Institution: University of Dundee

Unit of Assessment: 17 Geography, Environmental Studies and Archaeology

Title of case study: Bridging the gap between policy and regulation: new assessment tools for implementing the EU Water Framework Directive

1. Summary of the impact

Research by **Rowan** and ERG colleagues **Black**, **Bragg**, **Cutler**, **Duck** has addressed the science and policy challenges faced by statutory authorities meeting their duty to implement the EU Water Framework Directive (WFD) 2000. Assessing the sensitivity of aquatic systems to physical, chemical and biological pressures is the central theme, and through a series of commissioned projects funded by UK environment and conservation agencies, the research has:

- Developed new assessment tools used by statutory regulators to characterise the degree of flow alteration and physical modification to rivers and lakes;
- Developed the lake habitat survey (LHS) method, complete with accreditation programme, incorporated as best-practice in a CEN European Guidance Standard;
- Been translated directly into legally-binding and currently used environmental standards across the UK and Ireland (through new enabling legislation);
- Informed regulatory practices across Europe, particularly in Italy, Poland, France, Norway, Serbia and Montenegro.

2. Underpinning research

The introduction of the EU Water Framework Directive in 2000 is widely regarded as the most important environmental legislation introduced in Europe for a generation. Whilst politically ambitious, implementation is very challenging due to gaps in basic data and limited understanding of how rivers and lake respond to multiple pressures.

Since 1999 the Environment Research Group (represented by **Black**, **Bragg**, **Cutler**, **Duck** and **Rowan**) has undertaken a series of research projects (c. £0.5M) commissioned on behalf of statutory UK and Irish environment agencies. Early funding to **Black** *et al.* (2000) developed a modelling framework (DHRAM) quantifying the extent to which river flows and lake water levels deviate from natural due to water use pressures[3]. **Black** *et al.* (2002) developed guidance for determining when the degree of change would qualify as *'heavily modified'* and hence management targets would have alternative environmental objectives. These studies highlighted the absence of robust field methodologies and decision support tools leading to development of the Lake Habitat Survey over three phased projects (**Rowan** *et al.* 2003-2010). This research developed a comprehensive survey scheme, extensively tested by statutory regulators across the UK, Ireland, Italy, Poland, France, Norway, Serbia and Montenegro[5,6]. The absence of established evidence linking physical impairment to loss of ecological function required the adoption of risk-based approaches, including an important role for expert solicitation to define *thresholds of change*[3,4]. Acreman *et al.* (2008) used workshops and practitioner-based focus groups to define environmental standards for how much water can be abstracted from rivers without unacceptable risk to biota and to set statutory guidance on environmental flow releases from dams[1,2]. A similar approach was taken by **Rowan** *et al.* (2012) in setting thresholds of physical modification in the Lake-MImAS classification and decision-support tool[7]. This research was published under the auspices of the UK Technical Advisory Group (UKTAG) following extensive peer-review and a formal public consultation process before the results were translated (transposed) into legally-binding environmental standards. Overall this was ground-breaking research, with a strong co-production ethos required because the policy aspirations of the legislation were ahead of the science base.

3. References to the research

1. Acreman, M.C. *and 13 co-authors inc.* **Black, A.R.** 2008. Developing environmental standards for abstractions from UK rivers to implement the EU Water Framework Directive. *Hydrological Sciences Journal*, 53, 1105-1120. **DOI:** 10.1623/hysj.53.6.1105
2. Acreman, M.C. and *15 co-authors inc.* **Black, A.R.** 2009. Environmental flows from dams: The Water Framework Directive. *Proc. Inst. of Civil Engineers: Engineering Sustainability*, 162, 13-22. **DOI:** 10.1680/ensu.2009.162.1.13
3. **Black, A.R.**, **Rowan, J.S.**, **Duck, R.W.**, **Bragg, O.M.** and Clelland, B.E. 2005. DHRAM: a method for classifying river flow regime alterations for the EC Water Framework Directive. *Aquatic Conservation – Marine and Freshwater Ecosystems,* 15, 427-466. **DOI:** 10.1002/aqc.707
4. **Bragg, O. M., Black, A. R., Duck, R. W. & Rowan, J. S.** 2005. Approaching the physical-biological interface in rivers: a review of methods for ecological evaluation of flow regimes. *Progress in Physical Geography,* 29, 506-531. **DOI:** 10.1191/0309133305pp460ra
5. CEN 2011. Comité Européen de Normalisation (European Standards Agency). *Water Quality – Guidance Standard on assessing the hydromorphological features of lakes.* EN16039:E, pp. 39. (lead author **Rowan, J.S.**).
6. **Rowan, J.S.**, **Carwardine, J.**, **Duck, R.W.**, **Bragg, O.M.**, **Black, A.R.**, **Cutler, M.E.J.**, **Soutar, I**. and Boon, P.J. 2006. Development of a technique for Lake Habitat Survey (LHS) with applications for the European Union Water Framework Directive. *Aquatic Conservation – Marine and Freshwater Ecosystems*, 16, 637-657. **DOI:** 10.1002/aqc.786
7. **Rowan, J.S.**, Grieg, S.J., Armstrong, C.T., Smith, D.C. and Tierney, D. 2012. Development of a hydromorphological classification and regulatory decision-support tool for lakes. *Environmental Modelling and Software*, 36, 86-98. **DOI:** 10.1016/j.envsoft.2011.09.006

Selected Funding and Underpinning Research

£2.4 M GLOBOLakes (Global Observatory of lake responses to environmental change). NERC Consortium Grant (NE/J02211X/1) with Universities of Stirling, Glasgow, Edinburgh, CEH & NEODASS. CI, £397k to Dundee (2012-2015). **Cutler** (PI), **Rowan** & **Dawson**.

£20 k Assessing the legacy of historic mining on the hydromorphology and ecology of the Loch Fitty catchment. Funded by Scottish Coal (2010-2011), **Rowan** (PI).

£16 k Developing a lake hydromorphology typology for the UK. Funded by SNIFFER (2009-2010), SNIFFER Report WFD104 (2010), **Rowan** (PI).

£142 k Development of a method of Lake Habitat Survey. Funded by SNIFFER (2004-2010). Reports WFD40 (2004), WFD42 (2006), WFD99 (2008) **Rowan** (PI), **Black**, **Bragg**, **Cutler** & **Duck**.

£22 k Development of a European Water Quality Guidance Standard on lake hydro-morphological assessment. Funded by the British Standards Institution (2007-2009), **Rowan** (PI).

£45 k Development of decision-making frameworks for managing alterations to the morphology of lakes. Funded by SNIFFER (2005-2009), SNIFFER Reports WFD49a (2005) and WFD49f (2008). **Rowan** (PI).

£65 k Development of environmental standards (water resources) for rivers and lakes. Joint award between CEH Wallingford and Dundee. Funded by SNIFFER (2004-2005), SNIFFER Report WFD48 (2006). Acreman (PI) *et al.* CEH, **Black**, **Rowan** & **Bragg**.

£13 k Hydromorphology of lake systems in the UK. Funded by SNIFFER (2002-2003), SNIFFER Report WFD06 (2003). **Duck** (PI), **Rowan** & **Bragg**.

£77 k Assessing Heavily Modified Waters in Scotland. Funded by SNIFFER (2001-2002), SNIFFER Reports SR[02]11A-D (2002) Black (PI), **Rowan**, **Duck** & **Bragg**.

£34 k Anthropogenic impacts upon the hydrology of rivers and lochs: phase 1. CI, funded by SNIFFER (1999-2000), SNIFFER Report SR[00]01 (2000) **Black** (PI), **Rowan**, **Duck** & **Bragg**.

4. Details of the impact

With respect to the water resources (WFD48, 2006) and hydromorphological alteration (WFD49f, 2008) projects, the legislative obligations to implement the WFD meant that the commissioned research was rigorously peer-reviewed, and refined through public and stakeholder consultation, before being transposed into legally-binding environmental standards[1,2]. These are published under the auspices of the UK Technical Advisory Group (UKTAG), which is responsible for harmonising WFD implementation across the devolved administrations. **Rowan** served as an invited hydromorphology expert in its Lakes Task Team during the period 2006-2010.

The significance of the Dundee-based research is its adoption into regulatory practice and how it informs on-going policy development. In relation to environmental flows and lake hydromorphology findings adopted in UKTAG 2008a&b: "*UKTAG believes the proposals in this report are based on the most robust assessment possible, given current scientific understanding. Our report aims to advise the UK administrations on the standards and conditions that we believe the environment agencies should use for the first River Basin Management Plans"* (UKTAG, 2008b, p. 17). These standards were used to "*help guide decisions on the management of lakes"* (p. 54). Lake-MImAS tool was adopted for classification and impact assessment in the six-yearly cycle of statutory River Basin Management Plans[3] and implemented through new enabling legislation, e.g. Statutory Rules Northern Ireland 2011, making its use legally binding for ***all current and future*** lake management activities within the devolved administrations, as well as in the Republic of Ireland[4,5,10,11,12,13].

A key element in the dissemination of the Lake Habitat Survey was the development of an accredited training programme for environment and conservation agency staff[6]. Field-based training workshops, typically running for three days, were held throughout the UK (e.g. Lake Windermere 2008, Lough Neagh 2010) as well as internationally (Novi Sad, Serbia 2008 and Lago Maggiore, Italy 2009). In total, more than 60 environment and conservation agency staff (SEPA, EA, NIEA and EPA) were trained and achieved accreditation by **Rowan** (with inputs from Research Assistants **Bragg**, **Soutar** and **Carwardine**). A number of academics, graduate students and external commercial consultants were also trained[7]. Dissemination was also achieved through a series of international workshops and field demonstrations, e.g. **Rowan** was invited to CEN Mainz 2011; CNR Maggiore 2009; CEN Vienna 2008; UKTAG Dunadry 2008; JNCC Edinburgh 2008.

The international dimension of our research impact is also evident through the translation of our lake research into the 2011 European Committee for Standardisation (*CEN) Water Quality - Guidance standard on assessing the hydromorphological features of lakes* (EN16039), which endorsed the Lake Habitat Survey as the only internationally proven method trialled by statutory authorities in the UK, Ireland, Netherlands, Italy, France, Portugal, Poland, Norway, Spain, Serbia and Montenegro[8]. EN16039 was ratified in 2011 through a formal weighted-voting procedure involving all 34 CEN national member states and thereafter translated into French and German. Supported by the British Standards Institution, **Rowan** led the development of what is now the *de facto* standard method across Europe[10]. The significance of standards is that they are *"…one of the most important issues for businesses… crucial in facilitating trade… A standard represents a model specification, a technical solution against which a market can trade. It codifies best practice and is usually state of the art"*. The standard is available in the UK as BS EN 16039:201, published by the British Standards Institution[9].

The research programme has generated a suite of characterisation, monitoring and assessment tools accompanied by an accredited training programme to promote quality assurance and the adoption of common standards across all of the environment agencies of the UK and Ireland. Research outputs disseminated through a series of commissioned reports, academic papers and stakeholder engagement activities have been drawn formally into UK and Irish statutes, and more widely proven in an international context through the CEN Guidance Standard. The impacts discussed have occurred throughout the current 2008-2013 REF period, and indeed are on-going and will be used in the forthcoming round of River Basin Management Plans within the UK and Ireland.

5. Sources to corroborate the impact

The following links confirm the transposition and on-going application of Dundee lake hydromorphology research directly into national legally-binding standards:

1. UKTAG 2008a. UK Environmental Standards and Conditions (Phase 1) (SR1 – 2006). (http://www.wfduk.org./resources%20/response-stakeholders%E2%80%99-submissions-standards-and-conditions-phase-1).
2. UKTAG 2008b. UK Environmental Standards and Conditions (Phase 2) (SR1 – 2006). (http://www.wfduk.org./resources%20/uk-environmental-standards-and-conditions-phase-2).
3. Northern Ireland Environment Agency. 2010. River Basin Management Plans. (http://www.doeni.gov.uk/niea/pom_fw_morph.pdf).
4. Statutory Rules of Northern Ireland 2011 No. 10 Environmental Protection The Water Framework Directive (Priority Substances and Classification) Regulations (Northern Ireland) 2011(http://www.legislation.gov.uk/nisr/2011/10/made).
5. EPA (Environmental Protection Agency Ireland) 2011. *Water Framework Status Update based on Monitoring Results 2007-2009.* Ecological Status and Chemical Status of Surface Waters and Chemical and Quantitative Status of Groundwaters. Prepared in fulfilment of Articles 24 and 25 of SI 272 of 2009. ISBN: 978-1-84095-406-7 (http://www.epa.ie/pubs/reports/water/waterqua/waterframeworkstatusupdate.html).
6. SNIFFER 2008. Lake Habitat Survey in the United Kingdom. Development of a method of Lake Habitat Survey (LHS): Phase 3 (http://www.sniffer.org.uk/search?q=wfd99).
7. Testimonial highlighting importance of being one of the few commercial consultants outside of the statutory authorities to have LHS accreditation (*http://www.linkedin.com/pub/angela-darwell/45/83a/614*).
8. European Committee for Standardisation. Website listing the availability of *CEN Water Quality - Guidance standard on assessing the hydromorphological features of lakes* (EN16039), Standard BS EN (*http://esearch.cen.eu/esearch/extendedsearch.aspx).*
9. BS EN 16039:2011. *Water quality. Guidance standard on assessing the hydromorphological features of lakes,* September 2011, ISBN 978 0 580 69599 5 *(*http://shop.bsigroup.com/ProductDetail/?pid=000000000030212175).

Contacts:

10. Head of Ecosystems & Biodiversity Unit, Scottish Natural Heritage.
11. Evidence Scientist, Environment Agency, England.
12. Senior Scientific Officer, Northern Ireland Environment Agency.
13. Senior Scientific Officer, Environmental Protection Agency, Office of Environmental Assessment, Dublin, Ireland.

Institution: University of Dundee

Unit of Assessment: 34: Art and Design: History, Practice and Theory

Title of case study: Underwater 3D Visualisation

1. Summary of the impact (indicative maximum 100 words)

Research into 3D visualisation of shipwreck sites with historical significance or that pose a threat to the environment e.g. Costa Concordia, Deepwater Horizon, has led to multiple impacts:

- Changes in the business practices of international salvage companies
- Environmental clean-up of disaster sites
- Providing virtual access for the general public to maritime heritage sites

The research also led to the formation of a University spin-out company (ADUS) which surveys and visualises shipwrecks with great detail and accuracy. This informs critical decision-making during salvage, wreck removal and environmental clean-up operations.

2. Underpinning research (indicative maximum 500 words)

Key Researchers: Rowland PI (SL, Dundee University), Anderson (RA, Dundee University)

Rowland has developed the underpinning research,[2,3,4] which focusses on novel methods for visualising multi-beam sonar data of underwater historic shipwreck sites. The 3D visualisation research was instigated by Rowland's interest in visualisation aesthetics and undersea environments, first evident in the New Media Scotland, Alt-W award for Submerge. This work was further developed and applied to artefacts gathered from the Swan shipwreck site and over fifty other wreck sites worldwide.

WreckSight[1], an interactive software application, was developed by Rowland for both specialist and general audiences. This software exploits the research and implements it in real time, allowing users to interact with and explore the shipwreck visualisation in 3D. Two novel visualisation methods; Occlusion Objects and Locoramps, address specific problems inherent in the display of point clouds from multi-beam sonar and by applying digital cinematography, depth perception is improved:

- Occlusion Objects prevent the viewer from seeing through gaps in the data, thus improving visual depth cueing and improving the viewer's perception of the structure of a shipwreck. Traditional methods of surfacing sonar data result in important details such as cracks in the hull being hidden. Occlusion Objects retain these details while removing parallax errors caused by seeing through to the far side of the data set.
- Locoramps (Locally Oriented Colour Ramps) allow the careful placement and orientation of colour to specific features in the data to clearly highlight fine detail. By default, multibeam sonar contains no colour information. By aligning custom colour ramps to specific features of the wreck, and adjusting the colour threshold within the ramp, it is possible to separate the details from the background making them much easier to locate and identify.
- Digital Cinematography techniques were applied to improve the viewer's depth cueing. By moving virtual cameras around the data, depth perception and spatial understanding improves. This is referred to in "gestalt" theory where the brain looks for meaning in visual patterns. By moving the viewer's position, the structure of the wreck was better revealed in the data.

Applying the research in real world projects by employing a cycle of research-case study-review-research has led to direct feedback on research understanding. The research has been applied to high profile international environmental salvage projects including the Costa Concordia[5.2] in Italy and the Deepwater Horizon[5.1] oilrig in the Gulf of Mexico and HMS Royal Oak (2006)[5.3]. The Costa Concordia is the largest wreck removal project ever carried out (£520 million and rising) and the Deepwater Horizon caused the biggest oil spill in US history.

Project funding includes: Ministry of Defence, G8, NATO, Department for Transport, Maritime and Coastguard Agency, National Oceanic and Atmospheric Administration, English Heritage and Historic Scotland. Exclusive access was given to global underwater sites with challenging access and visualisation opportunities to investigate, extending research knowledge. The research portfolio has now extended to engage issues relating to the rapidly expanding offshore renewables and oil and gas decommissioning industry (e.g. Statoil (Norway) and Barrow Offshore Windfarm).

3. References to the research (indicative maximum of six references)

1. WreckSight: Visualising our Submerged Heritage. VAST2010, Le Louvre, Paris. Published by Eurographics. ISBN 978-3-905674-29-3 (Rowland REF2) The development of Occlusion Objects and Locoramps as they are applied in real time were described in this research paper. The paper describes how the research outcomes were incorporated in a software application (Wrecksight) and further developed to address the requirements of salvage and maritime heritage industries.
2. At Depths with Computer Graphics, Front Cover and Article: Visualising the Invisible. Computer Graphics Quarterly, Volume 40 No. 3, November 2006. Published by ACM, ISSN: 0097-8930 http://dl.acm.org/citation.cfm?doid=1186743.1186747
3. 3D Visualisation of Historic Shipwrecks. CAA 2007: Layers of Perception. Berlin, Germany. 2nd to 6th April, 2007. Paper: ISBN:978-3-7749-3556-3
4. The Fallen Oak. SIGGRAPH Computer Animation Festival 2007. San Diego, USA. August 5th to 9th 2007. Published by ACM. ISBN: 978-1-59593-693-6
5. The key outputs from the research are interactive 3D visualisations for each project. These are accompanied by white papers detailing findings. In some of the salvage related cases these are not available in the public domain due to commercial or legal sensitivities. Where this is the case, copies are supplied for review by the REF panel on request.

   Salvage and Environmental Projects:

   5.1. Deepwater Horizon Oil Rig (2010): The rig exploded and sank to 1,500 metres in the Gulf of Mexico in April 2010 creating the biggest oil spill in US history. ADUS were invited to survey the wreck in collaboration with Transocean to support US government investigations into the cause and effect of the disaster. 3D visualisation methods were adapted to cope with the very large dataset and distortion caused by extreme depth to provide an interactive representation of the wreck revealing its condition upside down on the seabed. Digital artefact: WreckSight and white paper report. (Rowland REF2).

   5.2. Costa Concordia (2012-13): The cruise liner ran aground at Isola del Giglio, Tuscany in January 2012 with a loss of 32 lives. Titan Salvage proposed a “parbuckling” method to remove the wreck. This involved rolling the wreck onto an underwater platform prior to re-floatation and removal. ADUS provided a full metrical dataset of the wreck prior to parbuckling, accurate to 25mm and further post-op data to reveal the damage to the submerged starboard side. The 3D visualisation combines laser data of the coastline and above sea-level section of the wreck with sonar data of the submerged section and surrounding seabed. The salvage operation is estimated to cost over £600m. Digital artefact: WreckSight and white paper report. (Rowland REF2).

   5.3. HMS Royal Oak (2006): The battleship was sunk at anchor in Scapa Bay, Orkney, in October 1939 by U-47 with a loss of 833 personnel. The wreck is a designated war grave, which still contains munitions and has been leaking marine oil into the environment for over sixty years. The MoD’s Salvage and Marine Operations Group commissioned the ADUS team to survey and visualise the wreck and surrounding seabed to establish its condition and potential threat to the environment. The resulting 3D visualisation successfully identified the location and order of the four torpedo strikes which sank the ship (contradicting earlier literature which suggested a minimum of 5 hits) while confirming that the wreck was in remarkable condition and unlikely to collapse in the short term. 3D Visualisation on DVD and white paper report. (Rowland RAE 2008).

Projects were funded directly from Government departments with additional grants for software development. Those involving collaboration with salvage companies were funded directly from those companies. Rowland, Dean, Lawrence, (ADUS): Combined salvage project funding circa £400,000 (Managed via Department of History, St Andrews University). 2006 - 2010
Rowland: Alt-W, New Media Scotland: Award 2001, £5000
Rowland: Software Development Grant, Scottish Enterprise Tayside: 2007-8 £23,000
Rowland: Orkney Heritage: In collaboration with Wendy McMurdo, NESTA: 2006, £5,000
Rowland: RASSE Project, English Heritage, Award 2008, £5,000
Rowland: 3D Visualisation for Offshore Renewables, ADUS Deepocean: 2013, £200,000.
Further examples of projects involving collaboration with salvage companies and Heritage

Agencies are represented on the ADUS website: http://www.adus-uk.com/wreck-images

4. Details of the impact (indicative maximum 750 words)

The main areas of impact from this research are the change in business practices on the international maritime salvage industry for wreck removal and environmental clean-up operations along with an improvement in public accessibility of maritime heritage sites.

The development of novel 3D visualisation methods for displaying high resolution multi-beam data through Rowland's research, combined with Dean and Lawrence's data collection methods, led to successful Government funded projects: e.g. HMS Royal Oak, SS Richard Montgomery and B159. Publicity resulting from these projects led to opportunities in the salvage and wreck removal industry where previously multi-beam sonar had not been considered useful beyond pinpointing the location of a shipwreck. This growing commercial interest led the ADUS research team to establish the spin out company ADUS Ltd (Advanced Underwater Surveys) in 2008. The company was partially acquired (50%) by Deepocean Ltd in 2013 and renamed ADUS-Deepocean[l]. ADUS has an exclusive licence to the 3D visualisation methodologies developed from the research.

Salvage and Wreck Removal:

The research has impacted on the maritime salvage industry through the provision of high resolution, highly accurate 3D visualisations of underwater sites, supporting risk assessment and critical decision-making for planning and execution of wreck removal operations. Prior to the development of the research, salvage companies relied heavily on diver based surveys which are hazardous and restricted by depth and environmental conditions (sea state, visibility etc).

Through ADUS and its often high profile work (Deepwater Horizon Oil Rig, Costa Concordia), the research is leading to an elevation of standards in the salvage and wreck removal industry and a growing demand for the improved 3D visualisation the research underpins.

Implementation of the visualisation techniques in WreckSight has allowed salvage planning and wreck removal to be based on accurate 3D data presented in an interactive interface. The 3D visualisation allows the data to be viewed from any angle whereas data from diver surveys (drawings, photographs) is limited to 2D views which are further restricted by levels of visibility in the water.

The Costa Concordia project[g] produced an accurate metrical dataset of the entire ship which was supplied to the salvage team ahead of operations. This was enhanced with subsea laser, in-air laser and photogrammetry data. The 3D visualisation was used by the salvage team to plan wreck removal operations, including the placement of significant sub-sea engineering works within a tolerance of 25mm.

MV New Flame, a Panamanian bulk carrier, sank off Gibraltar in 2007 was another example of the research being effectively employed in salvage operations. The project involved two surveys and visualisations (2008-09). The first, prior to salvage was used for risk assessment and planning. This revealed large amounts of cargo still remaining in the main section of the wreck had previously been undetected. The salvage plan was amended to remove the cargo prior to lifting the wreckage otherwise the lift would not have been possible. The second survey revealed that the savage team had missed a significant piece of upstanding wreckage which, if undetected would have caused a major hazard to shipping.

Maritime Heritage:

The research's impact is also in the provision of virtual access to previously inaccessible maritime heritage sites for the general public. The interactive visualisations in WreckSight and 3D animations and images of the shipwrecks are distributed online and placed in museums for wide public access[f,h,l,j] (e.g. Lyness, Orkney).

- The Battle of the Atlantic Project[k] (2011-2013) was funded by the US National Oceanic & Atmospheric Administration (NOAA): National Marine Sanctuaries. The project explores the site of the Battle of Convoy KS-520 which took place off North Carolina in 1942. A number of vessels lost in action are visualised interactively in WreckSight. These include U-Boats and the merchant vessels they sank. The WreckSight volume is being used by the National Marine Sanctuaries to promote the history of the site to a wider public audience. This work (2012-13), led to the commission of a further investigation into a US Civil War wreck; CSS Georgia which

sank in the Savannah River, Georgia, USA,1864.

- German WWI High Seas Fleet was scuttled in Scapa Flow, Orkney in 1919. Eight wrecks, which are regularly visited by sport divers were visualised in 2007. This project was the first to use the WreckSight software, which was distributed to dive boat operators at Scapa Flow to support safer dive planning. Supported by Historic Scotland, the shipwreck data was used in 2011 as a basis for the 3D illustrations on the www.scapaflowwrecks.com website promoting diving in the area. Scotland on Sunday newspaper[a] published a full-page article on the Royal Oak project, including images of the wreck and interviews with family members of the victims. This led to BBC news coverage[b] on TV and Radio, linking the 3D visualisation research to the oil clean-up operation. A review of the Scapa Flow edition of Wrecksight was published in Diver Magazine[d] and images from the Royal Oak visualisation feature on the Scapa Flow Wrecks web site (2011). A number of articles describing the research and its application for dive planning were published in the popular diving press e.g. Diver Magazine[e].

5. Sources to corroborate the impact (indicative maximum of 10 references)

a) Picture Perfect: The Fallen Oak. Feature article in Scotland on Sunday newspaper: http://www.scotsman.com/news/scotland/top-stories/picture-perfect-the-fallen-oak-1-1415434
b) The Material World. BBC Radio 4: http://www.bbc.co.uk/radio4/science/thematerialworld_20070208.shtml
c) The Royal Oak images on the Scapa Flow Wrecks website: http://www.scapaflowwrecks.com/wrecks/royal-oak/wreck.php
d) http://www.divernet.com/Diving_Gear/diver_tests/232100/visualiser_wrecksight_scapa_flow_edition.html
e) Scapa Flow in 3D Diver Magazine: http://www.divernet.com/Wrecks/159269/scapa_flow_in_3d.html Versions of this article were republished in Danish and Norwegian diving magazines (Dyk and Dykking) and also the US Sport Diver magazine.
f) Submerge: Shipwreck visualisation project funded by the Alt-W scheme and selected for the retrospective exhibition at CCA in 2008:Alt-W: New Directions in Scottish Digital Culture. http://www.mediascot.org/alt-w/exhibition/08
g) Costa Concordia Parbuckling Project: http://www.theparbucklingproject.com/
h) Portrait of a Shipwreck. SIGGRAPH 2007-2009, Travelling Art Show. Furlong Gallery, University of Wisconsin-Stout, USA January 29th to February 21st, 2008. The Niswonger Digital Media Center, East Tennessee State University. September 1st to 26th 2008.
i) DigitalEyes: New Esthetic Dimensions in Computer Visualisation Technology. Los Angeles Municipal Art Gallery, USA. November 6th 2008 to January 18th 2009. GlobalEyes. SIGGRAPH 2007 Digital Art Gallery, San Diego, USA. August 5th to 9th 2007. Published by ACM, ISBN:978-1-59593-646-2 http://www.digitaleyes2008.org/?q=art-royal-oak
j) Fishing With Sound: An Aesthetic Approach to Visualising our Maritime Heritage. EVA London 2011. Electronic Visualisation and the Arts. ISBN 978-1-906124-88-5 http://dl.acm.org/citation.cfm?id=2227241
k) http://sanctuaries.noaa.gov/missions/2010battleoftheatlantic/ Digital artefact: WreckSight. (Rowland REF2)
l) http://www.hydro-international.com/news/id6149-DeepOcean_Owns__Interest_in_ADUS.html