulster University provided input on data acquisition techniques for imaging wreck sites.

ROV surveys were conducted by a freelance pilot on behalf of Seatronics_An Acteon Company. Heriot-Watt University provided input into the specifications for data acquisition for the ROV survey and undertook marine biological studies on the submerged cultural heritage assets. The Ministry of Defence (MoD) provided input into the specifications for data acquisition for the geophysical and ROV surveys, specialist knowledge and environmental studies of the wreck sites. MV *Challenger* was the work platform for diver survey, side scan sonar (SSS) survey and interferometric bathymetry survey. SULA Diving led dive operations, side scan sonar surveys and provided vessel transfers. Triscom Marine Ltd undertook interferometric surveys. Funding support was provided by Historic Environment Scotland (HES) and appropriate licences granted by the MoD.

5.1 Side Scan Sonar and Multibeam Echosounder Survey

Side scan sonar (SSS) and multibeam echosounder (MBES) survey were selected to acquire data because these techniques provide a suitable level of detail to characterise the structure and extent of submerged sites. The data acquisition followed guidance in *Marine Geophysics Data Acquisition, Processing and Interpretation: Guidance Notes* (Plets et al., 2013). Acquisition of MBES data was also informed by strategies developed by ADUS DeepOcean Ltd (M. Dean, pers. comm.) and recently tested by Ulster University on WW1 wrecks in the Irish Sea (<https://irishseaww1wrecks.weebly.com/>).

The MBES survey was completed using a Teledyne Reson SeaBat 7125 drop keel mounted system and utilised FUGRO GNSS navigational positioning. A sound velocity profiler was deployed prior to the start of each survey session. The bathymetric survey on HMS *Royal Oak* required a smaller draft vessel than MV *Scotia* and was undertaken aboard MV *Challenger* by Triscom Marine Ltd using an interferometric Kongsberg system.

The SSS survey used a towed C-MAX Sonar CM2 Digital Towfish with data collected in real time using MaxView software to ensure that the best possible images of the site were recorded.

5.2 Predator II ROV Survey

The Predator II inspection class ROV undertook the ground truthing survey of the SSS and MBES data. The ROV captured video and stills footage, a marine archaeologist and biologist were on board assessing the images in real time – directing the survey in response to features identified.

5.3 ROV 3D

ROV 3D works from the data collected by the existing ROV cameras. It augments the data being collected to create 3D models in real time by identifying and matching thousands of reference points to calculate depth and geometry, and integrating camera textures.

5.4 Diver Ground-truthing

Self-contained underwater breathing apparatus (SCUBA) was used for diving operations. Diving was carried out according to the *Scientific and Archaeological Diving Projects Approved Code of Practice* (ACoP) published by the Health and Safety Executive (HSE 2014). A licence was obtained from the MoD for diving on HMS *Royal Oak* and HMS *Vanguard*, in accordance with the regulations for designated war graves, which have statutory protection under the Protection of Military Remains Act 1986.

Divers looked at the remains of the site to assess its survival, identification, character and apparent condition. Stills and video footage of key features were recorded. Written records and measured sketches were also made. No artefacts were recovered.

5.5 Acoustic Doppler Current Profiler

An acoustic Doppler current profiler (ADCP) belonging to Heriot-Watt University was deployed on the site of the *Royal Oak* on the 26th July 2017 and retrieved on the 30th July 2017.

5.6 Archival Research

Volunteers in the Orkney Maritime Archival Research Group (Julie Ritch, Edd Baxter, Jim Bright, Michael Ferguson, Laken-Louise Hives, Tom Hunter, Alette Kattenberg, Andrew Prentice, Jasmijn Sybenga and Tris Thorne) conducted research in the Orkney Archives, assisted by Sandra Henry and Kevin Heath. The group was initially formed to help with archive research for the HES-funded High Seas Fleet Salvage Sites project (Henry et al., 2018). Specifically, the group looked through and transcribed relevant newspaper reports and Metal Industries Ltd work logs.

6. DATA CAPTURE

This section details the data captured during the geophysical, ROV, ADCP and diver surveys during the project period of the 23rd July 2017 to 31st July 2017 aboard MV *Scotia* and MV *Challenger*, as well as the archival research conducted.

6.1 Side Scan Sonar

1st August 2017

A survey of HMS *Royal Oak* was conducted from MV *Challenger* using a C-Max CM2 side scan. Eighteen runs were conducted with ranges 100m and 325 kHz, 75m at 325 kHz and 50m on 780 kHz.

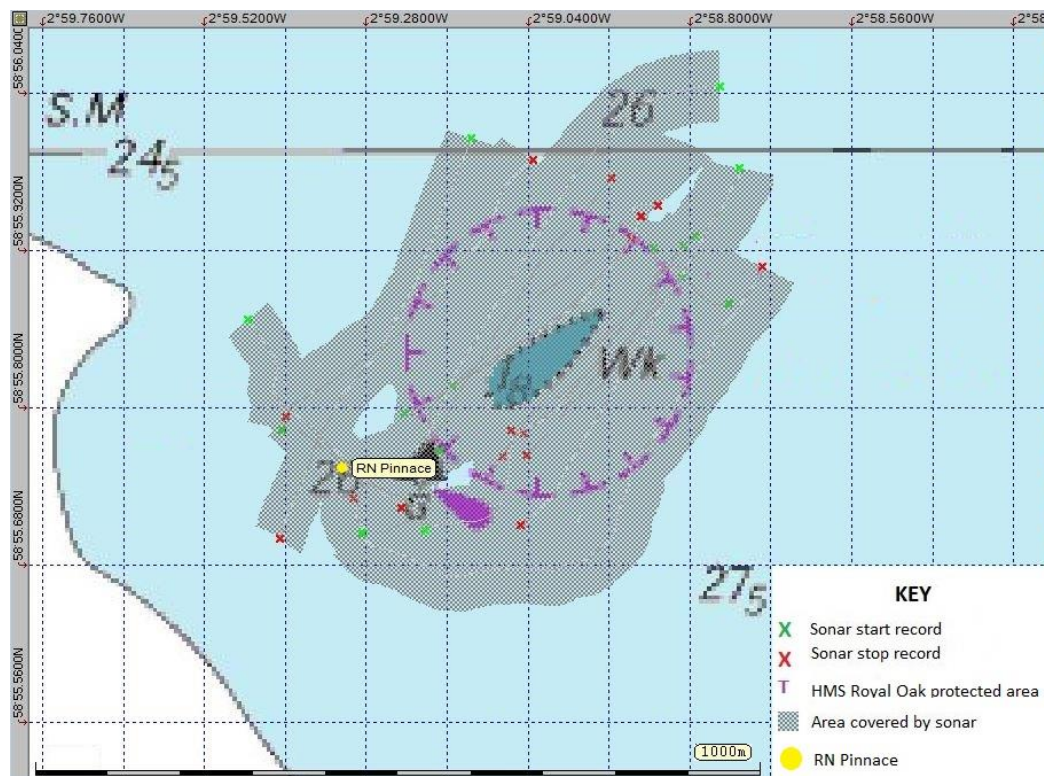


Figure 1: Royal Oak Side Scan Sonar Survey Area and pinnacle location

The images clearly show the rudders, prop shafts on one of the runs to the north of the wreck and the tow to the south clearly shows the damage to the bow and the superstructure on the seabed.

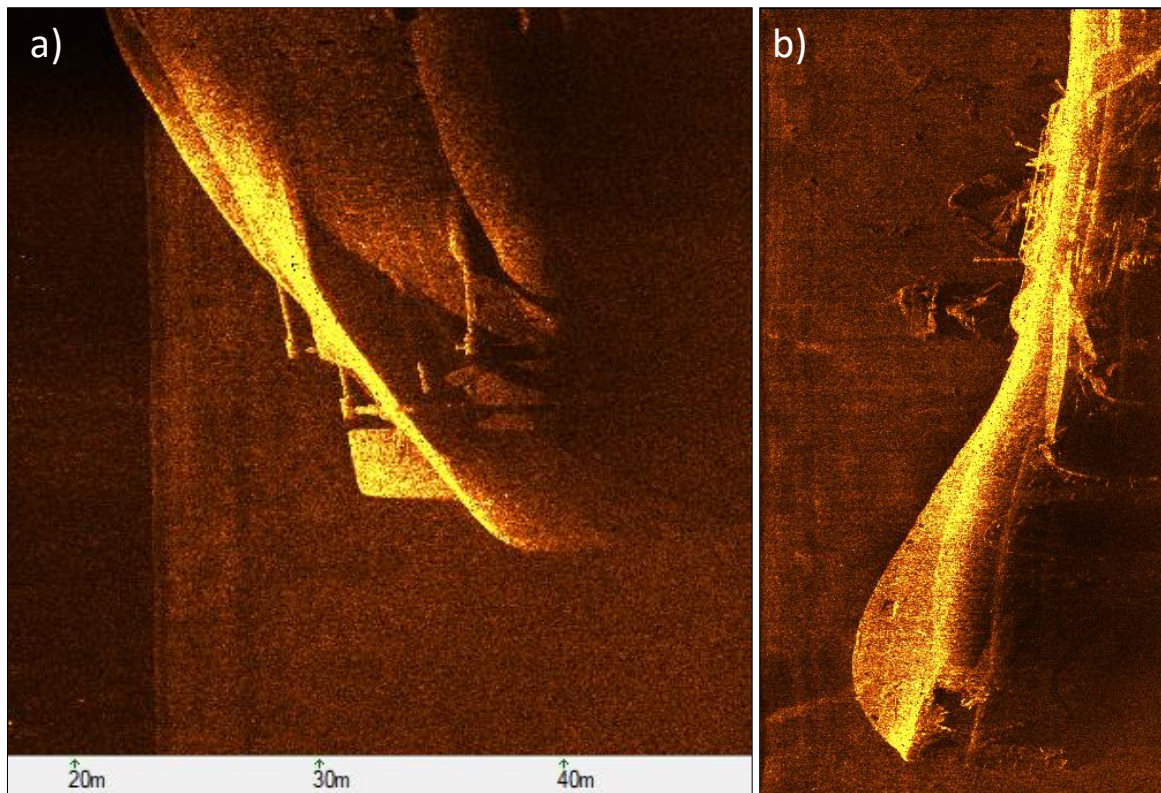


Figure 2: a) Stern of HMS Royal Oak b) Bow of HMS Royal Oak

A side scan survey was also conducted of the Royal Navy steam pinnace 300m west of HMS *Royal Oak*. Further data was collected on the pinnace by ROV and diver survey.

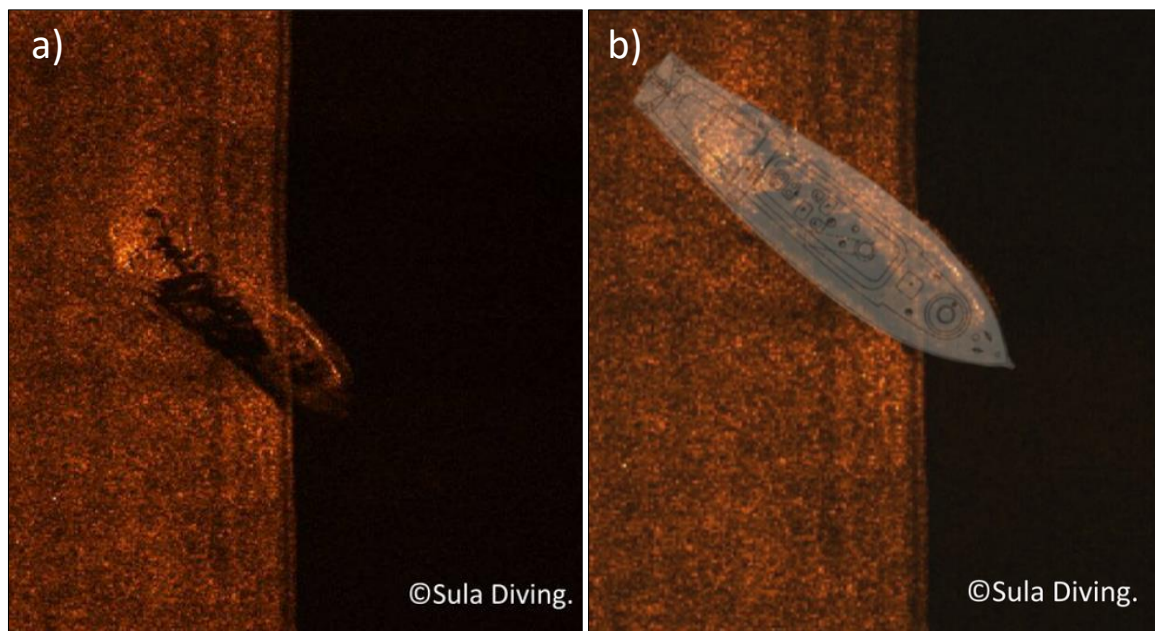


Figure 3: a) Royal Navy Pinnace b) Side scan sonar image overlain with outline of a pinnace

6.2 Multibeam Echosounder Survey

24th July 2017

0350-0407 UTC: The first multibeam survey session was on the site of HMS *Vanguard*. The initial data was captured using standard seafloor mapping parameters collecting data at a slow/moderate ping rate of 6.8 pings/second and wide 75m swath width. The survey parameters were then refined for wreck site imaging. The vessel maintained a speed between 2 and 4 knots. The data was acquired at a narrower 40m swath width, higher ping rate and more closely spaced (10-20m) survey lines.

1620-1957 UTC: The *Dresden* MBES survey parameters started at frequency setting 400Khz, speed 5.2 knots with a swath width of 60m and ping rate 14.5 p/s. The survey was interrupted briefly to test the use of dynamic positioning to acquire data; however, this method was not possible due to the strain on the bow thrusters. The survey continued collecting data on *Dresden* and *König* simultaneously using the same survey parameters whilst narrowing the angle from 100 degrees to 60 degrees, whilst the vessel maintained a speed between 2-4.5 knots.

2047-2345 UTC: Data initially collected on *Brummer* used a wide angle of 160 degree to identify the *Brummer* and *Köln*, the angle range was reduced to 60 degree upon locating the sites. The *Brummer* survey collected five lines of data parallel with the wreck site using the parameters as described for the *Dresden* survey. Survey parameters were the same for the imaging of the *Köln*, a total of 9 lines were collected running along the length of the vessel, perpendicular and diagonally.

25th July 2017

0033-0157 UTC: *Kronprinz Wilhelm* following the refined survey parameters with additional adjustments when possible. There were eight lines of data collected parallel to the wreck site. Acquired data was reviewed after this survey session to understand data gaps occurring during acquisition. It was noted that gaps were present in the data along with data artefacts created by sidelobes.

1800-2128 UTC: Survey on the *Karlsruhe* adjusted parameters to a maximum ping rate setting 50 p/s. Stops to acquisition during the survey aimed to address the ongoing technical issues with the multibeam system. To reduce these issues the MBES power was turned down for subsequent surveys.

26th July 2017

0025-0150 UTC: Survey parameters on the *Markgraf* used a 60 degree angle and max ping rate of 50 p/s. There were thirteen lines of data collected parallel and perpendicular to the wreck site.

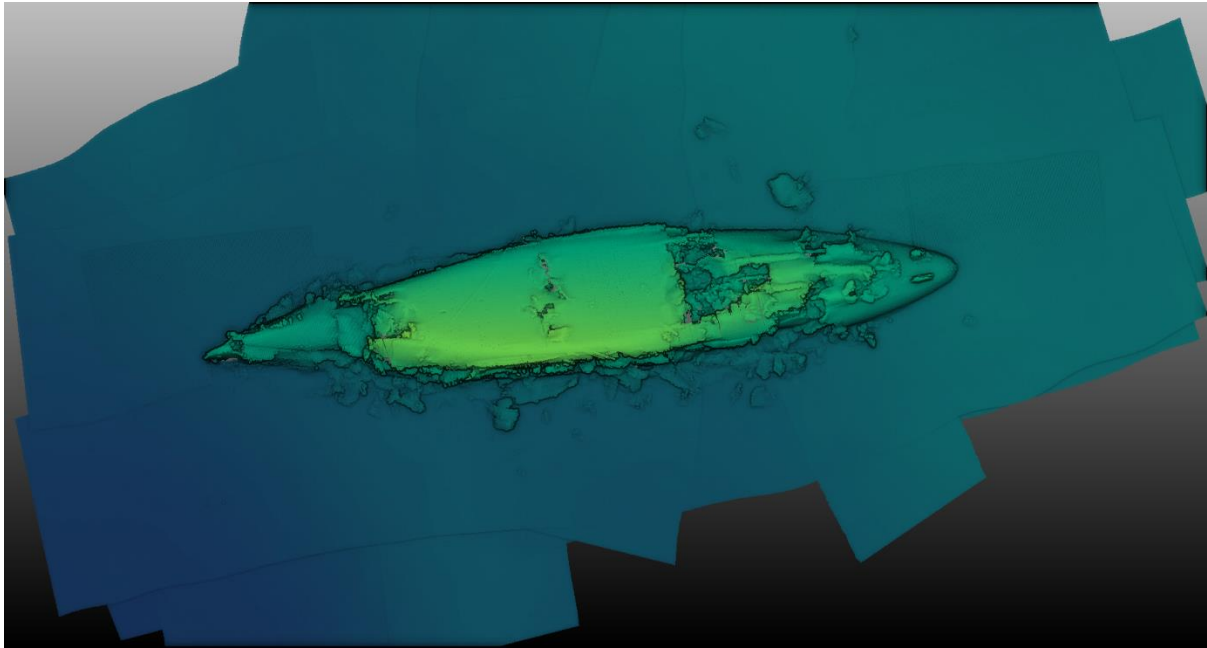


Figure 4: Image of the Markgraf produced by Kieran Westley, Ulster University.

0201-0423 UTC: Survey parameters were adjusted to 50m spacing and 128 degree angle to reduce data acquisition problems. Five lines of data were collected on *Grosser Kurfurst* and *Friederich de Grosse* primary salvage sites that consist of seabed depressions and associated wreck debris were imaged. Four lines of data were collected on the site of the *Bayern*, a high resolution pass was made over *Bayern* with a narrow angle of 60 degree.

1435-1520 UTC: The *Royal Oak* pinnacle was used to test collecting high density data, this survey utilised Dynamic Positioning (DP) and the vessel sat above the pinnacle. MV *Scotia's* draught of 6.2m prevented imaging of the *Royal Oak* due the shallow location of the wreck site.

26th & 27th July 2017

The research vessel left Scapa Flow through Hoxa Sound, travelling to the west to image the *Hampshire* wreck site located off Marwick Head.

2342-0052 UTC: The survey session on HMS *Hampshire* aimed to image the wreck by acquiring data using both closely spaced survey lines and narrow swaths over the wreck and additional lines using wider swaths and offset at greater distance from the wreck to mitigate the shadows created by overhangs. Survey parameters were set to a frequency 400Khz, 45 degree angle and a ping rate that varied around 7p/s. The survey collected 7 lines of data predominately parallel to the vessel. The survey was interrupted due to the loss of the Fugro navigational positioning system.

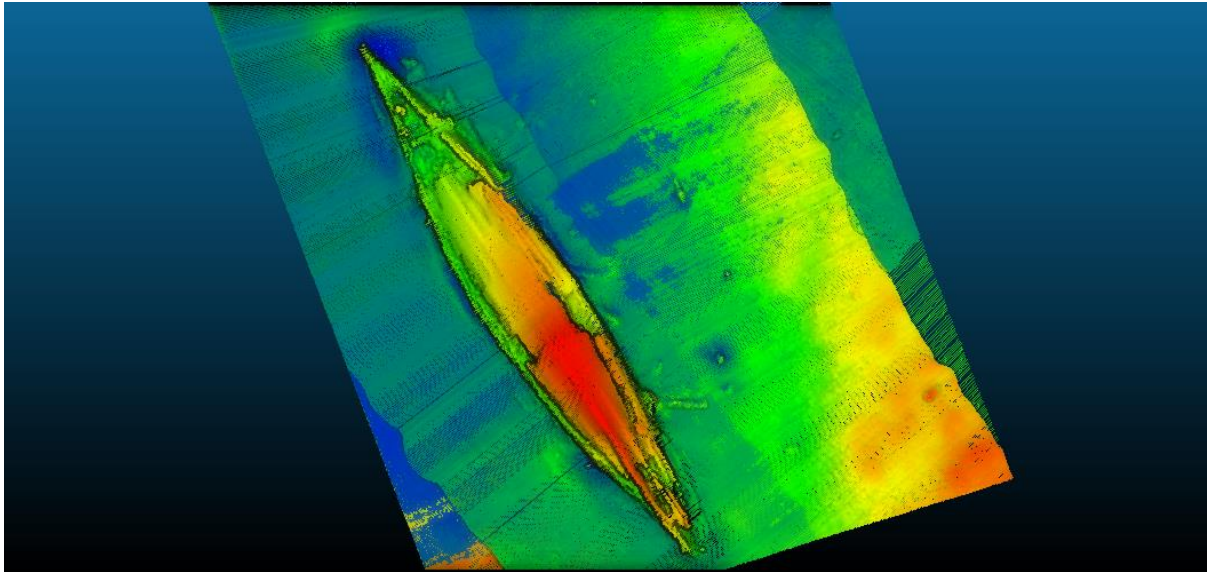


Figure 5: HMS Hampshire, image by author

0158-0420 UTC: The next survey session collected six lines of data perpendicular to the wrecksite before changing to a 90 degree angle for four lines and two lines at 120 degree before changing the angle to 60 degree for a further five lines.

The connectivity issues with the FUGRO navigational system that occurred during the HMS *Hampshire* survey continued for the rest of the project, this produced and increased errors in the positional accuracy of the data collected.

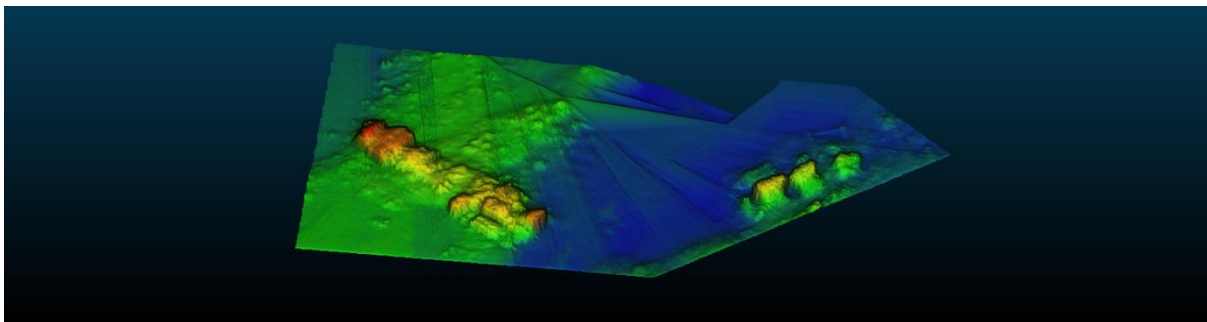


Figure 6: HMS Pheasant, image by author

1446-1626 UTC: HMS *Pheasant* exact location was unknown prior to this survey. The site was first dived by a team of technical divers in 1997 but the position was never released due to commercial reasons. An approximate position 'wreck 62013' was given to the UKHO. This position together with the U boat log for U80 and the document ADM 137/3716 "The loss of HMS *Pheasant*" were used to refine the search parameters which was centred on the UKHO position.

Reconnaissance survey parameters were 440Khz, 60 degree angle with a 100m swath width. Upon locating the wreck, a focused survey was undertaken on the wreck site. The survey parameters for the concentrated data collection were 45 degree angle and 400Khz frequency. The survey was aborted due to issues with the positioning system.

28th July 2017

The MV *Scotia* returned to Scapa Flow. At this point, it was determined to re-survey a number of sites to resolve issues identified in previous surveys. Returning to the sites provided an opportunity to

collect additional data to increase data density and fill in gaps created by the technical issues. Data collected included snippets and echosounder to show the seabed compaction for the salvage sites.

0130-0430 UTC: Issues with positional equipment and data acquisition session cancelled after issues couldn't be resolved.

2040-2104 UTC: Survey parameters were 400Khz frequency, 60 degree angle and an approximate ping rate of 11p/s. Three transects were run on the primary salvage site of *Bayern*.

28th & 29th July 2017

2250-0254 UTC: The re-survey parameters involved collecting numerous runs on each wreck site parallel, perpendicular and diagonal to the wreck site. Data acquisition used a 400Khz frequency, varying the angle from 60 to 100 degree and a ping rate of around 11p/s. *Koln* was the first wreck to be resurveyed.

0323-0540 UTC: *Brummer* was then surveyed varying the angle from 60 degree to 100 degree.

1751-2058 UTC: *Karlsruhe* was then resurveyed using the same parameters as the *Brummer*.

2104-2214 UTC: *Markgraf* resurveyed using the parameters as described above.

29th July 2017

Interferometric bathymetry survey conducted on HMS *Royal Oak* and associated pinnacle by Triscom Marine Ltd from MV *Challenger*. Interferometric Kongsberg geoswath 250kHz MPES system was used. Navigation was a PosMV 320 system in RTK mode, attitude data came from the GS+ built-in DMS05 MRU. RTK corrections came from Karl Coopers portable base station at Gaitnrip over UHF at 9600, roughly 99% realtime<1s.

29th & 30th July 2017

2222-0105 UTC: *Kronprinz Wilhelm* resurveyed using the parameters as described above.

0232-0510 UTC: *Konig* resurveyed using the parameters as described above.

30th July 2017

The last day of survey collected data on the *Dresden* and HMS *Vanguard*.

1718-2040 UTC: *Dresden* resurveyed using the parameters as described above.

2143-0233 UTC: *Vanguard* resurveyed using the parameters as described above.

6.3 Predator II ROV Survey

24th July 2017

The ROV operations were initially delayed until an Ultra Short Baseline (USBL) positioning system was taken on board to operate with the ROV.

25th July 2017

USBL was taken on board, the USBL & ROV were set up. The ROV undertook a survey on HMS *Vanguard*. The ROV survey focused on the portside and bow section of the wreck.

26th July 2017

Survey on the *Royal Oak* and associated pinnacle. The survey on HMS *Royal Oak* was abandoned due to concerns regarding risk of entanglement and bad visibility. Data was collected on the pinnacle, but entanglement issues delayed and then ended operations.

27th July 2017

HMS *Hampshire*, the ROV landed on site but moved away from the site and entanglement issues with the survey vessel aborted operations. No data was collected on the site of HMS *Hampshire*.

28th July 2017

ROV survey operations were then moved to focus on the smaller salvage sites. Data was collected on *Kaiser*, *Kaiserin*, *Derfflinger*, *Konig Albert*, *Printz Regent Luitpold* and *Bayern*. These operations were ended due to delays and entanglement issues.

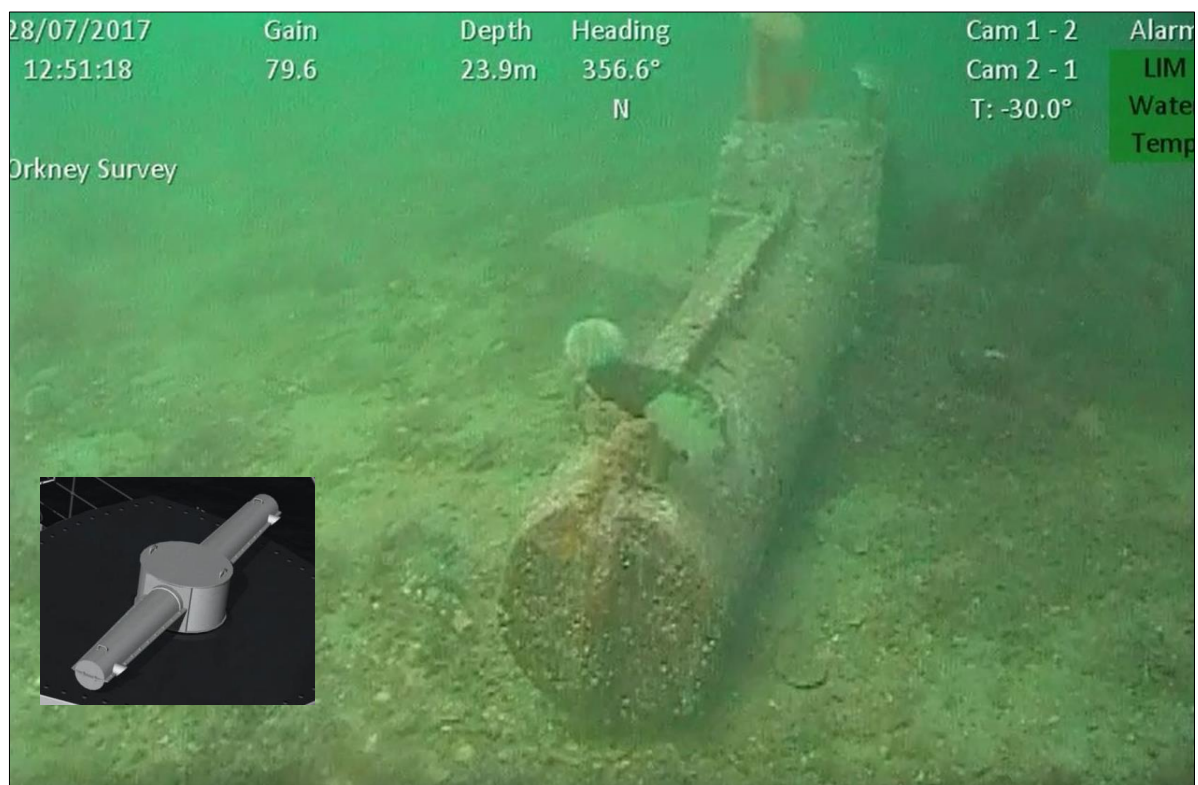


Figure 7: Salvage site Rangefinder, inset model rangefinder (M. Samuel <https://sites.google.com/site/3dwarships/Home>)

29th July 2017

ROV survey commenced on the intact vessels of the High Seas Fleet. ROV survey was undertaken on *Dresden*. Survey on both *Kronprinz Wilhelm* and *Konig* were abandoned due to entanglement issues. ROV survey operations were then undertaken on the salvage site of *Moltke*.



Figure 8: Moltke salvage site spotting top

ROV survey operations finished on the 29th July 2017.

6.4 ROV 3D

This survey method was unsuccessful in its application. The process showed that different lights and camera would need to be fitted onto the ROV system.

6.5 Diver Ground-truthing

27th July 2017

Diving operations were undertaken on HMS *Vanguard*. Recording methodologies involved taking site notes, still photography and video footage to determine the character and condition of wreckage. The dive survey also aimed to characterise the biological communities present on the wreck structures. The dive team comprised six individuals, diving in buddy teams with surface marker buoys who undertook one dive each. The dive times varied from 32-41 minutes with a 37m maximum depth. Decompression stop occurred at 6m for 3.

Diving focused on the stern of HMS *Vanguard* and the surrounding wreckage. Additional dives were carried out on the bow section located 203m from the stern with the aim of characterising the biological communities present on the wreck structures.



Figure 9: Turret wreckage on HMS Vanguard

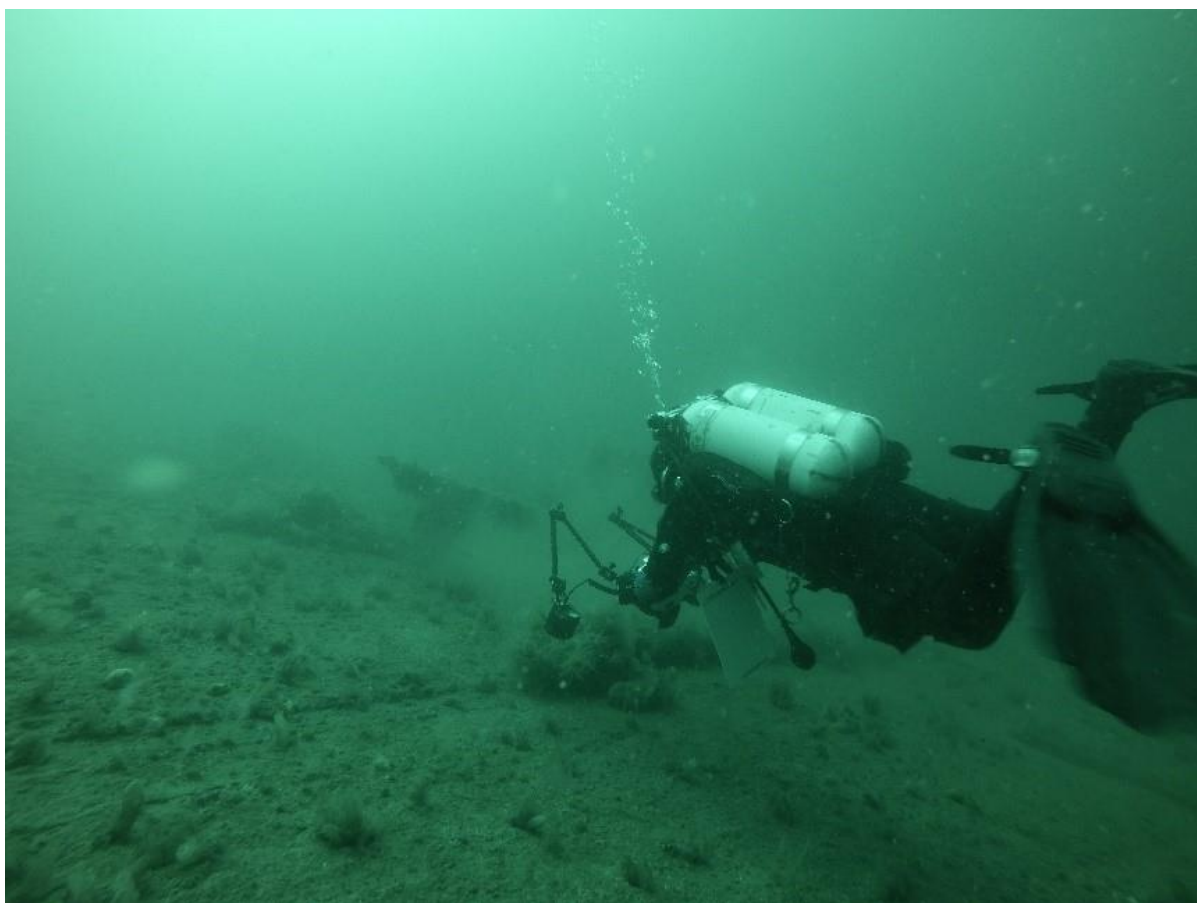


Figure 10: Diver conducting a biological assessment near the bow of HMS Vanguard

28th July 2017

Diving operations used the same recording practices on the site of HMS *Royal Oak* to achieve the same objectives.

The dive team comprised six individuals, diving in buddy teams with surface marker buoys who undertook one dive each on the site of HMS *Royal Oak*. The dive times varied from 34-42 minutes with a 33m maximum depth. Decompression stop occurred at 6m for 3. Given the relatively intact nature of the *Royal Oak*, divers were able to swim the entire length of the wreck. It was possible to access the bridge and gunnery spotting top structures lying on the seabed. Many of the deck structures were also accessible.

A dive team of three individuals undertook one dive on a geophysical anomaly lying approximately 250m to the south-west of the *Royal Oak*. Dive time was 26 minutes with a 34m maximum depth. Decompression stop occurred at 6m for 3.



Figure 11: Wreckage of small pinnace- type vessel lying to the south-west of HMS Royal Oak

This anomaly represented a small wooden vessel of a pinnace or picket boat design. The wreck was lying upright in approximately 28m water depth. The bow section was well preserved. Records indicate that a steam picket boat drifted away from the *Royal Oak* carrying survivors from the torpedo attack, but subsequently capsized and sank as it was overloaded. It almost certain that the wreckage examined on this survey was the remains of that vessel.



Figure 12: Propeller of pinnace

31st July 2017

The dive team comprised four individuals, diving in buddy teams with surface marker buoys, who undertook two dives each on the site of HMS *Royal Oak*. The dive times varied from 30-54 minutes with a 32m maximum depth. Decompression stop occurred at 6m for 3. Again, the divers were able to swim the entire length of the wreck. The divers collected footage to characterise the condition and biological communities present on the wreck site.



Figure 13: Compass remains HMS Royal Oak

6.6 Acoustic Doppler Current Profiler

The ACDP collected important information to characterise the environment of the *Royal Oak*. The data from this deployment are being looked at by Heriot Watt University, along with the information gathered on the biological communities present on the wrecksites.

6.7 Archival Research

The archival research provided information through newspaper articles relating to the loss of HMS Royal Oak to find mention of the steam pinnacle, which could then be followed up (<https://archaeologyorkney.com/2017/10/10/shiptime-maritime-archaeology-project-orkney-hms-royal-oak-steam-pinnacle-located/>).

The information from the Metal Industries log helped with the shiptime survey of the deeper salvage sites and, together with the surveys conducted from the MV *Scotia*, will contribute to the survey work planned on the HES-funded High Seas Fleet Salvage Sites: Phase 2.

7. DISCUSSION & LESSONS LEARNED

This project collected MBES, interferometric bathymetry, SSS, ACDP, ROV, diver and archival research data on the High Seas Fleet and Royal Navy wrecks in Orcadian waters.

MBES survey collected detailed high density data on the seven intact vessels of the High Sea Fleet: *Konig, Koln, Brummer, Dresden, Markgraf, Karlsruhe* and *Kronprinz Wilhelm*, along with the salvage sites *Bayern, Grosser Kurfurst* and *Friedrich de Grosse*. MBES data was captured on HMS *Vanguard*, HMS *Hampshire*, HMS *Pheasant* and the pinnacle potentially associated with HMS *Royal Oak*. Interferometric, SSS, ACDP, ROV and diver data were collected on the wreck site HMS *Royal Oak* and

associated pinnacle. Diver and ROV data was collected on HMS *Vanguard*. ROV survey data was acquired to varying degrees on the High Sea Fleet wreck sites *Dresden*, *Kronprinz Wilhelm*, *Konig* and the salvage sites; *Kaiser*, *Kaiserin*, *Derfflinger*, *Konig Albert*, *Printz Regent Luitpold* and *Bayern*.

The survey was focussed on only collecting high quality data, and a number of technical issues were encountered during the survey that limited the quantity of data collected.

Technical issues were encountered during the MBES data acquisition that resulted in poor/no acquisition of data at times, or additional post processing to bring the data up to the requisite standard. Technical issues included sidelobes, data gaps, lack of tidal corrections and loss of GPS. However, a number of these issues were addressed where and to the extent possible during the survey, such as refining the survey parameters to reduce sidelobes and data gaps, and using interferometric survey from a shallow draft vessel on HMS *Royal Oak*. Although this will require additional time for the post processing of data than initially anticipated, some technical issues, including the navigational and tidal corrections, can be rectified in the data post processing stages

The ROV experienced technical difficulties in regard to the acquisition parameters, positioning system as well as with lighting and camera issues, and entanglement difficulties. This reduced the quality of the data collected; however, it didn't prevent data acquisition. The ROV data acquired is currently being used in projects to further understand the nature of the cultural heritage remains on the Orcadian seafloor (High Seas Fleet Salvage Sites Project Phase 2). The ROV 3D data collection system was unsuccessful in its application. The process showed that lights and a camera with different specifications would need to be fitted onto the ROV.

The diver survey was a successful operation characterising the wreck structures and associated biological communities along with collecting high quality video and photographic data for interpretation, helping to compensate for issues encountered by the ROV. Diver surveys are always limited by time and budget, and it was no different with this project. More diver time on the wreck sites could have gathered an even greater quantity of informative data.

The surveys acquired an enormous amount of new and high quality data, producing highly detailed pictures of the wreck sites, mapping the extent of the wreck sites and their current condition nearly one hundred years after sinking. Participation of the project partners in the surveys, with their different skillsets, meant that there was the ability to react to and compensate for technical issues that arose in the field. The collaboration of such a wide variety of partners, making significant contributions of resources to the project, has ensured that the aims and objectives of the project have been or will be achieved.

8. PROJECT OUTCOMES AND DELIVERABLES

The surveys acquired an enormous amount of new and high quality data, producing highly detailed pictures of the wreck sites, mapping their extent and current condition, which will enable comparison with earlier survey data to assess and monitor their rate of decay. The datasets acquired will be useful for informing monitoring and management plans and strategies, including the Pentland Firth and Orkney Waters Marine Spatial Plan, as well as curatorial bodies such as HES, Orkney Harbours and Orkney Islands Council. Results include the identification of a pinnacle associated with HMS *Royal Oak* which is outwith that protected area; the confirmation of the exact location of HMS *Pheasant* which will enable greater statutory protection and monitoring.

Archive-friendly project data catalogues have been created, and can be disseminated to the project partners as and when required, along with datasets. HES currently holds a full copy of the datasets acquired.

An initial presentation of the survey results, *The Naval Wrecks of Scapa Flow*, was written by team members Sandra Henry, Kevin Heath and Jo Porter, and presented by Dr Jo Porter of Heriot Watt as part of the Orkney Science Festival on 8th September 2017 at the Orkney Theatre, Kirkwall.

Outreach and community inclusion activities included archival research by volunteers in the Orkney Maritime Archival Research Group. Information identified helped with the shiptime survey of the deeper salvage sites and, together with the surveys conducted from the MV *Scotia*, will contribute to the survey work planned on the HES-funded High Seas Fleet Salvage Sites: Phase 2.

The visualisation activity is to be conducted by Professor Chris Rowlands of Dundee University in 2018. HES personnel will also continue to process and manipulate data. It is intended that pProject partners will use the data to develop academic research and future projects, as well as producing academic publications and conference papers on the questions identified in the Project Proposal (Henry 2017).

The uploading of reports and publications onto the Scapa Flow Historic Wrecks website for wide public dissemination will happen as and when produced and approved.

Media and social media coverage has been a success so far, and there will be more as more outputs are created by the project partners. There have been four press releases associated with the Shiptime project so far:

1. Project Launch
2. HMS Pheasant Location Confirmed
3. Markgraf Multibeam Echosounder Image (digitally issued on UHI blog)
4. HMS Royal Oak Pinnacle Discovered.

The project itself attracted huge media interest with a series of stories featured on BBC News (twice), BBC Radio Orkney (twice), STV News (twice), *The Herald*, *The Scotsman*, *The Daily Mail*, *The Press & Journal*, *History Scotland* magazine (twice), *Archaeology Magazine* (USA), *Forces Network* (magazine for the British Armed Services), National Geographic TV, the local Orkney media and *Yachting and Boating World*.

Social media interaction was also intense with the blog posts being shared over 1,500 times from the UHI Archaeology Orkney blog. The Markgraf was shared 528 times from the blog post, Twitter posts were viewed 34,750 times and Facebook posts were viewed 27,302 times, with the HMS Royal Oak Pinnacle video being viewed 4,600 times from one post.

Further deliverables and outcomes, as described in the Project Proposal (Henry 2017), will be achieved at the appropriate times.

9. CONCLUSION

Despite the technical issues identified during the use and testing of various techniques and equipment, this survey project successfully collected various forms of data that will inform monitoring of internationally important wreck sites, creating a detailed account of the sites as they are in 2017. The datasets will form the basis for furthering management of the assets and maritime archaeological research, production of visualisations and public engagement with remains that are inaccessible to many. One of the strengths of the project has been the range of the project partners and their contribution of significant resources to achieve its aims and objectives.

The surveys and evaluations established the identity, extent of survival, character and condition of the remains in support of *Scotland's Archaeology Strategy* (HES 2016; <http://archaeologystrategy.scot/>). The aims of this strategy are to help deliver archaeology, to enhance the understanding of our past, to help care for, value and protect our historic environment, to encourage greater engagement with our past, and to provide opportunities for innovation and development of skills. While it is not within the remit of this survey project to address management issues, the evidence from this project (and the outcomes of previous surveys) should contribute to HES and other stakeholders' formulation of appropriate management and monitoring strategies for heritage assets within Scapa Flow and at a national level. This project provides baseline data for long-term monitoring of the sites, aiding promotion and protection of this submerged cultural heritage resource.

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