

Institution: University of St Andrews



Unit of Assessment: 17 – Geography, Environmental Studies and Archaeology

Title of case study: A sea-change in geophysical-marine surveying for protecting our Ocean's future

1. Summary of the impact

Safeguarding our seas through the establishment of marine Special Protection Areas and cultural heritage Seascapes is a fundamental aim of European Union Directives and the UK Marine and Coastal Access Act 2009. Over the past decade, sonar research development led by Dr Bates of the University of St Andrews has had widespread influence on international government and industry through accurate mapping of these assets, championing their importance and establishing new management strategies for their conservation. This work has been pivotal to the creation of 107 of the current legislated European Marine Special Areas of Conservation and Marine Special Protection Areas. The innovations in technology pioneered by this work also are providing critical findings on climate change impacts in the Earth's most sensitive and threatened environments with world media coverage on work in the Arctic including the award-winning TV series Operation Iceberg in 2012. Strong international media involvement has become one of the hallmarks of this work which simultaneously delivers research results as outputs of high quality across the globe. Furthermore, the technology has had economic impact in the form of three spin-out companies.



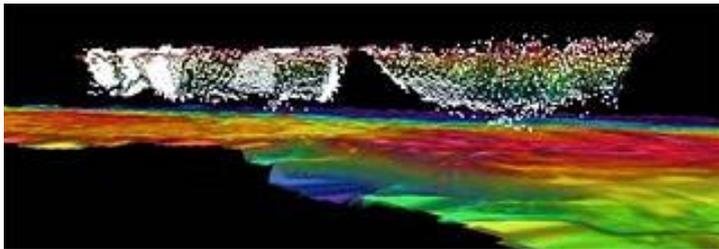
Public awareness of the world's threatened environments drives debate and action on climate change.

2. Underpinning research (indicative maximum 500 words)

Understanding complex systems on the Earth's surface requires a multi-disciplinary approach where information is needed that is both spatially and temporarily extensive. Over the past decade it has become increasingly clear that this coverage can only be made using remote sensing techniques such as provided by geophysical methods. In astronomy and petroleum exploration, for example, this has been achieved, but for other disciplines it has only relatively recently become possible. Seismic acoustic methods have been the mainstay of oil and gas exploration for over 40 years, but the last decade has seen important new technology developments based on multicomponent wave fields. Initial investigations on these techniques for characterising fractured gas reservoirs¹ in 2001 led Bates, a researcher at the University of St Andrews since 1996, to develop new methods for the application of acoustic techniques, in particular for multibeam sonar² that included imaging techniques, novel deployment and automated processing for very high resolution marine surveying thus producing 3D maps of seafloor and sub-seafloor fabrics, structures and environments. A number of publications ensued which demonstrated their application to multi-disciplinary fields spanning geology, biology, archaeology and environmental science which was used to capitalise publicity for the trial of the techniques for marine conservation management in the UK^{2,3}. In subsequent research Bates obtained hitherto unavailable detail on seabed habitats from ship-based measurements across major marine European Special Areas of Conservation that were previously only available in limited diver-based surveys. The success of the methods led to further adaptations for investigation and classification of threatened and protected species sites for deep-water coral in the North Atlantic³. In 2008, interest in the research prompted the Smithsonian Tropical Research Institute to ask Bates to test the methodologies at key fishing Protection Zones in the Pacific Central Americas where traditional survey had failed to recognise key seabed habitats. These were successfully characterised using the new methods.

Parallel to the research for biological applications, a programme of investigation into advances in novel sonar technologies for submerged cultural heritage discovery, mapping and monitoring change began in 2002. New automated pattern recognition algorithms for sonar images based on Wavelet Analysis Techniques were developed and tested on artificial and internationally important wreck sites⁴. In addition to increasing the success of correctly identifying marine cultural heritage, the techniques delivered a step-change in resolution of seafloor images, thus forming the basis for defining new protocols for marine cultural heritage surveying as part of long-term site management and protection⁵.

Recognition of the utility of sonar techniques for monitoring both short and long-term environmental changes has led in the last three years to experimentation with combining acoustic with laser measuring tools for climate impact studies of marine terminating glaciers in crucial locations such



Sonar image: the seafloor is in colour shaded by depth and the icebergs are 'hanging' in the water column.

as northern Greenland. In particular for these studies, laser scanning and sonar techniques are simultaneously deployed from bespoke survey craft at extremely hazardous locations to measure rates of calving and melt. This multidisciplinary research led by Bates is finding widespread interest in academic studies of glacial retreat⁶.

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

- ¹Bates, C. R., Phillips, R., Grimm, R and Lynn, H. 2001. The Seismic Evaluation of a Naturally Fractured Tight Gas Sand Reservoir in the Wind River Basin, Wyoming. *Petroleum Geosciences*, v. 7, pp. 35-44. DOI: [10.1144/petgeo.7.1.35](https://doi.org/10.1144/petgeo.7.1.35)
Winner of the European Association of Geoscientist and Engineers Best Paper Award for 2001.
- ²Bates, C. R. and Byham, P. 2001. Bathymetric Sidescan Techniques for Near Shore Surveying. *The Hydrographic Journal*, v. 100, pp. 13-18.
Winner of the Hydrographic Society Best Paper Award.
- ³Roberts, J. M., Brown, C. J., Long, D. and Bates, C. R. 2005. Acoustic Mapping using a Multibeam Echosounder Reveals Cold-water Coral Reefs and Surrounding Habitats. *Coral Reefs*, v. 24, pp. 654-669. DOI: [10.1007/s00338-005-0049-6](https://doi.org/10.1007/s00338-005-0049-6)
Article was published in a specialist peer-reviewed journal and has 41 citations in WoS.
- ⁴Atallah, L., Probert Smith, P. and Bates, C. R. 2002. Wavelet analysis of bathymetric sidescan sonar data for the classification of seafloor sediments in Hopvågen Bay - Norway. *Marine Geophysical Researches*, v. 23, pp. 431-442. DOI: [10.1023/B:MARI.0000018239.07561.76](https://doi.org/10.1023/B:MARI.0000018239.07561.76)
Article was published in an international peer-reviewed journal.
- ⁵Bates, C. R., Lawrence, M., Dean, M. & Robertson, P. 2011. Geophysical Methods for Wreck-Site Monitoring: the Rapid Archaeological Site Surveying and Evaluation (RASSE) programme. *International Journal of Nautical Archaeology*. v 40.2: 404–416. DOI: [10.1111/j.1095-9270.2010.00298.x](https://doi.org/10.1111/j.1095-9270.2010.00298.x)
Article was published in an international peer-reviewed journal.
- ⁶Neal, M., Bates, C. R., Blanchard, T. Hubbard, A. and Woodward, J. 2012. A hardware proof of concept for a remote-controlled glacier-surveying boat. *Journal of Field Robotics*. v29, 6, pp.880-890. DOI: [10.1002/rob.21420](https://doi.org/10.1002/rob.21420)
Article was published in a specialist peer-reviewed journal with an impact factor of 3.580.

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

The underpinning research was motivated by government, cross-industry and public need for better methods to monitor, manage, protect and publicise international marine assets, including sensitive habitats with endangered or threatened species, cultural heritage (in particular associated with World Heritage Sites) and critical climate-impacted environments. Sonar methodologies developed by Bates have provided a cornerstone to meeting the needs of government regulators while simultaneously providing the platform for furthering public understanding of the asset

Impact case study (REF3b)

importance of such sites and habitats through a global media effort. Specifically, the methods have been used (1) to define the existence, map the extent and establish the baseline habitat health of new Special Areas of Conservation and Marine Protection Areas (MPA) in Europe and Central America, (2) to provide the means to map, monitor and manage submerged heritage sites in European waters and (3) to record and broadcast to a global audience the changes in critical Arctic regions. In addition, (4) financial impact in the form of three spin-out companies ensuing from engagement efforts have resulted from the research.

Impact on Policy Directives for the Conservation of Sensitive Marine Habitats: The underpinning research conducted in the early 2000s by Bates resulted in commissioned conservation reports for government, for example on special areas of conservation, and through the development of new sonar technologies, the adoption of the technologies in mapping programmes. Following, Bates acted in an external consultant role for the definitive EU project for the mapping of European marine habitats – the [MESH Project](#) - *“Dr Bates’ work has been instrumental in the adoption of sonar-based technologies for broadscale sea bed surveys into mainstream use.... demonstrating how these products may be applied to policy development and operational deliveryhas bridged that gap between ‘standard research’ and operational delivery”*^{S1}. This ultimately culminated in the adoption of mandatory procedures developed by Bates and colleagues for benthic habitat survey based on the sonar methodologies which, in 2009, were adopted by all principal UK Conservation Organisations (e.g. Natural England, Joint Nature Conservancy Council, Scottish Natural Heritage) for conservation guidelines on habitat mapping that ultimately led to the establishment of over 107 internationally important sites of Special Areas of Conservation and Marine Special Protection Areas. *“These techniques have, and will continue to help in the implementation of the Habitats Directive, and more recently have been fundamental to the deliberations over MSPAs as required by the Marine (Scotland) Act and the delivery of commitments in the Marine Strategy Framework Directive”*^{S2}. The sonar methods, which provide key data for the management and thus protection of key designated areas, are now an internationally adopted practice (e.g. fisheries protection research conducted for the Smithsonian Tropical Research Institute, Panama under the Darwin Initiative); they also provide the stunning visualisation widely used for public dissemination of the information, for example with internationally important deep-water coral sites.

Impact on Public Understanding of Marine Cultural Heritage: Since the early successes of the multibeam programme for habitat evaluation, a parallel research stream, as discussed in section 2, was developed for its use in marine cultural heritage sites (wrecks, structures and drowned palaeo-landscapes) appraisal, monitoring and management. This led to research contracts from English Heritage to develop new visualisations and the mandate to adopt specific protocols for monitoring important submerged cultural heritage such as the UK Designated and Protected Wrecks under the Protection of Wrecks Act (1973)^{S3}. The site-specific investigations stimulated work on drowned landscapes on the European Shelf that are under increasing threat from climate impacts and development. Here, associated research on the submerged Neolithic remains around World Heritage sites in Orkney and Jersey revealed a lost world that not only caused widespread academic interest by uncovering new insights into early human expansion in Northern Europe but which also captured public imagination through a series of media events. Invited exhibits, included the Royal Society 2012 Summer Science Exhibition which saw over 11,000 visitors, made up of an audience of 15% educational, and 85% general public and media^{S8}, with [Europe’s Lost World](#) web and [Facebook pages](#) receiving over 38,000 unique hits over the exhibit period. Follow-up related media interest included over 3,360 reporting websites, 477 blog sites and 1630 discussion sites worldwide through 31 July 2013^{S9}, interviews, as far afield as California and Russia, published articles and commentary. This led to the request for the work to be displayed in the UK’s first dedicated Mesolithic to Neolithic hunter-gatherer permanent exhibit housed in an extension to the museum of [Tomb of the Eagles](#), Orkney that receives over 10,000 visitors pa. Media interest has broadened with radio, TV and major articles published in, amongst others, BBC Focus Magazine (average UK circulation, 65k/month) and National Geographic (average US circulation, 5million/month).

Impact on Public Understanding of Critical (Climate) Environments: A complementary dimension that developed from the sonar mapping research was first realised in 2009 with a request from [Greenpeace](#) to join their expedition to northern Greenland to use Bates’ techniques to

study the rapidly retreating, marine-terminating glaciers and areas of sea-ice melt which are habitats to some of our most threatened species, such as the polar bear. Significant public and governmental attention followed during the Copenhagen Summit, 2009, and with articles for National Geographic (US, Australia and China) and presentations to policy makers during the 2010 Arctic Frontiers conference. The interest in this work continued. In 2012 the BBC2 /Discovery Channel/ BBC Learning commissioned two programmes ([BBC2 Operation Iceberg](#)) dedicated to the research, specifically highlighting the sonar and laser scanning advances^{S4}. The programmes were broadcast in the UK in Nov 2012, with an audience in excess of 3.5 million and viewing numbers at 50% above slot averages^{S4}. Subsequently, it has been broadcast to international audiences through the Discovery Channel, an indication of the strong public interest in the research which also received acclaim by winning the 2012 Royal Television Society Best Science and Natural History Documentary^{S4}.

Economic Impact: Apart from the evident, yet difficult to account, economic impact resulting from public engagement events as listed above, the sonar research has been used in commercialisation with the establishment of the marine survey division of [SOI Ltd](#), a company dedicated to marine habitat conservation based at the University of St Andrews (sales of over £800k since incorporation)^{S7}. In 2008, the novel, high-fidelity acoustic technologies also resulted in the spin-out company, Advanced Underwater Surveys Ltd ([ADUS](#)). This company's success was demonstrated in 2013 when Deep Ocean UK, a marine industry leader with turnover in excess of £500Mpa, acquired a 50% stake in the company^{S6}. Finally, the survey methodologies developed in early tests led one of Bates' students in mid-2011 to establish [GeoSurv Ltd UK](#), an independent dedicated marine survey company that posted a first-year turnover of over £100k^{S5}.

The sonar developments and their adoption across a wide spectrum of applied marine spheres has had major national and international reach over the past 10 years, as manifest by increased widespread use of the methods, and has informed the attitude and awareness to significant global environmental and heritage issues by both government and the wider public. Further, the sonar developments have unlocked key information that is being used to reduce potential harm to environments and heritage sites with the establishment of Marine Protection Areas and Heritage Protection Sites, helping to preserve them for future generations.

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

Conservation – directly quoted in text

^{S1}Head of Marine Protected Areas, JNCC

^{S2}Principal Advisor (Marine), Scottish Natural Heritage

Submerged Cultural Heritage – direct use of research in the management of submerged heritage

^{S3}Head of Maritime Archaeology, English Heritage

Climate Impact – Glacial Retreat

^{S4}Executive Producer, [BBC2 Operation Iceberg](#) (<http://www.bbc.co.uk/programmes/p00tvcnx>) – Documentary Series statistics

^{S5}[GeoSurv Ltd UK](#) (<http://geosurvuk.com/>) verification of spin-out company

^{S6}Advanced Underwater Surveys Ltd, ([ADUS](#) - <http://www.adus-uk.com/>) verification of a spin-out company from the University of St Andrews with an economic benefit

^{S7}[SOI Ltd](#) (<http://www.soi.ltd.uk/how-we-work/>) - verification of the economic impact of the independent start-up company at the University of St Andrews as a result of the underpinning research

^{S8}Summer Science Exhibition Statistics sheet – corroborating audience make-up and numbers at exhibition

^{S9}Internet public interest statistics from period following media publicity of Drowned Landscapes exhibition