Wessex Archaeology

Aggregates Levy Sustainability Fund

Marine Aggregates and the Historic Environment

Wrecks Ecology 2007-08
Final

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AGGREGATE LEVY SUSTAINABILITY FUND
MARINE AGGREGATES AND THE HISTORIC ENVIRONMENT

WRECKS ECOLOGY 2007-08

FINAL REPORT

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1 INTRODUCTION

1.1.1 There is an interest in shipwrecks of marine archaeological importance from both an archaeological and ecological perspective.

1.1.2 The ALSF Round 2 *Wrecks on the Seabed* study (Wessex Archaeology, 2006b) highlighted that there may be merit in developing a clearer understanding of the relationships between marine archaeological sites and their associated benthic ecology. These relationships are particularly relevant in the context of archaeological mitigation strategies generally adopted for wreck sites within aggregate extraction areas and specifically the practice of implementing exclusion zones around historic wrecks.

Why study the benthic ecology of wrecks? - an ecological perspective

1.1.3 Archaeological exclusion zones may also be considered as 'benthic no-take zones' which have the potential to act as refuge areas for benthic communities which would otherwise be removed by aggregate extraction. They may therefore be important in the contributing to the benthic recovery process following cessation of dredging and provide additional benthic 'stock' to re-colonise adjacent areas. Archaeological exclusion zones may therefore be relevant in the context of ecological mitigation strategies adopted.

1.1.4 In addition, wrecks, particularly within aggregate extraction areas, often add structure and diversity to seabed types in an otherwise relatively uniform seabed (e.g. extensive areas of sand targeted for extraction). They are often found to support benthic and fish communities which differ to that of the surrounding seabed. Wreck sites may therefore have a nature conservation value, be of importance to local fisheries in the habitats they provide and the species they attract, or add to the general ecological value of a region by increasing biodiversity. All of these issues should be fully understood if effective mitigation strategies are to be adopted with respect to the ecological impacts of aggregate extraction.

1.1.5 Yet surprisingly, wrecks are typically omitted from ecological characterisation or baseline surveys which provide supporting information to describe the biological status of proposed dredge areas within Environmental Impact Assessments (EIAs) and Regional Environmental Assessment (REAs). As wrecks and the associated exclusion zones are not intended for dredging they are often not considered a priority for inclusion in the regional or licence area ecological monitoring programme and survey cost, time and effort is directed elsewhere within these areas (CEFAS, *pers. comm*.). In addition, shipwrecks have been, by convention, widely perceived as the subject of archaeological investigations.

1.1.6 Should wreck sites be considered for inclusion in ecological monitoring programmes however, remote sampling techniques routinely used to quantify infauna and epifauna, and substrate type (e.g. grabbing, drop down video and beam trawling) are not best suited to surveying wreck habitats. This is both from a safety point of view (for both the wreck and the survey vessel) and also because these remote techniques are not considered to be the most appropriate for the study of habitats typical of wreck sites (hard substrates with extremely variable topography). Techniques better suited to studying wreck ecology include those employed by diving and the use of Remotely Operated Vehicles (ROVs).

1.1.7 Wrecks may also provide suitable habitat and act as 'stepping-stones' for species to extend their geographical range. They may therefore provide suitable geographical focal points for monitoring range extension.

Why study the benthic ecology of wrecks? – an archaeological perspective

1.1.8 Benthic communities associated with wreck sites can almost certainly provide some information on prevailing environmental conditions and therefore have the potential to act as proxies to facilitate in the assessment of site stability and highlight potential vulnerabilities.

1.1.9 Benthic species (and habitats) are recognised as good indicators of prevailing environmental conditions (Connor, *et al*, 2004; Hiscock *et al*, 2005; Rees *et al*, 2006). Benthic species choose to live within a particular environment. They each have a preference for a certain combination of physical, chemical and biological factors which make up the environmental niche they occupy. In addition, each species has a different tolerance to different environmental conditions. Therefore spatial and temporal changes within environmental conditions are reflected in the changes in the distribution and abundances of the benthic community.

1.1.10 Environmental processes (physical, chemical and biological) around wreck sites are key factors in assessing the potential threats to sites of heritage value (Wheeler, 2002) and therefore need to be fully understood if effective archaeological mitigation strategies are to be adopted with respect to the impacts of aggregate extraction (Oxley, 2001).

1.1.11 In addition, a fundamental part of management plans for all wrecks designated under the Protection of Wrecks Act (1973) is the need for an assessment of wreck condition (English Heritage, 2007).

1.1.12 Yet, very little environmental data is measured or recorded during archaeological site surveys, whether these are being conducted in the context of a designated site assessment, an undesignated site assessment, or the archaeological component of an EIA/REA in support of aggregate extraction licence applications (Wessex Archaeology, 2006a, b and 2007; English Heritage, *pers. comm.*).

1.1.13 Recording techniques routinely used during archaeological site investigations are employed by diving and ROV; as are those which are best suited to the study of wreck ecology.

An Integrated Approach

1.1.14 There would clearly seem to be a strong case for considering the study of wreck site ecology, and particularly those sites within marine aggregate extraction areas with respect to the possible cross-over advantages of archaeological and ecological mitigation strategies.

1.1.15 However, further marine investigations such as diving and ROV operations best suited to wreck studies have additional cost and time implications. This may be overcome by integrating ecological survey methodologies into archaeological site investigations which already have divers and/or ROV deployed on site.

2 PROJECT AIMS

2.1.1 Develop an increased understanding of the environmental interactions of wreck sites and the (potentially cumulative) impacts on wreck sites from aggregate extraction.

2.1.2 Assess the usefulness and potential of ecological data collected as part of archaeological wreck site surveys to offer the aggregates industry benefits arising out of the cost-effectiveness of integrated surveys.

2.1.3 Investigate possible cross-over advantages from ecological and archaeological mitigation from the impacts of aggregate extraction.

3 PROJECT OBJECTIVES

O1 Investigate whether or not the presence/absence of benthic species can be used as proxies for assessing environmental conditions of wreck sites in relation to site vulnerability.

O2 Investigate whether archaeological exclusion zones may act as refuges for benthic species which may then contribute to the re-colonisation of adjacent areas following cessation of aggregate extraction?

O3 Investigate the nature conservation value of wreck sites in terms of the habitats they provide and the species they attract.

O4 Investigate the role of archaeological protected areas conserving ecological interests, particularly those within aggregate extraction licence areas.

O5 Investigate the role of ecological protected areas in conserving archaeological interests.

O6 Assess data (video and stills images) collected during the course of routine archaeological surveys for suitability for habitat and species assessment in the context of commenting on environmental conditions. If this is found not to be suitable, does it have the potential to be?

O7 Assess the scope for cost-effective acquisition of ecological data during archaeological surveys. Suggest suitable methods which would be compatible with standards and techniques acceptable within wider disciplines of marine science such as Marine Life Network (MarLIN), Data Archive for Seabed Species and Habitats (DASSH), Marine Monitoring Handbook (*Davies et al*, 2001).

O8 Build inter-disciplinary links and co-operation.

O9 Raise awareness of the marine historic environment through engagement with industry, resources users and other stakeholders during the assessment.

O10 Determine the potential for expanding combined archaeological/ecological surveying to Seasearch on a local and national level and into other archaeological/ecological survey programmes.

O11 Present the results of the ecological assessment, within the wider contexts of *Wrecks on the Seabed* to a wide range of audiences.

O12 Update existing *Wrecks on the Seabed* outreach materials by incorporating the results of the ecological assessment of existing wreck data into existing web pages and diver packs.

4 METHODS

4.1.1 Due to the limited timescale of the 2007-08 ALSF extension it was not possible to consider fieldwork in the approach to acquire data for the investigation. Instead, a desk-based study was carried out which included stakeholder engagement and a literature review.

4.1.2 In addition, a review was conducted of existing video and stills image data collected during the course of archaeological site investigations carried out under previous Protection of Wrecks Act (1973) and ALSF contracts.

4.2 STAKEHOLDER ENGAGEMENT

4.2.1 Stakeholder engagement was an integral part of addressing all of the objectives within the study. In order to build inter-disciplinary links and co-operation a range of stakeholders and organisations with an interest in the wrecks and the contexts within which they are being assessed were contacted. These included:

- The marine aggregate industry;
- Organisations involved in marine archaeological monitoring and conservation (such as local government area offices; local archaeological societies, English Heritage Maritime Archaeology, local shipwreck/heritage centres and voluntary organisations);
- Organisations involved in marine ecological monitoring and conservation (such as local government area offices, JNCC, Natural England, CEFAS, wildlife trusts and voluntary organisations);

- General scientific community (including environmental consultancies, academic institutions);
- Other sea-users (such as local Sea Fisheries Committees, local dive charter companies);
- Wreck licensees, adopters and nominated archaeologists;
- General diving public (such as diving associations, individual divers, dive clubs).

A list of stakeholders is presented in **Appendix A** for reference.

4.2.2 Initial contact was made with stakeholders to introduce the project aims and objectives, to enquire whether this type of integrated approach to surveying wreck sites had been carried out previously, and to invite any general queries, comments and views.

4.2.3 Stakeholders were further consulted in relation to key considerations identified for each objective, those of which are outlined below. The context in which each stakeholder was contacted is highlighted in **Appendix A**.

Key considerations for each objective

- O1: environmental factors affecting wreck site condition; those associated with impacts of dredging; current methods for measuring wreck site environmental conditions; current attributes which are currently assessed to judge site condition; using benthic species as indicators of prevailing environmental conditions.
- O2: biological impacts of dredging both within and adjacent to the extraction area; how extraction areas are currently re-colonised by adjacent benthic communities; exclusion zone size to provide enough 'stock benthos' and avoid the impacts of dredging;
- O3: effects of wrecks on seabed communities; determining what constitutes nature conservation value; why wrecks are not considered under the definition of reefs (Annex I habitat); other reasons why studying wreck site ecology may be of value.
- O4: how are designated archaeological features protected; how can this benefit ecological interests?
- O5: how are ecological features protected; how can this benefit archaeological interests?
- O6: suitability and quality of data collected during the course of routine archaeological site investigations for species and habitat identification; type of assessment which can be made on prevailing environmental conditions based on species and habitats present; type of assessment required on prevailing environmental conditions to aid wreck site condition assessment.

- O7: current integrated archaeological and ecological initiatives; current methods compatible with standards and techniques acceptable within other disciplines of marine science e.g. MarLin, DASSH, Marine Monitoring Handbook;

- O8 and O9 were met in part through addressing O1 to O7.

- O10: current integrated archaeological and ecological survey initiatives; current volunteer/recreational recording standards and methods.

- O11: to met in part by presenting the results of the study at the MALSF Conference held on 28 and 29 February 2008

- O12: existing *Wrecks on the Seabed* outreach materials – web pages and Diver Packs - will be updated to incorporate the results of the ecological survey and assessment.

4.2.4 East Sussex Council, Sussex Seasearch and Booth Museum of Natural History have been reviewing stills image data collected by Wessex Archaeology during archaeological site investigations in an attempt to identify wreck habitats and species in order to fill gaps in spatial coverage of data without having to fund the cost of fieldwork. This will provide information which may allow for the nature conservation potential value of such sites to be assessed. These organisations were consulted specifically to ascertain what methods were being used to review the data, whether they found the data of suitable quality for ecological assessment, what changes they would apply to the image data acquisition method to make it more useable for ecological assessment, and whether the resulting species and habitat data was of value with respect to improving knowledge on their spatial distributions.

4.2.5 In addition, interaction with Seasearch (and other volunteer/recreational diving organisations) was required to determine the potential for expanding combined archaeological/ecological surveying to Seasearch (both on a local and national level) and into other archaeological/ecological survey programmes to maximise the information gained from survey efforts (O10).

4.2.6 Other specific stakeholder engagement requirements for the project included:

- Interfacing with English Heritage Maritime Team with respect to current methods being developed in the management of protected wrecks and specifically assessing wreck vulnerability (O1, O5 and O6);

- Interfacing with CEFAS to investigate how the study of wreck sites and their exclusion zones may have mitigation and ecological value (O2, O3, O4 and O7).

4.2.7 Stakeholder engagement was also used to inform the literature search.

4.3 LITERATURE SEARCH AND REVIEW

4.3.1 The following resources were utilised to carry out a comprehensive search for available literature:

Library and online literature database resources

- British Library (www.bl.uk) – over 20,000 journals. Also includes book series, handbook and reference works.
- Science Direct (www.ScienceDirect.com) – over 2,000 journals. Also includes book series, handbooks and reference works.
- Ingenta Connect (www.IngentaConnect.com) – over 30,000 publications.
- Google Scholar (http://scholar.google.co.uk).
- The National Oceanographic Library (www.noc.soton.ac.uk/nocs/library.php)

Websites consulted

- Aggregate Levy Sustainability Fund - Marine Environment Protection Fund (www.alsf-mepf.org.uk)
- British Marine Aggregate Producers Association (www.bmapa.org)
- Crown Estate (www.thecrownestate.co.uk)
- Department for Environment, Food and Rural Affairs (www.defra.gov.uk/marine)
- East Channel Association (www.eastchannel.info)
- Hampshire and Wight Trust for Maritime Archaeology (www.hwtma.org.uk)
- Nautical Archaeological Society (www.nasportsmouth.org.uk/projects)
- Wessex Archaeology (www.wessexarch.co.uk/projects/marine)
- The 'Resolution Project' (www.resolutionproject.co.uk)
- Centre for Environment, Fisheries and Aquaculture Science (www.cefas.co.uk)
- East Sussex County Council – Coastal Biodiversity Office (http://www.eastsussex.gov.uk/environment/conservation/coastaldiversity/)
- The Ecotope Mapping Home Page (www.ecotope.org/index.htm)
- European Artificial Reef Research Network - (www.nocs.co.uk/soes/research/groups/EARRN)

- Florida Department of State (www.flheritage.com/archaeology/underwater/fsu_pua/docs)
- Hampshire and Isle of Wight Seasearch (http://www.hwt.org.uk/what-we-do/marine-conservation/seasearch-project.htm)
- Hampshire and Isle of Wight Wildlife Trust (http://www.southeastmarine.org.uk/frameset2.htm)
- National Marine Biological Library (www.mba.ac.uk/NMBL)
- Natural England (www.naturalengland.org.uk)
- Scientific Diving Supervisory Committee (www.uk-sdsc.com)
- Seasearch (http://seasearch.wisshost.net)
- Sussex Seasearch (http://mysite.wanadoo-members.co.uk/sussexseasearch)
- Sussex Sea Fisheries District Committee (www.sussex-sfc.gov.uk)
- Sussex Wildlife Trust (www.biodiversitysussex.org)
- The Marine Life information Network (www.marlin.ac.uk)
- The Marne Conservation Society (www.mcsuk.org)
- The UK Marine SACs Project (www.ukmarinesac.org.uk)
- The Health and Safety Executive – diving and publications (www.hse.gov.uk)
- The Joint Nature Conservation Committee (www.jncc.gov.uk)
- The Scottish Association for Marine Science (www.sams.ac.uk/research/departments/ecology/ecology-projects/reef-ecology)
- The National Parks Service (www.nps.gov/history/nr/travel/flshipwrecks)
- Northwestern Hawaiian Islands Coral Reef Assessment and Monitoring Program (http://hawaiianatolls.org/research/NOWRAMP2002/features/ship_ecol.php & http://www.hawaiianatolls.org/research/NOWRAMP2002/features/rea.php)

4.3.2 Due to budget and time constraints it was not possible to source of all of the titles highlighted during the literature search and review, this with respect to relevance to the project. Therefore, a list of these titles which have the potential to be of additional relevance is given at the end of this report, for future consideration.

4.3.3 The key considerations listed for each objective in **Section 4.2** formed the basis of the literature search.

4.4 REVIEW OF EXISTING WRECK DATA

4.4.1 The review of existing wreck data constituted four main tasks:

- Wreck site selection;
- Selection of a suitable sub-set of existing data for each wreck site;
- Ecological review of data; and
- Commenting on prevailing environmental conditions in the context of wreck site condition and vulnerability.

4.5 WRECK SITE SELECTION

4.5.1 Seven wreck sites were selected for inclusion in the study. These were selected on the basis of the following criteria:

- Previously surveyed through *Wrecks on the Seabed* (Wessex Archaeology, 2006b) and the PWA 1973 contract;
- Have biological communities which have been identified as being of ecological importance and have been designated sites of Marine Nature Conservation Importance (sMNCI);
- Designated under the Protection of Wrecks Act (1973);
- Close to aggregate extraction areas;
- Archaeological data collected during previous archaeological site surveys is available;
- Acknowledged to be of cultural heritage value;
- Span a wide range of water depths and include both metal and wooden wrecks and therefore should host a range of ecological communities in response to the differing environments present;
- Include both ephemeral and buried sites – both of which present a risk in the context of seabed development and for which consistent archaeological management strategies are required and
- Have had information collected under the aegis of Sussex Seasearch.

4.5.2 **Appendix B** lists each of the wreck sites selected for ecological review with summary information, including the data acquisition history for each wreck. The location of these wreck sites in relation to adjacent aggregate extraction areas is presented in **Figure 1**.

4.5.3 Of the wrecks detailed in **Appendix B,** three represent sMNCI. These are wrecks of HMS *Northcoates*, *City of Waterford* and the *Outer Mulberry* which have been assigned the non-statutory sMNCI designation. It was not

possible to include these sites in the ecological review, owing to a combination of lack of available data and the time constraints of the study.

4.5.4 Of the four other wreck sites listed in **Appendix B** a comprehensive review was possible in only one case, the HM/s *Holland V*. Image data for this site was of relatively good quality and spatial referencing of species and habitats was possible due to the relatively obvious nature of wreck features on the video and stills.

4.5.5 Owing to the quality of data and limited timescale of this project, it was not possible to carry out a full review of the remaining three wreck sites (Norman's Bay, Bottle Wreck and Portland Stone). Instead, a list of conspicuous species and habitats was produced for each of these wrecks. No attempt was made to assign biotopes, or carry out a spatial and temporal assessment of species and habitat distributions due to lack of suitable data.

4.6 SELECTION OF EXISTING DATA FOR ECOLOGICAL ASSESSMENT

Sourcing/Collation of existing video and stills image data and associated metadata.

4.6.1 All the image data collected during the diving and ROV archaeological site investigations carried out by Wessex Archaeology (**Appendix B**; marked *) were sourced, together with associated metadata. **Appendix C** summarises the diving and ROV effort for each archaeological site investigation, and the amount of video footage and number of stills images collected. In addition, details are included of any ecological recording surveys carried out separately by Sussex Seasearch for each wreck site.

4.6.2 Stills images were collected using a 4MP Canon G2 compact digital stills camera with in-built flash and 0.56 wide-angle adapter. Images were made available as compressed jpeg files and reviewed using Microsoft Office Picture Manager software to enable enlargement of images to aid habitat and species identification.

4.6.3 Video footage was acquired by divers using a hat-mounted, single chip, Colourwatch digital inspection camera, and by ROV (SeaEye 600). Footage was available in a combination of miniDV tape format and as .avi files (ROV footage). This was reviewed on a large screen monitor using the video editing software iMovie to enable the footage to be freeze-framed and enlarged to aid habitat and species identification.

4.6.4 To enable an assessment of the spatial and temporal distribution of species and habitats across each wreck site it was necessary to determine the proximity of image data in relation to each wreck. This was not always immediately obvious due to e.g. poor visibility, complexity of wreck site features. Therefore, this had to be determined using a combination of methods including the review of field logs, archaeological site investigation reports and diver/ROV position track data.

Review of data quality with respect to commenting on archaeological techniques, and selecting a sub-set of data suitable for ecological assessment

4.6.5 Image quality, with respect to the identification of species and habitat was reviewed in relation to underwater visibility, distance from subject,

speed/steadiness of footage (video), focus and lighting (stills), and whether any reference to scale was included.

4.6.6 The spatial coverage of image data acquisition across each wreck site was also reviewed. This was in an attempt to select a sub-set of data which incorporated images of the surrounding seabed (out-with the hydrodynamic influences of the wreck), the wreck/seabed interface, the main wreck structure (vertical and horizontal faces, prominent structures).

4.6.7 Data collected using different acquisition methods were also compared for image quality and suitability for ecological assessment, including video footage collected by diver and ROV, and stills images collected using a dedicated stills camera or from video screen grabs.

4.7 ECOLOGICAL REVIEW OF DATA AND COMMENTING ON PREVAILING ENVIRONMENTAL CONDITIONS IN THE CONTEXT OF WRECK SITE VULNERABILITY.

Review of species and habitats

4.7.1 A relatively comprehensive review was carried out on the *Holland V* wreck image data. However, owing to time-constraints, difficulties associated with spatially referencing the image data with respect to the wreck, and the quality of stills and video footage, the species and habitat assessment for the Norman's Bay, Bottle and Portland Stone wrecks was limited to noting the presence/absence of species from a very small number of video clips and stills. In addition, no attempt was made to assign biotopes from these three wreck sites, and no spatial or temporal assessment of species distributions was carried out.

4.7.2 Procedural guidelines (PG) outlined in the Marine Monitoring Handbook (Davies, *et al,* 2001) for the analysis of video (PG3-5) and stills images (PG3-12) were followed for the review of habitat and species.

4.7.3 The video footage was used primarily to assess the diversity and spatial extent of habitats and broad biotope complexes across each wreck site while the stills were used to provide more detailed information on species composition (JNCC, 2003 and 2004). On occasion video footage provided good close-ups enabling species to be identified.

4.7.4 Conspicuous biota was identified to the highest taxonomic resolution permitted by the image quality and, where it was possible to determine scale, Marine Nature Conservation Review (MNCR) SACFOR abundance was estimated (this scale records whether species are **S**uper abundant, **A**bundant, **C**ommon, **F**requent, **O**ccasional or **R**are; Connor *et al*, 2004). More often than not however, species could only be noted on a presence/absence basis. In addition, substrate type was assessed as far as was possible without any particle size analysis data available for groundtruthing.

4.7.5 Following this, biotopes were assigned following the most recent marine habitat classification (Connor *et al*, 2004). Where it was not possible to identify the characterising species (epibiotic or infaunal) to enable biotope classification, broad habitat types were assigned (Connor *et al*, 2004). The classification of biotopes occurring on artificial substrates (including wrecks) is currently limited to two codes. Rock equivalent biotopes which most

resembled the wreck habitats and their associated communities were therefore used.

4.7.6 To ensure recording methods and resulting data from the video and stills image analyses were compatible with existing ecological monitoring standards, species and habitat data were recorded using proforma broadly based on MNCR survey, site and habitat recording forms for sublittoral surveys (Connor *et al*, 2004; field recording and data management).

4.7.7 Owing to the limited suitability of the image data to consistently record abundances quantitatively, statistical methods could not be applied to assess spatial and temporal variations within the species data. The ecological assessment was therefore limited to subjective observations of changes in biotope distribution, species assemblages and abundances.

Assessment of prevailing environmental conditions using benthic species and habitats

4.7.8 Where possible comment was made on the spatial and temporal distribution of biotopes and species in the context of environmental influences across each site by reference to the environmental descriptions for biotopes within the national classification (Connor, *et al*, 2004) species information contained on the MarLIN species web pages (MarLIN, 2008b) and the Seabed Indicator Species Database (MarLIN, 2008a).

4.7.9 In addition, comment was made on whether or not the cause of the spatial and temporal variation could be determined to help identify potential threats to wreck site preservation.

Nature conservation value of wreck sites

4.7.10 Provision was also made for reviewing the conservation status (locally, regionally, nationally and internationally) of species and habitats identified from each wreck site. The following marine nature conservation legislation was consulted through stakeholder and engagement and literature review:

- BERN Convention;
- CITES;
- OSPAR;
- IUCN Red Lists;
- Natura 2000 (The EC Habitats Directive);
- Wildlife and Countryside Act 1981 (as amended in 1985); and
- UK Biodiversity Action Plan (BAP).

4.7.11 In addition, species and habitat data were submitted to the East Sussex County Council (Biodiversity Officer) for review in the context of local non-statutory marine nature conservation designations (Marine Sites of Nature Conservation Importance (mSNCI), Voluntary Marine Conservation Areas (VMCA), Sensitive Marine Areas (SMA) and Natural Areas (NA)), and for

comment on whether the ecological data from the assessment was of conservation importance or added to the knowledge and understanding of species and biotope distributions on a local, regional and national level.

4.7.12 Information was also sought through stakeholder engagement and literature review on whether or not the species and habitats recorded were within their current known geographical range or the presence on the wreck sites indicated a range extension.

5 RESULTS

5.1 STAKEHOLDER ENGAGEMENT

5.1.1 Details of whether or not dialogue was achieved with each stakeholder are highlighted in **Appendix A**. The results of the stakeholder engagement are discussed under the relevant objectives in **Section 6.**

5.2 LITERATURE SEARCH

5.2.1 Given the time-constraints of the project it was not possible to carry out an exhaustive search. However, it was felt that sufficient investigation was achieved, and enough preliminary information was sourced in order to provide comment on the key considerations of each objective. It also highlighted areas where more research was required in order to fully address some of the objectives.

5.2.2 The results of the review are discussed under the relative objectives in **Section 6.**

5.3 REVIEW OF EXISTING WRECK DATA

5.3.1 Suitability of archaeological data for ecological assessment

Video Footage

5.3.2 Over 60 diving days resulting in a bottom time of >4990 minutes were logged during archaeological site surveys of the *Holland V*, Norman's Bay, Bottle, and Portland Stone Wrecks (**Appendix C**). Video footage is recorded via the camera system installed on the diver's helmet for every dive made and for its entire duration, providing a potentially valuable and permanent visual record of the site ecology. However, of all of the video footage available for the four wrecks <10% was found to be of good enough quality to enable habitat and/or species identification. This was attributable to the manner in which the video was utilised during the archaeological surveys rather than video being an inappropriate technique for ecological surveying.

5.3.3 While suitable for the purposes of archaeological surveys, to enable the identification of conspicuous species and their associated habitats video footage needs to be of a particular quality with respect to lighting, distance from subject, focus, underwater visibility, and stability (steadiness of recording).

5.3.4 The quality of video footage collected during the course of archaeological site surveys was found to vary highly between the wreck sites as well as between dives at the same site. This was attributable to a number of factors, most of which seemed to be related to the archaeological task being carried out (e.g. making site measurements, dendrochronological sampling

etc.). The video cameras used by the archaeologists were of a high enough technical specification to produce images of the resolution required for ecological survey purposes.

5.3.5 Much of the footage was either too far away from the subject, badly lit (too dark, hotspots of light causing white-out), murky due to poor underwater visibility (often due to silt being kicked up by diver), unsteady (fast and erratic movements) or a combination of these factors.

5.3.6 While it was possible to identify broad habitat types based on physical features from the video, enabling biotope complexes to be assigned (e.g. Very tide swept faunal communities on high energy circalittoral rock: **CR.HCR.FaT**), the inability to identify the majority of species present from some of the video limited the level to which biotopes could be determined. Again, this was attributable to the manner in which the video was utilised during the archaeological surveys rather than video being an inappropriate technique for surveying epibenthic habitats and species.

5.3.7 In addition, in order to assess the spatial distribution of habitats and species across the wreck site and comment on spatial and temporal variations it was necessary to be able to position the data in relation to the wreck, either by GPS or by reference to wreck site features.

5.3.8 Although the diver/ROV (and therefore the video footage) position is tracked for the duration of each dive using a USBL tracking system (accurate to +/- 1m, depending on the system employed) determining the position of the diver (and therefore video image being reviewed) in relation to the wreck retrospectively is a convoluted and time consuming process. Where obvious wreck features were visible on the video footage the location of the habitat and species data could be drawn directly onto the site plan. However, in many cases, the lack of obvious features (due to the video quality or complex nature of site) meant this was not possible. The position of archaeological observations and finds are recorded within site logs in DIVA (Microsoft Access based diver recording system developed by Wessex Archaeology) but unless ecological observations are associated with these this is of limited use. Determining the location of the ecological data in relation to the most of the wrecks therefore was generally found to be problematic.

5.3.9 The relatively restricted extent of (good quality) video coverage was a limiting factor in commenting on habitat and species distributions across each wreck site, both spatially and temporally. Footage was often limited to a particular area of the site such as a cannon or anchor for which archaeological measurements and records were being made. This did not allow for an overview of the full range of habitats and species and therefore different environmental ‘zones’ (conditions) around the site. Furthermore, it was often difficult to relocate the same areas from much of video between years. This made a review of temporal changes in habitat and species distribution problematic.

5.3.10 Video footage reviewed for habitats and species was generated from both diver and ROV surveys. The ROV video footage was generally found to be of better quality for revealing habitats and species compared to the diver collected footage. This is almost certainly owing to the fact the ROV seemed to be deployed to gain a broad scale overview of the sites at which it was

used, as well as focussing on select features. In addition, the ROV footage was more stable than that of the footage collected by the diver who was focussing on archaeological recording and sampling.

Stills images

5.3.11 From the >60 dives and >4990 minutes of total bottom time accrued on the 4 wreck sites >800 stills images were taken to record select archaeological features. Of these <5% were found to be of good enough quality to enable habitat and/or species identification. As with the video, this was attributable to the manner in which the camera was utilised during the archaeological surveys rather than stills photography being an inappropriate technique for surveying epibenthic habitats and species.

5.3.12 Similar to video footage, stills images need to be of a minimum resolution and quality to enable habitat and species identification. In addition, if an estimation of species abundance is to be made the seabed area represented in the image needs to be defined (e.g. scale bar, quadrat, fixed frame). The camera used was of a high enough technical specification to produce images of the resolution required for ecological survey purposes.

5.3.13 The quality of the stills images for ecological review varied highly. Many were out of focus, too far away from the subject, either over or under exposed, and with a lot of additional backscatter. Of the images that were of use it was possible to identify broad habitat types based on physical features, including those of seabed sediments, thus enabling biotope complexes to be assigned. However, it was often not possible to identify conspicuous species which, as with the video, limited the level to which biotopes could be determined (**Plate 1**).

5.3.14 Determining the location of many of the stills images in relation to the wrecks was slightly less problematic compared with the video footage, but nevertheless still a relatively convoluted process. Stills images are typically collected in relation to an archaeological observation and the ID number and position of each observation recorded within DIVA. However, relating this to the image numbers was difficult as few records had been made connecting photo and observation IDs. Therefore, where possible, locating the images was limited to relating them to the obvious features on the site plan.

5.3.15 As with the video footage the relatively restricted extent of coverage of good quality stills limited the ability to review the distributions of species across each wreck site, both spatially and temporally. Although a greater number of images were of suitable quality to enable broad habitat type to be assessed across a wider area.

5.3.16 Overall, the stills images collected during archaeological site surveys were found to be more useful in identifying species compared to the video footage, although again, this was attributable to the manner in which the camera was utilised during the archaeological surveys rather than stills photography being an unsuitable technique for surveying epibenthic habitats and species.

5.3.17 In addition, while video and photographic techniques are suitable for surveying epibenthic benthic habitats and species of non-sedimentary sites they still have some generic limitations. Many epibenthic groups are difficult to identify remotely (e.g. bryozoans, hydroids and sponges) and require

more detailed examination. Therefore, the collection of reference specimens is also recommended, where possible.

5.3.18 The review of benthic communities of sedimentary habitats could not be carried out using video/stills owing to the limited suitability of these techniques for sediments. Comment could be made on broad habitat type present but further sampling (e.g. grabbing, coring) would be required to assess the infaunal species and communities.

5.3.19 The results of the species and habitat review are presented in **Appendices D to G**.

5.4 SPECIES AND HABITAT ASSESSMENT

HMS/m *Holland V*

5.4.1 A full review of the spatial extent of habitats across the *Holland V* wreck and the component species was limited. Although the video footage provided a relatively good overview of the site this was often too far away from the subject to observe conspicuous species. The stills images, which had the potential to provide finer detail, were restricted to prominent features on the main wreck structure with little information on the surrounding seabed sediments or those within the immediate vicinity of the wreck. In addition, many of the images were taken at too wide an angle and pixelated when enlarged in an attempt to identify species.

5.4.2 The position of habitat and species data in relation to the wreck was determined by referencing their proximity to obvious structural features, made possible in this instance by the well defined nature of the *Holland V* site.

5.4.3 The results of the ecological assessment are also discussed within the context of the prevailing environmental conditions. Further discussion in the context of judging wreck site condition and assessing vulnerability is included in **Section 6.2**.

Main wreck structure 2001

5.4.4 In March 2001 the wreck structure itself appeared subject to heavy biofouling and was colonised by a dense turf of robust hydroids. This was noted to be particularly well established on prominent features (e.g. propeller blades, bow cap, conning tower) and vertical surfaces of the wreck in comparison to horizontal faces (**Plates 2-5**). The horizontal features were also noted to have a layer of sediment accumulation.

5.4.5 The dense turf appeared mainly to comprise of the Oaten Pipes hydroid *Tubularia indivisa*, although the identification of other species present was not possible due to the limited data available. As a result it is difficult to determine with certainty which equivalent rock biotope it most closely resembles, although it is likely to be **CR.HCR.FaT.CTub** (*Tubularia indivisa* on extremely tide-swept circalittoral rock). This biotope is typically found on the vertical and upper faces of strongly tide-swept (>3kn), wave exposed bedrock and boulders (Connor, *et al,* 2004). It was not possible to determine whether or not any other biotopes were present on the wreck structure in March 2001.

Main wreck structure 2005

5.4.6 In September 2005 the spatial extent of biofouling *Tubularia* community across the main wreck structure appeared to have changed from that observed in 2001, and a large amount of fishing net was observed snagged around the wreck. In addition, a discarded lobster pot was identified on the wreck debris to the stern, together with a considerable amount of fishing tackle (line and lead weights) indicating the site has been used by both the commercial and recreational fishing community.

5.4.7 The turf community colonising the main wreck structure was confirmed as that resembling **CR.HCR.FaT.CTub**. Taxa recorded in association with this biotope included the Sea Beard hydroid *Nemertesia antennina*, fine hydroid and bryozoan turf species, *Pomatoceros* Sp. Porifera Sp. and Tompot Blennies (*Parablennius gattorugine*).

5.4.8 The spatial extent and density of the biofouling turf community appeared reduced in comparison to 2001. This was most notable on protruding features on top of the wreck (such as the conning tower (**Plates 7a & b**) and the exhaust system hatch (**Plate 8**)), as well as on vertical and horizontal areas covered by net.

5.4.9 Here, a patchy, ephemeral encrustation (~2-3cm) of *Sabellaria spinulosa* was recorded, with an increased amount of silt in comparison to 2001 (**Plates 7a, b** and **8**). Species identification was again limited due to the quality of the data (with video providing better close-up of the *Sabellaria* than stills) however, Keel Worms (*Pomatoceros* Sp.), empty barnacle shells, bryozoan turf, sponges (Porifera Sp.) and fine hydroid species were noted in association with *S. spinulosa,* together with mobile species such as Hermit and Edible Crabs (Paguriidae Sp. and *Cancer pagurus*, respectively). This *S. spinulosa* biotope was found to most closely resemble **CR.MCR.CSab.Sspi.ByB** (*Sabellaria spinulosa* with a bryozoans turf and barnacles on silty, turbid circalittoral rock). This biotope is typically found encrusting mixed substrates subject to strong and moderately strong currents (1-6kn) and high turbidity levels (Connor, *et al*, 2004). It is unclear whether this biotope was present on the wreck structure in 2001 owing to the lack of suitable data.

5.4.10 While the *T. indivisa* turf (**CR.HCR.FaT.CTub**) was relatively well established on the prominent features (e.g. bow cap: **Plate 6b**; propeller: **Plates 10** and **11**) recessed areas, and vertical faces (hole in pressure hull: **Plate 9**) which were not covered in net it was still notably reduced from that observed in 2001. In addition, these features also appeared to have less silt/sediment accumulation compared to horizontal surfaces.

5.4.11 Insufficient data was available to review whether there was any variation between communities on the down and upstream faces of the wreck to the dominant current flow.

5.4.12 The snagged fishing gear which remained on the wreck was observed to have small, yet dense aggregations of mussels (*Mytilus edulis*) and Slipper Limpets (*Crepidula fornicata*), both species capable of extensive fouling. These appeared to be limited to the nets, rope and buoy, and were not observed on the wreck itself.

Main wreck structure 2007

5.4.13 Review of the species and habitats for the September 2007 survey was based on very limited video and stills data. However, broad comparisons could be drawn with the observations made from the 2005 survey. A greater proportion of the horizontal surfaces appeared to lack the biofouling *T. indivisa* turf in comparison to 2005, and a notable silt accumulation remains present. Although it is not possible to ascertain from the image data whether the amount of silt accumulation has changed since the previous survey.

5.4.14 On areas where *T. indivisa* turf had remained established (vertical faces such as the bow cap: **Plate 17**, propeller) this was noted to be more dense in comparison to that observed in 2005. Furthermore, local changes in the composition of dominant species within the *T. indivisa* turf community were also noted from review of video footage.

5.4.15 It was not possible to comment on whether there were any changes in the density and distribution of other conspicuous biofouling fauna, such as the mussels and slipper limpets observed to have established on the nets, due to the lack of suitable data from the 2007 survey.

Surrounding seabed outwith influence of wreck (~60m SW of wreck)

5.4.16 This area of seabed was included in the assessment to establish the nature of the benthic community and habitats outwith the hydrodynamic influences of the wreck, and allow a comparison with habitats and species within immediate proximity to the wreck to be made.

2001

5.4.17 No 2001 data was available.

2005

5.4.18 The seabed comprises of slightly rippled silty, medium sand with some fine shell material (Dive 398 video). No obvious epibiota or signs of infauna (e.g. burrows, casts) were observed. The circalittoral fine sand biotope (**SS.SSA.CFiSa**) was tentatively assigned to this habitat based upon the physical characteristics alone. Further groundtruthing by grab or core sampling would be required to assess the infaunal species. This broad habitat type is reported to be typical of open coasts in depths of >15m and in areas of weak tidal streams (<1kn: Connor *et al*, 2004).

5.4.19 A large boulder in this area provided suitable hard substrate for an epibenthic community although this was noted to be slightly different to that identified from the wreck. The boulder fauna was identified as a combination of **CR.MCR.CSab.Sspi.Byb** & the mixed faunal biotope **CR.HCR.XFa** (**Plate 16**; and Dive 398 video). An ephemeral encrustation of *Sabellaria spinulosa* was present together with a dense hydroid and bryozoan turf which notably lacked *Tubularia indivisa* and instead was characterised by the Hornwrack *Flustra foliacea* , ?*Cellaria* Sp. and fine hydroid species. **CR.HCR.XFa** is typically recorded in areas with moderately strong tidal steams (1-3kn) and variable wave exposure.

2007

5.4.20 No data were available from the 2007 survey to allow a temporal comparison of habitats and species in this area.

Seabed within immediate proximity to wreck

5.4.21 This area of seabed was included in the assessment in an attempt to assess the level of stability of near wreck sediments which are known to be dynamic in nature (Dix *et al*, 2007).

2001

5.4.22 No data was available for this area in 2001.

2005 - Upstream

5.4.23 The seabed habitat along much of the starboard side (upstream of the wreck to the dominant current flow) comprised of rippled sand, gravel, pebbles and cobbles and identified as a circalittoral mixed sediment biotope (**SS.SMX.CMx**: Plates 13 and 15). This broad biotope complex is found in a wide range of tidal streams and wave exposures (Connor *et al*, 2004). The amount of coarse sediment material decreased with increasing distance upstream from the wreck (~west) gradually changing into fine sand (**SS.SSA.CFiSa**). However, it was not possible to identify any species from the video and stills data due to the limited quality of the images and the sedimentary nature of the habitat. Further sampling and more detailed video/stills acquisition is required to enable additional comments to be made on the communities present which would in turn give an indication of the degree of scour and mobility of seabed sediments in this area.

5.4.24 Wreck faces near the seabed (free of discarded fishing net) were colonised by relatively dense hydroid turf (**Plate 14**) and occasional anemones (*Actinothoe sphyrodeta*) and Dead Men's Fingers *(Alcyonium digitatum:* **Plate 12**). Further identification of species within the community here was limited due to the quality of the data (video only). Although this appeared to be similar to that identified on upper areas of the wreck (**CR.HCR.FaT.CTub**) this could not be determined with any certainty.

2005 - Downstream

5.4.25 The seabed on the port side (downstream of the wreck from the dominant current flow) comprised of mixed sediments (**SS.SMX.CMx**; indicative of a wide range of tidal streams and wave exposures) and appeared less sandy in nature with a higher proportion of course material compared to that on the upstream side. It was not possible to identify many taxa from the video and stills data due to the limited quality of the images and the sedimentary nature of the habitat. However sponge and colonial ascidian species were observed, together with some low lying bryozoan/hydroid growth on the stones.

5.4.26 No suitable image data was available from the 2007 data for comparative purposes.

5.4.27 Effort was made to source Seasearch data collected from the *Holland V* wreck site to support the ecological assessment (Mark Beattie-Edwards, *pers. comm.*). However, this was not obtained within the limited time constraints of the study for inclusion.

Norman's Bay, Bottle and Portland Stone Wrecks

5.4.28 Owing to time-constraints, difficulties associated with spatially referencing the image data with respect to the wreck, and the quality of stills and video footage, species and habitat assessment was limited to stills taken of a few obvious features. In addition, the assessment was limited to recording species on a presence/absence basis for each wreck site as a whole. As a result, it was not possible to classify the biotopes present. The results of the species and habitat review are presented in **Appendices B, C and D** respectively, for reference.

5.5 ASSESSMENT OF THE PREVAILING ENVIRONMENT INDICATED BY SPECIES AND HABITATS (BIOTOPES) PRESENT

HM/s Holland V

~60m west of the wreck (considered to be outwith the influence of the main structure)

5.5.1 An assessment of temporal changes within prevailing environmental conditions in this area cannot be carried out due to the lack of suitable data from the 2001 and 2007 site visits. Comment on the seabed environment is therefore limited to that occurring in September 2005. At this time near seabed tidal streams were indicated to be weak, and with limited wave exposure (e.g. little turbulence) indicated by the presence of slightly rippled **SS.SSA.CFiSa** (Connor *et al*, 2004). The presence of a boulder provided suitable substrate for **CR.MCR.CSab.Sspi.Byb** and **CR.HCR.XFa** biotopes which are typically present in areas of moderately strong currents (1-6kn: Connor *et al*, 2004), and relatively exposed and turbid conditions. This is likely to reflect the local scour conditions attributable to the presence of the boulder.

Seabed within immediate proximity to wreck (upstream and downstream)

5.5.2 Again, a temporal assessment of prevailing environmental conditions within immediate proximity to the wreck cannot be carried out due to the lack of suitable data from the 2001 and 2007 site visits. Comment on the seabed environment in this area is therefore limited to that found to be occurring in September 2005 only.

Upstream

5.5.3 Due to the lack of suitable data it was not possible to comment on the strength of near seabed tidal streams within immediate proximity to and upstream of the wreck structure other than this appeared to decrease with increasing distance from the wreck (indicated by a transition of **SS.SMX.CMx** into **SS.SSA.CFiSa**). In addition, no assessment can be made on the stability of these sediments due to the inability to assess species composition of sediments with video and stills images.

5.5.4 Hard substrates (wreck faces, artefacts, cabling and occasional cobbles) free from net near the wreck/seabed interface upstream from the wreck appeared to be free from the effects of excessive sediment abrasion typically associated with scour (erosion). However, the ability to identify species and biotopes from these areas was limited due to issues related to spatial coverage and quality of data. Therefore, this assessment was based

solely on the presence of relatively dense hydroid turf and occasional anemones locally on hard features.

Downstream

5.5.5 Again, due to the lack of suitable data on species and habitat type only a broad biotope classification could be determined here, the identity of which is one typically recorded in a wide range of tidal stream conditions. Although there appeared to be some erosion of finer substrates here the coarser material present did not appear to be subject to excessive abrasion (associated with scour) and seemed to be relatively stable. This was indicated by the increased proportion of coarse substrate and reduced sand component compared to that on the upstream side. In addition, sponges, colonial ascidians and low lying bryozoans/hydroid growth were present on the coarse material. These groups are typical of stable substrates in areas of tidal flow. However, the spatial coverage and quality of data limited any further assessment.

The Main Wreck Structure

5.5.6 The well established hydroid turf biotope present in 2001 (thought to be **CR.HCR.FaT.CTub** following review of 2005 data) indicated that wreck structures with height from the seabed were subject to strong to very strong (3 to >6kn) tidal streams and exposed to extremely exposed wave action (Connor, et al, 2004). The reference to wave action may be interpreted as the influence of turbulence in the tidal flow around the wreck (Dix *et al,* 2007; Zinten *et al*, 2008). It is not possible to ascertain whether or not the *Sabellaria* biotope was also present here at this time, or assess the degree of silt accumulation on horizontal surfaces due to a lack of suitable data.

5.5.7 Had the snagged trawl net and structural damage (bent exhaust pipes) not been present on site to provide some obvious clues, it would have proved difficult to determine with any certainty whether the temporal changes observed in the distribution of **CR.HCR.FaT.CTub** and **CR.MCR.CSab.Sspi.Byb** biotopes on the wreck structure between 2001 and 2005 were attributable to natural variations in the prevailing environmental conditions, biological effects in response to anthropogenic activities, or a combination of both.

5.5.8 Natural, seasonal variations in growth patterns are likely to be contributing to the changes observed in the overall density spatial extent of *T. indivisa* dominated turf (Zinten *et al*, 2008). The 2001 images were collect towards the end of March (exact date unclear), whereas the 2005 and 2007 images were all collected end and mid September, respectively.

5.5.9 *T. indivisa* is reported to be short lived and can also be transient in nature (Zinten *et al*, 2008). In areas where it occurs as a permanent element of the annual cycle its biomass is reported to be lowest in October, increasing again to its peak in July (Zinten *et al*, 2008). Larval settlement in early spring is followed by a period of rapid growth. It is possible that the turf observed in the 2005 and 2007 surveys was dying back and the 2001 images captured the turf during the rapid growth phase. This highlights the importance of understanding the natural dynamics of wreck communities in order to establish the cause of such changes, and ascertain whether these are anthropogenically derived so effective (ecological or archaeological) mitigation strategies can be developed and implemented.

5.5.10 Another factor contributing to a reduction in density and extent of hydroid turf was physical abrasion and disturbance sustained by the habitat.

5.5.11 Insufficient data was available to assess whether or not there were differences between the wreck communities and those occurring on natural hard substrates outwith the influence of the wreck. Therefore it was not possible to establish the shifting environmental baseline attributable to the reef effect against which additional anthropogenic impacts can be assessed. This is compounded by the lack of published literature on the short and long term ecological dynamics of historic wreck site communities.

5.5.12 *T. indivisa* is also reported to be sensitive to increases silt accumulation such as those observed on horizontal surfaces in both 2005 (Zinten *et al*, 2008). This increase in silt may be a result of either an increase in water turbidity levels in the area, the net material present acting as a local sediment trap, or both. An increase in water turbidity levels can be caused by a number of factors including dredging, storm events and an increase in riverine inputs. However, insufficient data is available to ascertain what may be causing the apparent increase in silt accumulation.

5.5.13 **CR.HCR.FaT.CTub** biotope on vertical areas of wreck not thought to be subject to net abrasion owing to their location and aspect (e.g. recessed or overhung), or observed to have silt accumulation, still appeared less dense in 2007 compared with 2001. This supports the suggestion that the changes observed were not solely attributable to the trawl net and increased silt accumulation, and that seasonal variation in growth patterns was also probably occurring.

5.5.14 Much information exists on the preferred habitat and environmental conditions favoured by *Sabellaria spinulosa* (UK Marine SACs Project, 2008; Marlin, 2008a), notably its preference for high turbidity levels. However, whether its presence indicates high levels of water turbidity in the area, the net material present acting as a local sediment trap, or both, is unclear due to the lack of available spatial and temporal data.

5.5.15 In addition to the environmental conditions, a review of the benthic species present has the potential to provide information on some of the biogenic processes occurring across the wreck site which may affect wreck preservation. This is discussed in **Sections 6.1** and **6.2**.

5.5.16 The prevailing environmental processes assessed by proxy using benthos are discussed in the context of judging wreck site condition and assessing vulnerability in **Sections 6.1** and **6.2**.

Norman's Bay Wreck

5.5.17 Due to the lack of spatial referencing of image data it was not possible to carry out a spatial or temporal assessment of species and biotope distributions across the Norman's Bay wreck site.

5.5.18 In addition, owing to data quality, species identification was limited, with many records remaining at phylum or class level. It was not possible to record SACFOR abundance; therefore species records were limited to presence/absence. For these reasons, no biotopes were assigned to the Norman's Bay image data. Species and habitat data for the Norman's Bay wreck are presented in **Appendix E**.

5.5.19 Prominent features (cannons) were noted to have dense *Mytilus edulis* growth. This species is reported to be found in a wide range of tidal streams (<1kn–6kn) and wave exposures (very sheltered to very exposed; MarLIN, 2008b). The spatial and temporal distribution of this could not be commented on due to the lack of suitable data.

5.5.20 Other species noted from the Norman's Bay site were robust hydroids (including *Tubularia indivisa*), Common Starfish (*Asterias rubens*), Keel Worms (*Pomatoceros* Sp.), barnacles (Cirripedia Sp.), Lobster (*Homarus gammarus*) and unidentified sponge species (Porifera Sp.).

Bottle Wreck

5.5.21 As with the Norman's Bay wreck, the lack of spatial referencing of image data prevented a spatial or temporal assessment of species and biotope distributions across the Bottle wreck site.

5.5.22 Species identification was limited, with many records remaining at phylum or class level. It was not possible to record SACFOR abundance; therefore species records were limited to presence/absence. For these reasons, no biotopes were assigned to the Bottle wreck image data. Species and habitat data for the Bottle wreck are presented in **Appendix F**.

5.5.23 Seabed sediments within the vicinity of the wreck comprised silty, sandy, shell gravel (mainly *Crepidula fornicata*) with occasional pebbles and cobbles. It was not possible to ascertain what infaunal species or biotopes were present.

5.5.24 Species inhabiting hard substrates (pebbles, cobbles and wreck artefacts) included robust hydroids (*Nemertesia antennina*), bryozoan turf (*Flustra foliacea*), sponges (Porifera Sp. indet.), colonial ascidians (*Botryllus schlosseri*), Keel worms (*Pomatoceros* Sp. indet.) and barnacles (Cirripedia Sp. indet.).

Portland Stone Wreck

5.5.25 Due to the lack of spatial referencing of image data it was not possible to carry out a spatial or temporal assessment of species and biotope distributions across the Portland Stone wreck site.

5.5.26 Species identification was also limited, with many records remaining at phylum or class level. It was not possible to record SACFOR abundance; therefore species records were limited to presence/absence. For these reasons, no biotopes were assigned to the Portland Stone wreck image data. Species and habitat data for the Portland Stone wreck are presented in **Appendix G**.

5.5.27 In addition, many of the wreck features had also been cleared of epibenthic growth for archaeological purposes, further limiting a species assessment.

5.5.28 Owing to the relatively shallow depth of the Portland Stone wreck red algal species were observed to have colonised available hard substrates and were considered to be the characterising species. However, it was not possible to ascertain the identity of this due to the quality of image data.

5.5.29 Other species present across this site included the bryozoan *Flustra foliacea*, dead men's fingers (*Alcyonium digitatum*) and the anemone *Actinothoe sphyrodeta*.

5.5.30 Substrates within the vicinity of wreck features were observed to comprise a mix of sand, gravel, pebbles, cobbles and shell debris. No infaunal burrows or casts were observed, although the ability to assess their presence was limited by the quality of the image data.

5.6 NATURE CONSERVATION VALUE OF WRECK DATA

5.6.1 Species data was of insufficient resolution to comment whether or not the biotopes recorded from the *Holland V* wreck were entirely typical in composition for the national classification, or exhibited variations attributable to regional location or their occurrence on artificial features rather than naturally occurring rock.

5.6.2 Feedback on advice sought from conservation organisations with respect to assessing the value of the wreck species and habitat data, and whether this had conservation relevance in the context of local marine nature conservation designations and regional distributions was still outstanding at time of writing.

HM/s *Holland V*

5.6.3 No species or habitats identified from the *Holland V* wreck site were listed within current marine nature conservation legislation highlighted in **Section 4.7.10**. Although *Sabellaria spinulosa* was recorded this occurred as a thin ephemeral encrustation rather than in densities and growth forms which may be considered as reef under the Habitat Action Plan for *S. spinulosa* reefs (MNCR biotope code **SS.SBR.PoR.SspiMx:** Connor *et al*, 2004).

5.6.4 No species recorded were found to be occurring outwith their current geographical range (Marlin, 2008b).

Norman's Bay Wreck, Bottle Wreck and Portland Stone Wreck

5.6.5 Due to quality of image data, lack of spatial referencing and time constraints, limited species and biotope data could be generated from these three wreck sites. None of the taxa identified from these wrecks were listed within current marine conservation legislation. However, it is felt that further data acquisition from these wreck sites would be required to fully comment on whether or not the sites host species or biotopes of nature conservation value.

5.6.6 This is also true with regards to commenting on species which may be occurring at these sites which are outside their known geographical range.

6 DISCUSSION AND CONCLUSIONS

6.1.1 To facilitate the discussion below, the project objectives have not been addressed in numerical order.

6.2 OBJECTIVE 1: CAN THE PRESENCE/ABSENCE OF BENTHIC SPECIES BE USED AS A PROXY FOR ASSESSING ENVIRONMENTAL CONDITIONS OF WRECK SITES IN RELATION TO SITE VULNERABILITY?

6.2.1 It is well established that benthic (bottom-dwelling) species are good indicators of prevailing environmental conditions. The relationship between benthic organisms and the environments they occupy has been well studied at both species (Hiscock *et al*, 2005) and community (biotope) level (Connor *et al*, 2004).

6.2.2 There is a strong relationship between the abiotic (non-living chemical and physical factors) nature of seabed habitats and the biological composition of the benthic community it supports. Benthic species chose to live within a particular environment and they each have a preference for a certain combination of physical, chemical and biological factors which make up the environmental niche they occupy. In addition, each species has a different tolerance to different environmental conditions and therefore variations in their spatial and temporal distributions reflect the spatial and temporal changes within the surrounding environment.

Biotope approach to environmental monitoring

6.2.3 Biotopes, a term used to describe the combined biological and physical nature of seabed habitats, are considered to represent a balance between a regional pool of species and local environmental conditions (Olenin and Ducrotoy, 2006). The JNCC developed a classification system for marine habitats as a tool to aid the management of seabed environments in relation to the EC Directive 92/43/EEC (also known as the EC Habitats Directive). This national classification (Connor *et al*, 2004) provides a practical system for the consistent description of habitats to enable benthic communities to be categorised and assessed spatially and temporally in relation to changes in prevailing environmental conditions.

6.2.4 In addition, information is provided on which environmental conditions each biotope is typically associated with (e.g. salinity, wave exposure, tidal stream, depth) however, this often covers quite a broad range. For example, one of the biotopes identified on the *Holland V* wreck structure (**CR.HCR.FaT.CTub**) is reported to be typically found in a wide range of both wave exposures (exposed to extremely exposed) and tidal streams (strong: 3-6kn to very strong:>6kn).

6.2.5 While this data can provide information on broad ranges of environmental conditions typically expected as indicated by the biotopes present, it is unclear whether this resolution of environmental data is sufficient to make a judgement on wreck site vulnerability from prevailing environmental processes. In addition, changes in natural processes e.g. tidal stream strength (either spatially across the site or temporally) on a scale which has a detrimental effect on wreck site preservation may not be significant enough to alter the distribution or composition of biotopes and therefore be not be discernable within the benthic community. Also, the complexity of habitats and local small scale environmental variations attributable to the presence of a wreck makes the identification of biotopes difficult.

6.2.6 Although biotope classification has been established for communities occurring on artificial substrates, this is currently limited to two biotopes. These include an *Ascidiella aspersa* dominated fouling biotope typically

found on discarded fishing nets and mooring lines (**CR.FCR.FouFa.Aasp**) and an *Alcyonium digitatum* and *Metridium senile* dominated biotope typically found on wrecks (**CR.FCR.FouFa.AdigMsen**).

6.2.7 Due to the absence of species which characterise these biotopes within the communities observed on the *Holland V* wreck site (e.g. *Metridium senile, Alcyonium digitatum,* and *Ascidiella aspersa*; all of which are conspicuous and would have been obvious from the *Holland V* image data), these were not used to classify the *Holland V* communities. Instead, biotopes across the *Holland V* wreck site were classified using those circalittoral rock biotopes which most resembled the wreck communities and which were found to be a better fit than the artificial biotope codes available.

6.2.8 However, it is almost certainly the case that, as a result of the reef effect, the communities associated with the artificial wreck habitat actually represent different environmental conditions (e.g. tidal streams, wave exposure) to those of their circalittoral rock equivalents (Perkol-Finkel and Benayahu, 2007). Therefore, by using the equivalent rock biotopes this may actually provide slightly spurious information with respect to assessing prevailing environmental condition in relation to wreck site vulnerability.

6.2.9 Although wreck biotopes are not naturally derived they can host benthic and fish communities which differ to, but are equally as diverse as naturally occurring features such as rocky reefs. In addition, the communities on historic wrecks may represent well established, climax epibenthic communities, often in deep water.

6.2.10 A better understanding of wreck biotopes is required in order to establish the shifting environmental baseline attributable to the reef (or wreck) effect. This is particularly important if effective assessment strategies are to be adopted with respect to the ecological and archaeological impacts of aggregate extraction. In addition, the natural ecological dynamic of wreck sites needs to be fully understood if additional anthropogenic impacts are to be differentiated from the 'wreck' effect. This includes the surrounding seabed sediments within the hydrodynamic influence of the wreck.

Indicator species approach environmental monitoring

6.2.11 The indicator species approach was also considered in relation to identifying and assessing changes in prevailing environmental processes.

6.2.12 The indicator species approach to environmental monitoring and assessing the prevailing environmental conditions is not a new concept. Many studies have been carried out to date, a large number of which have been in relation to pollution gradients (Pearson and Rosenberg, 1978; Gray and Pearson, 1982; Kingston, 1987). More recently, work has been carried out on indicator species in relation to a number of applications (Hiscock *et al*, 2005; IOC, 2004). Hiscock *et al,* (2005), for example, identified suitable indicator species to support the implementation of the EU Habitats and Water Framework Directives (the results of which are available via the MarLIN Seabed Indicator Species Database: MarLIN, 2008a). This database lists the tolerance level of select species to different impacts (e.g. physical disturbance, substratum loss, increased suspended sediment). Changes in species abundances can thus be related to changes in environmental processes (whether naturally or anthropogenically derived).

6.2.13 An attempt was made to use the MarLIN database for species data generated from the video and stills review. However, due to the lack of suitable image data this was limited to conspicuous species (e.g. *Tubularia indivisa*: *Holland V* wreck) and not those listed in the database which could be considered as the best indicators of the environmental processes most relevant to wreck site preservation and vulnerability.

6.2.14 The presence/absence of epibenthic groups provided some indication of the sedimentary and hydrodynamic processes present. For example the presence of sponges, colonial ascidians and bryozoans/hydroids on coarse seabed sediments downstream from and with the immediate proximity to the *Holland V* wreck suggested this area did not appear to be subject to excessive abrasion (associated with scour) and seemed to be relatively stable. However, the magnitude of stability or scour could not be quantified, either spatially or temporally, although this was - in part - due to the limitations of the image data and current acquisition methods (see O7).

6.2.15 Where data allowed spatial and temporal changes in species abundances to be recorded it was not possible to ascertain how much of the change was attributable to natural variations and how much was anthropogenic, due to the lack of suitable background/reference (outwith wreck influence) data. In addition, it was not possible to ascertain how the reduction/increase in species numbers could relate to scales of change within the prevailing environmental conditions in order to apply this to a wreck vulnerability assessment.

6.2.16 It would seem therefore, that while species and habitats can act as proxies to provide information on the prevailing abiotic environmental processes of wreck sites, this is limited by the following:

- Current methods of collecting image data during the course of archaeological site surveys;
- The lack of a suitable wreck conservation/management framework to which benthic data could be applied makes it difficult to determine whether the broad ranges of environmental conditions indicated by the biotopes are sufficient for the purposes of assessing wreck condition and threats to wreck site preservation; and
- The lack of a suitable suite of dependable indicator species for both biogenic and non-biogenic processes relevant to wreck sites.

6.2.17 These three issues are discussed further under Objectives 6 and 7.

Monitoring biogenic processes

6.2.18 The use of benthic species to provide information on the prevailing biotic processes of wreck sites suggests another important reason for studying the ecology of wreck sites.

6.2.19 Benthic species can physically and chemically modify their environment, either directly or indirectly. They are (directly) responsible for wood boring, accretion/biofouling, and bioturbation (Pournou *et al*, 2001; Brown *et al*, 1988; Grayson, 2001; Palma, 2005; Lenihan, 1990, Ferrari and Adams, 1990). In addition, they can also indirectly affect their environment by

creating suitable conditions and micro-niches in which other organisms, such as bacteria responsible for corrosion, can thrive.

6.2.20 A recent study by Watzin *et al* (2001) found that mussel growth on iron wreck surfaces, historically thought to slow corrosion by protecting surfaces with their dense cover from seawater, actually accelerated corrosion rates. The byssus threads of the dense mussel growth were found to trap organic matter, under which complex bacterial communities thrive, accelerating the corrosion process.

6.2.21 Small, dense patches of mussels (*Mytilus edulis*) were observed on fishing net material on the *Holland V* in 2005. However, insufficient data was available to determine whether or not these had moved onto the wreck itself in 2007.

6.2.22 Although no published literature was found to support the suggestion, it is entirely feasible that dense mats of other fouling organisms, such as hydroid turfs, may also have the ability to trap organic matter within which bacterial communities responsible for metal corrosion can thrive. In this instance, processes which reduce such fouling growths may be found to be beneficial to metal artefacts rather than detrimental as previously assumed.

6.3 OBJECTIVE 6: IS ARCHAEOLOGICAL DATA SUITABLE FOR HABITAT AND SPECIES ASSESSMENT IN THE CONTEXT OF COMMENTING ON ENVIRONMENTAL CONDITIONS?

6.3.1 An assessment of prevailing environmental conditions using benthic species and habitats as a proxy from existing archaeological image data was constrained by a number of factors:

- The quality of available image data;
- Difficulties in spatially referencing image data containing ecological data in relation to the wreck;
- Limited coverage of image data, both spatially and temporally;
- Limitations associated with the use of benthic species and habitats as proxies for commenting on prevailing environmental conditions (see discussion above under Objective 1) and;
- Lack of a suitable archaeological conservation/management framework for which benthic data could be applied to judge condition and vulnerability.

6.3.2 It is important to recognise that this data was collected for archaeological, rather than ecological purposes, and was constrained by the limits imposed by both time and the sites concerned. While not ideal for ecological purposes, the data is entirely adequate and suitable for archaeological purposes, and represents a step change in archaeological surveying, being significantly better than data collected for the same purpose in the past.

Quality of image data

6.3.3 Seabed video and photography techniques are routinely used in a variety of ecological applications, such as surveying areas of seabed unsuitable for

grab sampling, and are appropriate for the identification of seabed habitats and species.

6.3.4 Images are often used to ground truth sidescan data interpretation and to assess the distribution and species composition of epibenthic communities.

6.3.5 Semi-remote techniques such as ROV and drop down video are best suited for deep sites or surveys where multiple deployments have priority over the need for fine detail, the latter being required for the identification of less conspicuous species and to make a more quantitative estimate of abundance.

6.3.6 Diver deployed video, such as that collected during the course of archaeological investigations however, has the potential to provide data which provides both wide spatial coverage and the fine detail required for a more comprehensive species assessment.

6.3.7 This study found that the video and stills image data reviewed and collected by diver and ROV (video only) during the course of routine archaeological surveys of the study sites was generally of a quality not suitable for identifying species and habitats. While the technical specification of the video and stills equipment used is sufficient to provide footage of adequate resolution, the manner in which the video is deployed (either by diver or ROV) and stills images are taken needs to be addressed if data is to be subsequently reviewed for species and habitats.

6.3.8 Video footage is required to be steady, slow moving, close to the substrate to enable good view of species, well and evenly lit and with minimal disturbance to avoid deterioration of the underwater visibility. The quality of video footage for ecological assessment would also benefit from being mounted on a pistol-grip rather than hat mounted.

6.3.9 Stills images must be in focus, macro, rather than wide angle, with good close-up, evenly exposed and with minimal disturbance of sediments to avoid backscatter.

Spatial referencing of image data in relation to the wreck

6.3.10 Spatial referencing of the image data is necessary in assessing the spatial distribution of habitats and species across the wreck site and in order to comment on spatial and temporal variations.

6.3.11 Although WA tracks the diver/ROV (and therefore the video footage) position throughout each dive using a USBL tracking system, determining the position of the video image in relation to the wreck retrospectively was a convoluted and time consuming process.

6.3.12 This difficulty could be easily addressed by adding a commentary to the recorded footage stating what area and feature of the wreck site is in view. In addition, the possibility of overlaying the real-time USBL position of the diver/video camera on the video screen could be investigated, although this might increase the time required to post-process the video data. Waypoints could be also recorded in a video log (incorporated into DIVA) together with the counter time on the video tape for reference (Davies *et al*, 2001: PG3-5 and 3-13).

6.3.13 In respect of stills images, a limited number of the total number of images acquired for each study site (usually those related to a specific feature or point of interest on the wreck) were recorded against observation IDs in DIVA. Being of a general nature, the majority of images were not recorded in DIVA, and this made spatially referencing the stills images problematic.

6.3.14 Again, this could issue could easily be addressed in future archaeological surveys by noting the frame number, what the photo was taken for (e.g. for species identification), its (cardinal) orientation, angle (vertical, horizontal or oblique), USBL position and its position in relation to wreck features within a photo log in DIVA (Davies *et al*, 2001: PG3-12).

Limited coverage of image data, both spatially and temporally

6.3.15 The limited coverage of image data precluded a full overview of the range of habitats, species and different environmental 'zones' (conditions) across the wreck sites.

6.3.16 There is a need for good coverage of data acquisition across a wreck site in order to understand the reef effect and the natural dynamic stability of wreck ecology if this is going to be used as a proxy for assessing prevailing environmental conditions in the context of wreck preservation.

6.3.17 There is also a need for good coverage of data if the ecological importance of a wreck site is to be assessed, and to further investigate the potential for the associated exclusion zone to act as a refuge with respect to recolonisation (Objectives 2 and 4).

6.3.18 It is important to understand the local reef effect/dynamic so this can be differentiated from biological effects of anthropogenic impacts. This is relevant with respect to determining effective ecological mitigation strategies.

Lack of suitable conservation/management framework for which benthic data could be applied to judge condition and vulnerability.

6.3.19 Relating species and habitat data to wreck site condition and vulnerability assessment was difficult owing to a lack of targets and attributes against which data could be assessed/compared.

6.3.20 In order to determine whether species data can be used to assess wreck site condition and vulnerability there is a requirement for the necessary framework to be in place first.

The application of species and habitat data in assessing wreck site condition

6.3.21 Shipwreck management is a complex issue and one which is currently rapidly evolving (Oxley, 2001; English Heritage, 2007). The recent Government White Paper on Heritage Protection for the 21st Century (Great Britain Department for Culture, Media and Sport, 2007) calls for the development of an improved UK-wide system of marine heritage protection. This includes publishing new selection criteria for marine designations (ACHWS, 2007), including those designated under the Protection of Wrecks Act (1973).

6.3.22 A management framework is currently being developed by English Heritage (English Heritage, 2007) to assess the preservation state of all designated marine historic assets (protected wrecks), identify potential threats, and provide effective management measures to mitigate against them.

6.3.23 This English Heritage framework includes a risk assessment handbook which is designed to provide a consistent approach to assessing threats to designated wrecks.

6.3.24 The risk assessment considers various parameters such as local environmental factors (e.g. substrate type and site energy) and principal vulnerabilities (e.g. biological decay, benthic ecology) with the purpose of making an objective judgement on the overall condition of a wreck site. However, for many of these parameters there is, as yet, no formal programme in place for measurement. Therefore, the objective judgement of overall site condition is based upon subjective evidence rather than measured data.

6.3.25 It is possible that benthic data can be used to contribute to this risk assessment process. However, in order to determine the resolution at which species need to be recorded and suggest suitable methods for its acquisition it is necessary to identify which attributes of wreck sites can define condition and which of these can be assessed using benthos.

6.3.26 Parallels may be drawn between the management of features of cultural heritage importance and those of marine conservation importance, the latter being well established.

6.3.27 The basic principle underpinning the strategy and framework developed by The Joint Nature Conservation Committee (JNCC, 2003) for the condition assessment of feature of marine conservation importance in relation to the EC nature conservation legislation (*Natura* 2000 and EC Habitats Directive, 1992) may provide some useful reference with respect to heritage management plans to assess the conservation needs of wreck sites, judging current condition (e.g. state of preservation) and identifying risks which may alter this condition.

6.3.28 A key step in any conservation framework involves the establishment of a set of conservation objectives. The feature(s) of interest may have several objectives, all of which are assessed by monitoring attributes which define the desired condition of the feature. Targets are generally set for each attribute. These may be an upper or lower threshold beyond which the condition of the feature is considered to be in decline and vulnerable, or targets may exist as a range within which fluctuations are deemed acceptable. By identifying attributes and defining targets, appropriate methods and techniques can then be considered to measure these. Until these attributes and targets are defined it is not possible to judge condition and therefore vulnerability of a feature, and as a result values or ranges of measured data can merely be reported.

6.3.29 Many studies have been carried out to assess wreck sites in relation to their state of preservation and vulnerability (Brown *et al*, 1988; Church *et al*, 2007; Grayson, 2001; O'Shea, 2002; McCarthey, 2000; Conlin and Russell, 2006; Palma, 2005; Lenihan, 1990). Yet there remains no consistent framework to which the measured data is applied to judge vulnerability.

6.3.30 While determining what attributes are suitable for defining the condition of wreck sites lay beyond the scope of this study, it has been possible to identify the environmental processes which contribute to the site formation and therefore may affect preservation. This in order to consider appropriate methods for the assessment of wreck site preservation and vulnerability.

6.3.31 In addition, it is also important to identify which processes occur naturally across wreck sites as a result of the 'reef effect' and furthermore, which of these natural processes can be altered by anthropogenic pressures. Wreck deposition alters seabed habitats and ecology from those occurring pre-wreck (referred to as the reef effect in relation to planned artificial structures: see Objective 3). Understanding the 'wreck' effect is important to aid the identification of change across the wreck site and differentiate between natural from anthropogenic sources (Oxley, 1990; O'Shea, 2002), which is particularly relevant when considering wrecks in proximity to aggregate extraction areas from both and ecological and archaeological point of view. This is further supported in the case of the assessment of the *Holland V* video and image data assessed in this study (**Section 5.4**).

6.3.32 The condition of a shipwreck depends on the nature of the site environment (this includes the wreck itself as well as the surrounding seabed deposits) which varies considerably spatially and temporally (Muckelroy, 1977; Wheeler, 2002). There are a vast number of complex, inter-related environmental processes affecting wreck site preservation (deterioration) which are highlighted in the literature and attempts have been made to categorise these in a number of different ways historically. For the purposes of this study these processes are categorised as follows (whether naturally or anthropogenically derived):

- Biogenic Processes
- Marine organisms (ranging from microbes to macrobenthos) can physically and chemically modify their environment. Modifications occur by:
    - Boring of wood (Pournou *et al*, 2001; Brown *et al*, 1988; Grayson, 2001; Palma, 2005);
    - Corrosion of metal (Brown *et al,* 1988; Church *et al*, 2007; McCarthey, 1982; Palma, 2005; Lenihan, 1990; Watzin *et al*, 2001; Russell *et al*, 2006);
    - Accretion/biofouling of surfaces (Lenihan, 1990; Conlin and Russell, 2006; Watzin *et al*, 2001; Palma, 2005; Grayson, 2001);
    - Bioturbation (mixing) of sediments by benthic organisms, which can affect the burial of material and modifies the stratigraphy (Ferrari and Adams, 1990; Brown *et al*, 1988); and
    - Mechanical damage by widening of crevices for habitation (Ferrari and Adams, 1990)
- Non-Biogenic Process (i.e. physical and chemical)

- Hydrodynamics e.g. turbulence, current flow (Dix *et al*, 2007);
- Geodynamics including scour/erosion and accumulation/deposition (Dix *et al*, 2007; O'Shea, 2002; Quinn *et al*, 2007; Bates *et al*, 2007; Conlin and Russell, 2006);
- Depth (numerous studies);
- Temperature (Palma, 2005; Church *et al*, 2007); and
- Chemical properties of seawater and sediments (Palma, 2005; Church *et al*, 2007).

6.3.33 The references in brackets indicate those studies which have measured each of the environmental process listed, specifically around wreck sites, and include information on the range of methods and techniques used. Additional well established methods for measuring these processes are considered under Objective 7.

6.3.34 A call for an integrated approach to the management of shipwrecks is not a new concept. Muckelroy's early investigation into historic shipwrecks and their environments (1977) highlighted the importance of understanding site sediment dynamics when considering the survival of archaeological material. The study concluded that every report on a wreck site should include environmental data as a matter of course.

6.3.35 McCarthey (1982), Oxley (2001) and recently Palma (2005) have all identified the need for a comprehensive understanding of all components of environmental processes, and support O'Shea's (2002) recommendations that this needs to be based on quantified data from multiple disciples of marine science, and collected to recognised standards. Wheeler (2002) also stated that if archaeological resources are to be effectively conserved then an understanding of the environmental variables to which they are exposed is essential.

6.3.36 Many of the wreck studies concerned with wreck ecology have surveyed the biology to assess biogenic processes directly affecting wreck condition (Pournou *et al*, 2001; Brown *et al*, 1988; Grayson, 2001; Palma, 2005; Church *et al*, 2007; Lenihan, 1990; Watzin *et al*, 2001; Conlin and Russell, 2006; and Ferrari and Adams, 1990) or to investigate the reef effect (Church *et al*, 2007; Davies *et al*, 1982; Fabi *et al*, 2002; Perkol-Finkel and Benayahu, 2007; Ambrose and Anderson, 1990; Steimele *et al*, 2002), rather than using the benthos as a proxy to assess environmental (non-biogenic) processes. Environmental processes have historically been measured directly (O'Shea, 2002; Quinn *et al*, 2007; Bates *et al*, 2007; Conlin and Russell, 2006; Palma, 2005; and Church *et al*, 2007) by e.g. geophysical surveys, or modelled (Dix *et al*, 2007).

6.3.37 Exceptions to this include studies of more modern wrecks such as HMS *Royal Oak* (ERT, 1997) and MV *Braer* (Kingston *et al*, 1995), although these are concerned with the oil pollution effects on benthic ecology.

6.3.38 From the list of environmental processes affecting wreck site preservation a suite of suitable benthic indicator species could be developed and used to

monitor changes in both the biogenic and non-biogenic processes (see Objective 1). This would also provide information to support or perhaps ground truth data measured by remote methods (e.g. sidescan sonar and multibeam bathymetry).

6.3.39 The inherent difficulties associated with selecting dependable indicator species (Hiscock *et al*, 2005) would be compounded by the need for a good understanding of the natural ecological dynamics of wrecks and wreck communities, which is currently lacking.

6.4 OBJECTIVE 7: IS THERE SCOPE FOR COST-EFFECTIVE ACQUISITION OF ECOLOGICAL DATA DURING ARCHAEOLOGICAL SURVEYS?

6.4.1 The archaeological and ecological recreational diving communities have already recognised the benefits of an integrated approach to wreck sites and are recording basic levels of ecological/archaeological information during their respective dives. The main motivation for this is to maximise the information gained out of the small budgets available for fieldwork and data acquisition.

6.4.2 Sussex Seasearch (Kate Cole, *pers. comm*.) Hampshire and Isle of Wight Seasearch (Jolyon Chesworth and Vicky Swale *pers. comm*.), Hampshire Wildlife Trust (HWT: Jolyon Chesworth, *pers. comm.*), Hampshire and Wight Trust for Maritime Archaeology (HWTMA: Julie Satchell *pers. comm*.), and Nautical Archaeological Society (NAS) are currently involved in joint training and field work initiatives to share vessel costs and teach their divers how to record both useful archaeological and ecological information during their dives (e.g. WreckMap: www.nasportsmouth.org.uk/projects/wmb2006/index.php; Seasearch: www.seasearch.org.uk; OASIS project: www.hwtma.org.uk/projects/oasis/index.htm.) While these initiatives are encouraging, the resolution of data generated from these integrated approaches is insufficient for the purposes of wreck site condition and vulnerability assessments such as those carried out in relation to the Protection of Wreck Act (1973).

6.4.3 Basic changes could be made however, to the archaeological data acquisition techniques developed by Wessex Archaeology (Wessex Archaeology, 2006b) and currently in use within the scientific community, to improve the quality of image data collected and provide video footage and stills images suitable for species identification. The key areas requiring improvement and suggestions pertaining to this are discussed in **Section 6.3**.

6.4.4 Resolution of these issues may be further aided by the inclusion of advice (from an ecological surveyor) either at the survey planning stage or in the field during acquisition.

6.4.5 In order to improve on the current limited coverage of image data, both spatially and temporally, an ecological data acquisition strategy needs to be developed for wreck sites. The form of the strategy will depend on whether the data is to be used to feed into a wreck site condition and vulnerability assessment, an ecological evaluation of the site for assessing biological or conservation status in relation to EIAs/REAs, or both.

Suggestions for acquisition strategy

6.4.6 Data acquisition could be carried out in two stages: an initial broad scale overview using video (Davies *et a*l, 2001: PG3.13), and further quantitative sampling for groundtruthing and the assessment of indicator species by fixed point quadrat photography (hard substrates: Davies *et al*, 2001: PG3.7 & 3.12) and core sampling (sediments: Davies *et al*, 2001: PG3.8).

6.4.7 Such a staged approach to ecological data acquisition could be integrated with the staged approach to archaeological recording developed by Wessex Archaeology and applied on the *Wrecks on the Seabed* project (Wessex Archaeology, 2006b).

6.4.8 To ensure that adequate spatial coverage is achieved for both a broad scale overview and targeted sampling, particularly when data is required to contribute to wreck site condition assessment, there would be a requirement to 'sample' the different environmental zones across the wreck site.

6.4.9 Dialogue with organisations concerned with wreck site (National Aquarium, Plymouth) and reef feature monitoring (Hampshire and Wight Wildlife Trust, Sussex Seasearch, Sussex County Council) and literature review (Davies *et al*, 2001; JNCC, 2004; Dix *et al*, 2007) highlighted the following environmental zones occurring around wrecks:

- **Reference area:** outwith the hydrodynamic influences of the wreck and representative of all substrates within the locality. This should encompass both sedimentary and hard substrates, if possible, for comparison to those near the wreck.

- **Surrounding seabed in immediate proximity to wreck**: within the hydrodynamic influences of the structure and subject to the reef effect. This should ideally also encompass both sedimentary and hard substrates for comparison to those in the reference area, and include exposed, low lying artefacts. Sampling strategy within this area may be informed by geophysical data and sediment modelling (if available), or from the broad scale video data itself. Data should ideally be acquired from points both upstream and downstream from the wreck in areas of both erosion and deposition (Dix *et al*, 2007; Church *et al*, 2007; Deborah Snelling, *pers. comm.*).

- **The main wreck feature**: Data should be collected with increasing height from the seabed starting at the wreck/seabed interface and moving up the wreck structure to a prominent feature/area to assess vertical zonation and near seabed scour. Areas should ideally be located within the prevailing current, and on the opposite in the lee. A belt transect(s) approach could be used, and could even be continuous between the prevailing and lee sides. In addition, vertical and horizontal faces of the wreck would need to be considered as these are generally occupied by different species.

6.4.10 The position of fixed point quadrat photography and/or cores within each zone could be determined from a combination of reviewing available geophysical data (e.g. sidescan sonar, swath bathymetry), sediment model and video data. The ability to locate these points again would have to be considered for repeat surveys to provide a temporal assessment (either by

spatial referencing, USBL position or by establishing fixed points on hard substrates).

Logistical considerations

6.4.11 The acquisition of this data during a dedicated ecology survey would need to be done using divers. This would involve mobilising a four person team, a vessel and crew to site and establishing the orientation of the site. Ecological dive teams tend to use air on SCUBA and dive in buddy pairs, rather than solo diving on surface supply. This limits the available daily bottom time and therefore the amount of work that can be achieved per day, although the use of Nitrox is becoming more common, which can extend bottom times (as well as provide safety benefits). Nevertheless, mobilisation of the dive team to site alone has cost implications.

6.4.12 The cost implications of acquiring the ecological data may be minimised by using archaeological divers, already mobilised and established on site with a good working knowledge of the wreck. There is an added advantage in having a real-time view of the data being collected on the seabed at the surface, and two-way voice communication with the diver. This provides an option for the diver to be directed by an ecologist on the surface, if required, to ensure the quality of the data acquired is of a suitable standard and to conduct suitable video/stills/core logs and *in-situ* record keeping (such as MNCR recording forms: Davies *et al*, 2001; Connor *et al*, 2004). Alternatively, data could be collected for ecological assessment during dedicated 'ecology' dives during the archaeological field visit, perhaps following the archaeological work.

6.4.13 It is possible, given the amount of bottom time available to archaeological divers using surface supply techniques, and that the broad scale video acquisition may be achievable in a day and the targeted sampling from within environmental zones achievable in a further day on site.

6.4.14 Clearly, video and stills collected during the course of routine archaeological tasks are currently not suitable for ecological review due to the issues around quality, resolution and lack of suitable spatial referencing of the data. However, these issues could be addressed in part through minor changes to archaeological survey and recording practices.

Data analysis considerations

6.4.15 To improve the usefulness of the species and habitat data, both spatially and temporally, an ecological data analysis strategy needs developed for wreck sites. Again, this would depend on whether the data was to be used to feed into a wreck site condition and vulnerability assessment, an ecological evaluation of the site for assessing biological or conservation status, or both.

6.4.16 Video footage can be assessed for species and biotopes present. This should be considered in the field during acquisition to inform the sampling strategy. Further, more detailed assessment should also be considered post survey. Although it is currently unclear how biotope data and the proxy environmental information it represents can feed into wreck site condition and vulnerability assessments (see **Section 6.2**), it may be relevant for supporting ecological and conservation assessments in relation to licence applications (where wreck sites are typically omitted from ecological

surveys). Furthermore, this can provide additional information to increase knowledge of the local, regional, national and international importance of biotopes, help develop the marine habitat classification (Connor *et al*, 2004) with respect to biotopes occurring on artificial substrates (fouling communities) and provide a geographical focus for monitoring range extension of select biotopes and species.

6.4.17 Stills images and core samples can be assessed for indicator species. An assessment of stills images would need to be done post survey. The presence of indicator species could be quantified either by presence/absence, SACFOR, or frequency counts, depending on the resolution of data required. The latter of these would require the quadrants to be gridded (Davies *et al*, 2001: PG3.7). SACFOR and frequency counts would allow for a quantitative comparison of spatial and temporal distribution of epibenthic indicator species.

6.4.18 Stills images can also provide further, quantitative data to support the species and biotope assessment from video if required.

6.4.19 An assessment of core samples could be approached either in the field or by laboratory analysis post survey, depending on the resolution of data required. General, qualitative observations could be made on sediment type and the presence/absence of indicator species (assuming they were large enough to be visible with the naked eye). This method is considered to be very crude and if used would limit the ability to assess changes in the spatial and temporal distributions of infaunal indicator species. Quantitative macrobenthic and PSA analyses of cores could be made to count the abundance of indicator species and provide measured PSA data, the latter of which would support the interpretation of sidescan sonar data (if applicable).

6.4.20 Benthic cores, if analysed fully for all species present can also provide further, quantitative data to support the species and biotope assessment from video, if required.

6.4.21 The use of indicator species in the data analyses rather than analysing the data for all species present would perhaps save resources (and therefore cost), and provide data best suited to representing the processes affecting wrecks.

6.4.22 However, the indicator species approach relies on the identity of a dependable suite of species being available, which is capable of representing all the processes affecting wreck site condition (both biogenic and non-biogenic listed in **Section 6.2**). This establishment of such a suite of indicators would require further work and investigation.

Evaluation and assessment of cost-effectiveness of suggested methods

6.4.23 The cost-effectiveness of the approaches and techniques suggested above would require further investigation. In addition, field evaluation would be required in order to assess the usefulness of the data resulting from the strategies suggested in relation to each of the following: wreck site condition and vulnerability assessments; ecological and conservation assessments; and the development of aggregate extraction mitigation strategies.

6.4.24 It is worth recognising at this point that there is also scope for including volunteer-based organisations (such as HWT, NAS, Seasearch and HWTMA) to contribute to the evaluation of methods such as those suggested above. These organisations are proactive with respect to carrying out fieldwork and have the potential to contribute to the development of field methods and data acquisition in general.

6.5 OBJECTIVE 2: CAN ARCHAEOLOGICAL EXCLUSION ZONES ACT AS REFUGES FOR BENTHIC SPECIES WHICH MAY THEN CONTRIBUTE TO THE RECOLONISATION OF ADJACENT AREAS FOLLOWING CESSATION OF AGGREGATE EXTRACTION?

6.5.1 A review of published literature and stakeholder engagement revealed that considering historical wrecks and their associated exclusion zones with respect to habitat restoration appears to be a new concept. Artificial reefs are being used as a tool in coastal management for many different purposes including restoration of fish stocks, increase fisheries yield and production, recreational diving and prevention of trawling (Baine, 2001). Historic wrecks may be considered as unplanned, artificial reefs and therefore may be considered in the same context with respect to coastal management (this is further discussed under Objective 4).

6.5.2 The main purpose of exclusion zones is to prevent damage to the archaeological site from dredging activities (mitigation by avoidance) and to prevent the damage to the dredging equipment (i.e. draghead).

6.5.3 Archaeological exclusion zones may also be considered as benthic 'no-take zones' within extraction areas. However, a number of other issues need to be considered if the potential of benthic no-take zones to contribute to re-colonisation of adjacent dredged areas is to be fully evaluated. These issues have been highlighted below for future consideration.

6.5.4 The extent of the area encompassed by the archaeological exclusion zone is relevant when considering its potential as an ecological refuge. It would have to be large enough to ensure that a) the benthic communities within are not impacted by adjacent dredging, and b) that it can provide enough parent 'stock' to re-colonise adjacent dredged areas. In addition, should these two criteria be addressed by an exclusion zone of suitable size and extent, a further key issue to take into consideration is that the physical nature of the seabed within the dredged area requiring re-colonisation may differ significantly to that remaining within the exclusion zone due to removal of the seabed, and this new habitat may not be suitable for parent stock species within the exclusion zone to re-colonise.

Impacts of dredging relevant to archaeological exclusion zones

6.5.5 The biological effects of the physical impacts of aggregate extraction on both infaunal and epibenthic communities have been extensively documented in scientific literature including Smith *et al*, (2006); Robinson *et al*, (2005); Kenny and Rees, (1996); Van der Veer *et al,* (1985), de Groot, (1996); Newell *et al*, (2004); Boyd *et a*l, (2003), Oakwood Environmental, (1999) and Bates *et al*, (2004).

6.5.6 The principal, physical impacts on environmental resources in areas adjacent to dredging (such as those within archaeological exclusion zones) include the dispersion and deposition of the sediment plume. There is a diversity of results on the biological effects of fallout of the sediment plume,

but many report a reduction in species diversity, abundances and biomass (Boyd *et al*, 2003 and 2005; Newell *et al*, 1998) which in turn affects the re-colonisation and recovery process (Boyd *et al*, 2004).

6.5.7 The extent of physical impact from the sediment plume was reviewed extensively by Newell *et al* (1998) who concluded that effects on biological resources were likely to be confined to distances within a few hundred meters of the dredger. More recent work in the southern North Sea by Robinson *et al* (2005) reported that this could extend up to 3km from the dredge area and concluded that impact/recovery predictions for dredged sites differ at each location in response to varying environmental characteristics. This issue would need to be taken into consideration when considering the size of the archaeological exclusion zone as a potential benthic no-take/buffer zone.

Size of exclusion zone to provide enough parent stock to improve re-colonisation rates

6.5.8 Earll (2006) briefly discussed the 'active passive recovery' of benthic communities following cessation of dredging, which relies on natural re-colonisation with the additional measure of designating a non-disturbance 'buffer' zone around the site during exploitation and/or excluding damaging activities from the site after exploitation has ceased. However, no published literature was found on how to determine the extent of such buffer zones in order to improve current re-colonisation rates.

6.5.9 Much work has been done in relation to studying re-colonisation of dredged areas following cessation of dredging (Cooper *et al*, 2005, 2007; Dernie *et al*, 2003; Szymelfenig *et al*, 2006;Boyd *et al*, 2004, 2005, and Newell, *et al*, 2004).

6.5.10 Re-colonisation rates are reported to be highly variable within the published literature and are affected by a number of different site specific factors including dredging intensity, local environmental conditions and the topography and composition of the seabed following cessation of dredging (Boyd *et al*, 2005; Earll, 2006). This also depends on the reproductive biology, seasonal recruitment success to and the ecological succession of the parent stock within the locality.

Additional considerations: the reef-effect

6.5.11 The presence of a wreck structures alter the composition of the benthic community within the exclusion zone sediments (i.e. parent stock) from that existing in surrounding sediments as a result of the reef-effect (Davies *et al*, 1982; Fabi *et al*, 2002; Perkol-Finkel and Benayahu, 2007; Ambrose and Anderson, 1990). This may result in a community different in composition compared with that of pre-dredge 'background' colonising adjacent dredge areas (see Objective 3). The extent of the reef effect would therefore also have to be taken into consideration.

How are exclusion zones currently defined and typically what area do they encompass?

6.5.12 Exclusion zones for marine aggregate dredging have historically been designed as a circular boundary centred on the object or area considered to be of archaeological importance. The radius of exclusion zones is not governed by law and therefore varies. It can typically range from ~200m

down to a few meters i.e. dredging takes place up to within a few meters of wreck structure, resulting in a relatively small area of seabed remaining undredged.

6.5.13 The radius is currently determined on a site-by-site basis by consultant archaeologists based upon parameters such as the heritage importance of the site and the extent in relation to the overall extraction area to minimise loss of available aggregate resource (Wessex Archaeology, *pers. comm.*).

6.5.14 However, the process of determining the boundaries of exclusion zones is currently undergoing review by way of developing a regional sediment mobility model for submerged archaeological sites to predict the spatial and temporal variability of tidal flows and sediment transport (Dix *et al*, 2007). Although the results of the modelling recommend a change in shape to the design of exclusion zones (from circular to elliptical, in the direction of the dominant flow) the overall area of seabed they encompass remains largely unchanged from the previous process of defining boundaries.

6.5.15 In addition, parallels may be drawn with studies relating to Marine Protected Areas (MPAs) which may provide some useful information with respect to the size and extent of archaeological exclusion zones if they are to be considered further as benthic buffer/no-take zones in extraction areas.

6.6 OBJECTIVE 3: DO WRECK SITES HAVE NATURE CONSERVATION VALUE IN TERMS OF THE HABITATS THEY PROVIDE AND THE SPECIES THEY ATTRACT?

Ecological importance of wrecks

6.6.1 A wealth of information exists on the effects of artificial reef structures on marine ecosystems. No attempt has been made here to provide a full review of this literature within the scope and timescale of this study.

6.6.2 Some of the key issues relating to why wrecks are of ecological importance have been highlighted to support the call for an integrated monitoring approach to wreck sites.

6.6.3 Artificial reef research with a wide range of different aims is ongoing on a global scale by organisations such as (but not limited to) the European Artificial Reef Research Network (EARRN); The Northwestern Hawaiian Islands Coral Reef Assessment and Monitoring Program (NOWRAMP); The National Marine Aquarium, Plymouth (*HMS Scylla*); US Minerals Management Service (MMS: rigs-to-reefs programme); and recently also encompassed study of the artificial reef effect in deep water (Church *et al*, 2007).

6.6.4 Studies have also been carried out on the effects of shipwrecks on marine ecosystems, but these have primarily focussed on the pollution effects of relatively modern wrecks such as HMS *Royal Oak* (ERT, 1997) and MV *Braer* (Kingston *et al*, 1995).

6.6.5 However, the ecological importance of wrecks in terms of how they may possibly add nature conservation value, either locally, regionally, nationally or internationally does not appear to have been considered.

6.6.6 Exceptions of note are The OASIS Project, funded by The Wildlife Trusts' South East Marine Programme and English Nature through DEFRA's

Aggregate Levy Sustainability Fund. This project was set up to investigate 'Offshore Aggregates and Species Inhabiting Historic Shipwrecks' with the aim of demonstrating the importance of the marine environment as a whole, highlighting the inter-dependence of seabed deposits, sea life and historic shipwrecks' (Julie Satchell, *pers. comm*.). Attempts were made to find out more about the methodologies and techniques employed during this project together with the key findings however this information remains outstanding at time of writing.

6.6.7 In addition, a number wreck sites in East Sussex have been designated, or are soon to be designated, as non-statutory Marine Protected Areas (MPAs), including the Outer Mulberry Unit, HMS *Northcoates* and the *City of Waterford*. These sites have been identified on account of their special interest with regard to habitat, wildlife, geology or geomorphology. The designation of mSNCIs was pioneered by local Sussex authorities who recognized the conservation importance of unnatural features such as wrecks but, owing to their artificial nature, did not qualify for statutory protection under *Natura 2000* (EC Annex I Habitats and Annex II Species Directives).

6.6.8 More emphasis on the assessment of wreck site habitats and species during routine archaeological surveys would help inform local authorities and regional conservation agencies, with respect to identifying the ecological and potential conservation importance of these artificial habitats.

6.6.9 Wrecks are typically omitted from ecological characterisation or baseline surveys which provide supporting information to describe the biological and conservation status of proposed development areas within Environmental Impact Assessments (EIAs) and Regional Environmental Assessment (REAs). For example, wrecks within licence extraction areas and the associated exclusion zones are not intended for dredging therefore, they are often not considered a priority for inclusion in the regional or licence area ecological monitoring programme and survey cost, time and effort is directed elsewhere within these areas (CEFAS, *pers. comm*.). However, the benthic ecology and conservation importance of a locality needs to be fully understood if effective mitigation strategies are to be adopted with respect to the impacts of development.

6.6.10 In addition, shipwrecks have been, by convention, widely perceived as the subject of archaeological investigations and therefore largely ignored by ecologists.

6.6.11 Furthermore, wrecks, by their physical nature fit the description of Annex I 'Reef' habitat (Davies *et al*, 2001: Section 3 reefs). A wide range of topographical reef forms meet the EC definition of this habitat type (e.g. bedrock ledges, boulder fields), but wrecks are not one of them. The only apparent reason being is that they are not naturally occurring (JNCC, *pers. comm*.).

6.6.12 Wreck sites add structure and diversity to seabed types, particularly in extensive areas of sand and gravel targeted for extraction which are otherwise relatively uniform seabed.

6.6.13 Wrecks are often found to support benthic and fish communities which differ to that of the surrounding seabed as a result of the reef effect (Davies *et al*,

1982; Fabi *et al*, 2002; Perkol-Finkel and Benayahu, 2007; Ambrose and Anderson, 1990; Steimle *et al*, 2002). For example, they can provide microhabitats for larger mobile epibenthic species (Conger eels, various crab species, Lobsters, demersal fish) of both commercial and non-commercial value. They can also provide stable, hard substrate in a number of different environmental conditions which would otherwise not be available for slow growing epibenthic species to colonise.

6.6.14 Research on the reef effect, whether for artificial reefs or deep wrecks (Church *el al*, 2007), has shown that these structures can increase infaunal diversity, biomass and productivity in the surrounding sediments (Ambrose and Anderson, 1990; Fabi *et al*, 2002; Davies *et al*, 1982). In addition, the stable habitat provided by a wreck promotes the development of a diverse epibenthic community (Church *et al*, 2007; Lapointe and Bourget, 1999; Perkol-Finkel and Benayahu, 2005).

6.6.15 Wrecks are also of importance to fish communities. Whether through habitat limitation or behaviour preferences, wreck structures attract fish (Bohnsack, 1989) and mobile shellfish species such as Lobster (Sussex Sea Fisheries Committee, *pers comm*.). As a result, wrecks are important resources for local fisheries.

6.6.16 Wrecks may also be considered important with respect to fish and shellfish stock enhancement and rehabilitation. Published literature on artificial reefs suggests that artificial structures (such as wrecks) can help in the re-establishment and enhancement of commercially important species (Bohnsack, 1989; Jensen *et al*, 1994; Wilson *et al*, 2002).

6.6.17 Stakeholder engagement highlighted that wrecks are also important to other sea users such as divers and anglers, both locally and nationally. Many dive charter businesses depend on wreck sites to provide features of interest both from an historical and ecological point of view for their divers. This is particularly the case in areas where much of the seabed is flat sand and gravel, and considered 'boring' and of limited interest to the general diving public. The often increased density of fish around wreck features (Bohnsack, 1989; Sussex Sea Fisheries Committee, *pers. comm*.) in comparison to the surrounding, featureless seabed provides important resource for the recreational fishing community.

6.6.18 Wrecks may also provide suitable substrate and act as a network of stepping stones for species to extend their geographical range (Hiscock, 2005). By studying wreck sites more closely for species which are known to be on the edge of their geographical range in adjacent areas this may provide suitable geographical focal points for monitoring range extension in response to climate change.

6.6.19 Furthermore, the study of wreck site ecology may help inform and progress the development of the national classification of marine habitats (Connor *et al*, 2004) with respect to fouling faunal communities. The importance of this is discussed under Objective 1: biotope approach to environmental monitoring.

6.6.20 Wreck sites are of importance to local fisheries and other sea users:

- in the habitats they provide and the species they attract;

- because they add to the general ecological value of a region by increasing biodiversity; or

- because they provide suitable geographical focal points for monitoring range extension in response to climate change.

Conservation importance

6.6.21 If wrecks sites add to the ecological value of a region and increase biodiversity should they be evaluated with respect to their potential conservation importance? Should wrecks be considered for their conservation importance for their ability to provide stable habitat and reef communities similar to that of Annex I habitats (natural rocky reefs), often in areas where the geology dictates that these features are limited? Should wrecks be considered for their conservation importance with respect to the habitat and community structures they provide as a result of the reef effect which may differ slightly from their rock equivalents (Perkol-Finkel and Benayahu, 2007) and therefore represent unique features?

6.6.22 These questions deserve further consideration.

6.6.23 Species data from the wreck sites in the current study was of insufficient resolution to comment whether or not the biotopes recorded were entirely typical in composition for the national classification or exhibited variations attributable to regional location or their occurrence on artificial features rather than naturally occurring rock.

6.6.24 No species or habitats identified from the 4 wreck sites were listed within current marine nature conservation legislation highlighted in **Section 4.7.10.** However, this may be attributable, in part, to the quality of the image data provided for assessment.

6.6.25 Furthermore, at time of writing feedback was still outstanding from conservation organisations with respect to:

- assessing the value of the species and habitats recorded from the wreck sites in the current study; and

- whether this had conservation relevance in the context of local statutory and non-statutory marine nature conservation designations and regional distributions.

6.7 OBJECTIVE 4: CAN ARCHAEOLOGICAL PROTECTED AREAS CONSERVE ECOLOGICAL INTERESTS, PARTICULARLY THOSE WITHIN AGGREGATE EXTRACTION LICENCE AREAS?

6.7.1 Little published literature in relation to this issue was found to be available. However, common sense suggests that the protection afforded to wrecks designated under the Protection of Wrecks Act (PWA, 1973) can also have benefits for the ecological interests by their association.

6.7.2 Some protected wrecks are well marked (buoyed) to inform sea users of their location and status. The PWA (1973) effectively restricts certain activities on all designated sites (trawling, fishing and diving) and the designation includes a surrounding exclusion area of 50-300m radius (Firth and Ferrari, 1992). Protecting wrecks from such activities as trawling,

fishing, diving can only help to protect their associated ecological communities from the potential impacts resulting from such anthropogenic activities.

6.8 OBJECTIVE 5: DO ECOLOGICAL PROTECTED AREAS HAVE A ROLE IN CONSERVING ARCHAEOLOGICAL INTERESTS?

6.8.1 As with **6.7.1** above, common sense might suggest that the protection afforded to statutory Marine Protected Areas (MPAs) such as Special Areas of Conservation (SACs) and Marine Nature Reserves (MNRs) can also have benefits for the archaeological interests by their association. However, the blanket type restrictions on activities of the PWA do not exist within MPAs.

6.8.2 Restrictions imposed within MPAs are determined on a site by site basis depending on the nature of the feature(s) for which the area is designated, and do not necessarily apply to the MPA as whole. For example, if an area is designated because if the occurrence of an Annex I habitat (e.g. Horse Mussel bed) then activities such as benthic trawling, for example, are likely to be prohibited across the feature but may still be permitted in other parts of the designated area.

6.8.3 The main shortcoming of this approach with respect to conserving archaeological interests, is that it obviously relies on archaeological interests occurring in association with the protected feature.

6.8.4 No prohibition of activities is imposed within non-statutory MPAs such as Marine Sites of Nature Conservation Interest (mSNCIs), Voluntary Marine Conservation Areas (VMNCs), Sensitive Marine Areas (SMAs), Natural Areas (NAs: within 6 nautical miles) and Marine Natural Areas (MNAs: from 6 nautical miles). Codes of conduct within these MPAs are often drawn up by local conservation organisations but as yet these are not governed by any law. The Government is currently in the process of developing a Marine Bill which may help protect these areas.

7 RECOMMENDATIONS

7.1 OBJECTIVE 1: CAN THE PRESENCE/ABSENCE OF BENTHIC SPECIES BE USED AS A PROXY FOR ASSESSING ENVIRONMENTAL CONDITIONS OF WRECK SITES IN RELATION TO SITE VULNERABILITY?

Using biotopes as proxies for monitoring environmental processes

7.1.1 The current national habitat classification is limited to two artificial biotopes. This classification requires development to incorporate the wide variety of benthic communities inhabiting wreck sites.

7.1.2 In addition, in order to assess whether the broad ranges of environmental conditions represented by biotopes are of suitable resolution with respect to wreck site condition assessment a suitable conservation framework needs to be developed (see Objective 6).

7.1.3 Species and habitat data required to develop the artificial habitat classification could be collected by integrating ecological methods within routine archaeological site surveys.

7.1.4 In addition, gaining an increased understanding of wreck biotopes is of importance to increasing the current level of knowledge of the dynamic

stability of wreck sites. This is required whether wreck sites are being assessed from and ecological or archaeological mitigation perspective, against which anthropogenic impacts can be assessed.

7.1.5 The development of artificial biotope classification is also of relevance with respect to assessing the nature conservation value of wrecks.

7.1.6 Furthermore, if archaeological exclusion zones are to be considered as benthic no-take zones the physical and biological composition of seabed sediments around wreck sites needs studied in relation to the magnitude and extent of the reef effect

Using species as proxies for monitoring environmental processes

7.1.7 Existing suites of indicator species such as those developed in relation to the EU Habitats and Water Framework Directives are unsuitable for use in wreck site assessments.

7.1.8 A dependable suite of indicator species needs to be developed for the environmental processes relevant to wreck site stability. This includes both non-biogenic and biogenic processes highlighted in the discussion.

7.1.9 Information such as that from the MarLIN species information pages and the recently developed MES genus traits handbook could be used to inform this.

7.2 OBJECTIVE 2: CAN ARCHAEOLOGICAL EXCLUSION ZONES ACT AS REFUGES FOR BENTHIC SPECIES WHICH MAY THEN CONTRIBUTE TO THE RECOLONISATION OF ADJACENT AREAS FOLLOWING CESSATION OF AGGREGATE EXTRACTION?

7.2.1 Further investigation is required for all of the issues identified under this objective to fully evaluate the potential of archaeological exclusion zones with respect to enhancing benthic re-colonisation of adjacent dredged areas.

7.2.2 Issues requiring further consideration include:

- Size and dimensions of exclusion zones, to ensure that they can provide enough parent stock unaffected by the reef effect to enhance re-colonisation.
- Size and dimensions of exclusion zones, to ensure that the parent stock community within the no-take zone is unaffected by adjacent dredging (such as fall out from the dredge plume).
- Whether new seabed habitats resulting from dredging is suitable for the parent stock community is to re-colonise.

1.2 OBJECTIVE 3: DO WRECK SITES HAVE NATURE CONSERVATION VALUE IN TERMS OF THE HABITATS THEY PROVIDE AND THE SPECIES THEY ATTRACT?

Ecological value

7.2.3 Wrecks have been identified as having ecological and socio-economic value. The current understanding of wreck communities and the reef effect needs to be developed to improve knowledge of wreck ecosystems, and to assess the importance of wrecks to fish communities (of both commercial and non-commercial value).

7.2.4 Understanding the natural dynamics of wreck ecosystems is also important if the reef effect is to be differentiated from other anthropogenic impacts (e.g. the shifting environmental baseline needs to be established).

7.2.5 This could be achieved by integrating ecological methods with routine archaeological site surveys.

7.2.6 In addition, the study of wreck site species and habitats during the course of routine archaeological site surveys would serve to fill the spatial gap in ecological knowledge for aggregate extraction areas for wreck sites, which are often omitted from ecological surveys carried out in relation to EIAs and REAs.

7.2.7 Furthermore, this data may also provide a geographical focal point for monitoring the distribution of species on the edge of their current range.

Conservation value

7.2.8 Although wrecks are not natural habitats they do have conservation value, and a number of wrecks have been designated MPAs. This is particularly important in areas where, owing to local geology, natural habitat of conservation importance (such as reefs) is limited.

7.2.9 Ecological data collected during routine archaeological surveys would provide valuable information on such habitats. This should be made available to organisations concerned with assessing the conservation value of habitats, on both a local and regional level.

7.2.10 Data should also be made available to local sea fisheries (collect once- use many times, best use) to improve the understanding the importance of wrecks as providing essential fisheries habitats.

7.3 OBJECTIVE 4: CAN ARCHAEOLOGICAL PROTECTED AREAS CONSERVE ECOLOGICAL INTERESTS, PARTICULARLY THOSE WITHIN AGGREGATE EXTRACTION LICENCE AREAS?

7.3.1 Providing the distributions of ecological features of interest are within the boundaries of the PWA wreck exclusion zones, they will benefit by their association. Integration of ecological methods within routine archaeological surveys would provide suitable ecological data to assess the distribution of habitats and species in relation to PWA designation boundaries.

7.4 OBJECTIVE 5: DO ECOLOGICAL PROTECTED AREAS HAVE A ROLE IN CONSERVING ARCHAEOLOGICAL INTERESTS?

7.4.1 Wrecks within MPAs have limited protection from their association with ecological designated features, as these designations are non-statutory, and are not protected by law. The Marine Bill may change this.

7.5 OBJECTIVE 6: IS ARCHAEOLOGICAL DATA SUITABLE FOR HABITAT AND SPECIES ASSESSMENT IN THE CONTEXT OF COMMENTING ON ENVIRONMENTAL CONDITIONS?

7.5.1 On the whole, image data generated during the course of routine archaeological site surveys was not suitable for species and habitat assessment. This was attributable to data quality, issues related to spatial

referencing of image data, limited coverage of image data, and the lack of suitable conservation framework against which the data could be assessed.

7.5.2 Data quality and spatial referencing of the image data could be improved by training archaeologists in ecological methods, and/or seeking ecological advice/input at the planning and fieldwork stages of archaeological investigations.

7.5.3 The current Protected Wrecks conservation framework requires development. This should include establishing a set of clear objectives for wreck features.

7.5.4 Attributes also need to be established which define the desired condition of wreck features.

7.5.5 Targets need to be established for each of these attributes, beyond which the feature is considered to be in decline, or vulnerable.

7.5.6 Once attributes and defining targets have been set, then appropriate methods and techniques, including those which utilise benthic species as proxies, can be considered and fully evaluated.

7.5.7 Parallels may be drawn between the management of features of cultural heritage importance and those of marine conservation importance which have been established by the JNCC, when considering the development of the heritage framework.

7.5.8 Recommendations with respect to improving spatial coverage of ecological data acquisition are given under Objective 7 below.

7.6 OBJECTIVE 7: IS THERE SCOPE FOR COST-EFFECTIVE ACQUISITION OF ECOLOGICAL DATA DURING ARCHAEOLOGICAL SURVEYS?

7.7.1 The main issues which need addressed in relation to developing an integrated approach to wreck site surveys include:

- Improving the quality and spatial referencing of image data (video and stills) acquired;
- Development of an acquisition strategy which improves the spatial and temporal coverage of ecological data;
- Investigating the use of other sampling techniques during the course of routine archaeological site surveys to provide quantitative epibenthic data for non-sedimentary habitats (e.g. fixed quadrat photography), and quantitative infaunal data for sedimentary habitats (e.g. core samples); and
- Development of a data/sample analysis strategy, suitable for assessing spatial and temporal changes in species and habitat distributions.

7.6.1 A suitable first step would be to carry out a desk-based scoping exercise to develop the discussion points raised in Section 6.3 further, and propose different ecological acquisition and data/sample analysis strategies,

additional field resources, and how these could be incorporated into current archaeological site surveys.

7.6.2 Following this, field evaluation would be required to assess the suitability of proposed strategies, resources, logistics, and comment on cost effectiveness.

7.7 OBJECTIVES 8 & 9: BUILD INTER-DISCIPLINARY LINKS AND CO-OPERATION, AND RAISE AWARENESS OF THE MARINE HISTORIC ENVIRONMENT THROUGH ENGAGEMENT WITH INDUSTRY, RESOURCES USERS AND OTHER STAKEHOLDERS

7.8.1 A wide range of stakeholders was contacted during the course of study. Feedback was not achieved from all, although this was largely due to the time constraints of the project.

7.8.2 Overall, there seemed to be a general consensus that, whether for the purposes of wreck site condition and vulnerability assessment, adding to the understanding of local, regional, national and international ecological biodiversity, importance and conservation value of wreck sites, or fully assessing the biological and conservation status of proposed dredge areas within Environmental Impact Assessments (EIAs) and Regional Environmental Assessment (REAs), wreck-ecology relationships merited further consideration than currently given.

7.8.3 Continued advice and feedback should be sought from the stakeholders identified in **Appendix A** should any of the recommendations be taken up in future.

7.9 OBJECTIVE 10: IS THERE POTENTIAL FOR EXPANDING COMBINED ARCHAEOLOGICAL/ECOLOGICAL SURVEYING TO SEASEARCH ON A LOCAL AND NATIONAL LEVEL AND INTO OTHER ARCHAEOLOGICAL/ECOLOGICAL SURVEY PROGRAMMES?

7.9.1 There is clearly scope for including Seasearch and other volunteer-based organisations in archaeological/ecological survey programmes, although the nature of such collaboration is something that would need further discussion.

7.10 OBJECTIVES 11 & 12: PRESENT THE PROJECT RESULTS TO A WIDE RANGE OF AUDIENCES AND UPDATE EXISTING *WRECKS ON THE SEABED* OUTREACH MATERIALS

7.10.1 The project and its results were presented at the MALSF Conference, 28-29 February 2008, and received a positive response from those attending. Informal discussions at the conference suggested that there is merit in further work along the lines of this project.

7.10.2 News items and popular articles describing the project and its results are being drafted, and will be submitted to at least one suitable diving magazine.

7.10.3 Further dissemination of the project results will accrue through the publication of the project report on the Archaeological Data Service (ADS) website as part of the ALSF Dissemination on the Web project.

7.10.4 The *Wrecks on the Seabed* web pages are in the process of being updated to reflect the ecological assessment of the Bottle and Portland stone wrecks. The relevant Diver Packs are also being updated to reflect the ecological assessment.

7.10.5 Shortly after its commencement the project was posted on WA's Coastal and Marine Section blog. The blog will be updated at the same time as the *Wrecks on the Seabed* web pages to reflect the results of the project.

REFERENCES

Ambrose, R.E. and Anderson, T.W., 1990, 'Influence of an artificial reef on the surrounding infaunal community', *Marine Biology*, Vol 107: 41-52.

Baine, M., 2001, 'Artificial reefs: a review of their design, application, management and performance', *Ocean and Coastal Management*, Vol 44: 241-59.

Bates, R., Dean, M., Lawrence, M., Robertson, P., Tempera, F. and Laird, S., 2004, *Innovative approaches to Rapid Archaeological Site Surveying and Evaluation (RASSE)*, Report prepared by St Andrews University for English Heritage (Project No. 3837).

Bohnsack, J.A., 1989, 'Are high densities of fishes at artificial reefs the results of habitat limitation or behavioural preference?', *Bulletin of Marine Science*, Vol 44(2): 631-645.

Brown, R., Bump, H., and Muncher, D.A., 1988, 'An *in-situ* method for determining decomposition rates of shipwrecks', *The International Journal of Nautical Archaeology and Underwater Exploration*, Vol 17(2): 143-145.

Boyd, S.E., Rees, H.L., Vivian, C.M.G. and Limpenny, D.S., 2003, 'Review of current state of knowledge of the impacts of marine aggregate extraction – a U.K. perspective', Presented at the European marine sand and gravel – shaping the future, EMSAGG Conference, 20-21 February 2003, Delft University, The Netherlands.

Boyd, S.E., Cooper, K.M., Limpenny, D.S., Kilbride, R. Rees, H.L., Dearnaley, M.P., Stevenson, J., Meadows, W.J. and Morris, C.D., 2004, *Assessment of the re-habilitation of the seabed following marine aggregate dredging*, CEFAS Technical Report No. 121.

Boyd, S.E., Limpenny, D.S., Rees, H.L., and Cooper, K.M., 2005, 'The effects of marine sand and gravel extraction on the macrobenthos at a commercial dredging site (results 6 years post-dredging)', *ICES Journal of Marine Science*, Vol 62: 145-162.

Church, R., Warren, D., Cullimore, R., Johnston, L., Schroeder W., Patterson, W., Shirley, T., Kilgour, M., Morris, N. and Moore, J., 2007, *Archaeological and Biological Analysis of World War II Shipwrecks in the Gulf of Mexico: Artificial Reef Effect in Deep Water*, Prepared under MMS Contract 1435-01-03-CT-73095 (M03PC00012) by C & C Technologies, Inc.

Conlin, D.L., and Russell, M.A., 2006, 'Archaeology of a Naval Battlefield: *H. L. Hunley* and *USS Housatonic', The International Journal of Nautical Archaeology,* Vol 35(1): 20–40.

Cooper, K.M., Eggleton, J.D., Vize, S.J., Vanstaen, K., Smith, R., Boyd, S.E., Ware, S., Morris, C.D., Curtis, M., Limpenny, D.S. and Meadows, W.J., 2005, *Assessment of the rehabilitation of the seabed following marine aggregate dredging - part II*, CEFAS Technical Report 130.

Cooper, K.M., Boyd, S.E., Eggleton, J. D., Limpenny, D.S., Rees, H., and Vanstaen, K., 2007, 'Recovery of the seabed following marine aggregate dredging on the Hastings Shingle Bank off the southeast coast of England', *Estuarine,*

Coastal and Shelf Science, Vol 75: 547-558.

Connor, D., Allen, J., Golding, N., Howell, K., Lieberknecht, L., Northen, K. and Reker, J., 2004, *The Marine Habitat Classification for Britain and Ireland Version 04.05 JNCC*, Peterborough, ISBN 1 861 07561 8 (internet version), www.jncc.gov.uk/MarineHabitatClassification

Davies, N., Van Blaircom, G.R. and Dayton, P. K., 1982, 'Man-made structures on marine sediments: effects on adjacent benthic communities', *Marine Biology*, Vol 70: 295-303.

Davies, J. (ed), Baxter, J., Bradley, M., Connor, D., Khan, J., Murray, E., Sanderson, W., Turnbull, C. and Vincent, M., 2001, *JNCC Marine Monitoring Handbook*, (http://www.jncc.gov.uk/PDF/MMH-mmh_0601.pdf)

de Groot, S.J., 1996, 'The physical impact of marine aggregate extraction in the North Sea', *ICES Journal of Marine Science*, Vol 53: 1051-1053.

Dernie, K.M., Kaiser, M.J., Richardson, E.A., and Warwick, R.M., 2003, 'Recovery of soft sediment communities and habitats following physical disturbance', *Journal of Experimental Marine Biology and Ecology*, Vol 285-286: 415-434.

Dix, J.K., Lambkin, D.O., Thomas, M.D. and Cazenave, P.W., 2007, *Modelling Exclusion Zones for Marine Aggregate Dredging*, English Heritage ALSF project no. 3365, School of Ocean and Earth Science, University of Southampton.

Earll, R.C., 2006, *Recovery and restoration of marine habitats – can we fix it?, Post Conference Briefing,* The Wildlife Trusts.

English Heritage, 2007, *Protected wreck sites at risk: A risk management handbook*, Final report, (http://ifamag.files.wordpress.com/2007/10/protected-wreck-sites-risk-handbook.pdf).

ERT Ltd., 1997, *HMS Royal Oak environmental impact assessment* (ERT Ref: S97/231/S018), A report to the MOD.

European Community, 1992, *Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora*.

Fabi, G., Luccarini, M., Panfili, Solustri, C., and Spagnolo, A., 2002, 'Effects of an artificial reef on the surrounding soft-bottom community (central Adriatic Sea)', *ICES Journal of Marine Science*, Vol 59: 343-349.

Ferrari, B. and Adams, J., 1990, 'Biogenic modifications of marine sediments and their influence on archaeological material', *The International Journal of Nautical Archaeology and Underwater Exploration*, Vol 19(2): 139-151.

Firth, A. and Ferrari, B., 1992, 'Archaeology and Marine Protected Areas (MPAs)', *International Journal of Nautical Archaeology*, Vol 21(1): 6-74.

Gray, J.S. and Pearson, T.H., 1982, 'Objective selection of sensitive species indicative of pollution-induced change in benthic communities: Comparative methodology', *Marine Ecology Progress Series,* Vol 9:111-119.

Grayson, R.I., 2001, *Report on the shipwreck and biological survey conducted on the coast of Flemming Key*, Program in Underwater Archaeology, Florida State University, Department of Anthropology, Research Report No. 12.

Hiscock, K., 2005, *Seabed species redistributions,* North-East Atlantic marine ecoregion climate change workshop, 16 and 17 June 2005, www.wwf.org.uk/neameworkshop/seabedspeciesredistributions.pdf

Hiscock, K., Langmead, O., Warwick, R. and Smith, A., 2005, Identification of seabed indicator species to support implementation of the EU Habitats and Water Framework Directives. Second edition, *Report to the Joint Nature Conservation Committee and the Environment Agency from the Marine Biological Association.* Plymouth: Marine Biological Association, JNCC Contract F90-01-705. 77 pp.

Intergovernmental Oceanographic Commission (IOC), 2004, *Indicators of stress in the marine benthos*, Proceedings of an International workshop on the promotion and use of benthic tools for assessing the health of coastal marine ecosystems Torregrande-Oristano, Italy 8–9 October 2004.

Jensen, A.C., Collins, K.J., Free, E.K. and Bannister, R.C.A., 1994, 'Lobster (*Homarus gammarus*) movement on an artificial reef; the potential use of artificial reefs for stock enhancement', *Crustaceana*, Vol 67(2), 198-211.

JNCC, 2003, *Guidance for common standards monitoring*, www.jncc.gov.uk/page-2201 and www.jncc.gov.uk/pdf/CSM_introduction.pdf

JNCC, 2004, *Common Standards Monitoring Guidance: Common Standards Monitoring Guidance For Generic Introduction for Marine Feature Guidance*, ISSN 1743-8160 (online), www.jncc.gov.uk/PDF/CSM_marine_introduction.pdf

Kenny, A.J. and Rees, H.L., 1996, 'The effects of marine gravel extraction on the macrobenthos:results 2 years post-dredging', *Marine Pollution Bulletin*, Vol 32: 615-622.

Kingston, P.F., 1987, 'Field effects of platform discharges on benthic macrofauna', *Philosophical Transactions of the Royal Society of London, Series B*, Vol 316: 545-565.

Kingston, P.F., Dixon, I.M.T., Hamilton, S., and Moore, D.C., 1995, 'The impact of the Braer oil spill on the macrobenthic infauna of the sediments off the Shetland Isles', *Marine Pollution Bulletin*, Vol 30(7): 445-459.

Lapointe, L. and Bourget, E., 1999, 'Influence of substratum heterogeneity scales and complexity on a temperate epibenthic marine community', *Marine Ecology Progress Series*, Vol 189: 159-170.

Lenihan, D.J., 1990, *Submerged culture resources study: USS Arizona memorial and Pearl Harbour National Historic Landmark*, Southwest Cultural Resources Centre Professional Papers No. 23.

MarLIN, 2008a, Seabed Species Indicator Database, www.marlin.ac.uk/indicatorspp/Indicator_search.php

MarLIN, 2008b, Species information pages, www.marlin.ac.uk/sah/species_information.php

McCarthey, M., 1982, 'A wreck inspection programme as an aid to the co-ordinated management of a large number of wreck sites', *The International Journal of Nautical Archaeology and Underwater Exploration*, Vol 11(1): 41-52.

McCarthey, M., 2000, 'Iron and steamship archaeology: success and failure on the SS Xantho', *The Plenum Series in Underwater Archaeology*, Kluwer Academic/Plenum Publishers.

Muckelroy, K., 1977, 'Historic wreck sites in Britain and their environments', *The International Journal of Nautical Archaeology and Underwater Exploration*, Vol 6(1): 47-57.

Newell, R.C., Seiderer, L.J. and Hitchcock, D.R., 1998, 'The impact of dredging works in coastal waters: A review of the sensitivity to disturbance and subsequent recovery of biological resources on the seabed', *Oceanography and Marine Biology: An Annual Review*, Vol 36: 127-178.

Newell, R.C., Seiderer, L.J., Simpson, N.M. and Robinson, J.E., 2004, 'Impacts of Marine Aggregate Dredging on Benthic Macrofauna off the South Coast of the United Kingdom', *Journal of Coastal Research*, Vol 20(1): 115-125.

Olenin, S. and Ducrotoy, J.P., 2006, 'The concept of biotope in marine ecology and coastal management', *Marine Pollution Bulletin*, Vol 53: 20-29.

Oakwood Environmental Ltd., 1999, *Strategic cumulative effects of marine aggregates dredging (SCEMAD)*, Research Report prepared for MMS Contract No: 1435-01-98-CT-30894.

O'Shea, J.M., 2002, 'The archaeology of scattered wreck-sites: formation processes and shallow water archaeology in western Lake Huron', *The International Journal of Nautical Archaeology*, Vol 31(2): 211-227.

Oxley, I., 1990, 'Factors affecting the preservation of underwater archaeological sites', *Nautical Archaeology*, Vol 19(4): 340-341.

Oxley, I., 2001, 'Towards the Integrated Management of Scotland's Cultural Heritage: Examining Historic Shipwrecks as Marine Environmental Resources', *World Archaeology*, Vol. 32(3): 413-426.

Palma, P., 2005, 'Monitoring of Shipwreck Sites', *The International Journal of Nautical Archaeology*, Vol 34(2): 323–331.

Pearson, T.H. and Rosenberg, R., 1978, 'Macrobenthic succession in relation to organic enrichment and pollution of the marine environment', *Oceanography and Marine Biology Annual Review*, Vol 16: 229-311.

Perkol-Finkel, S. and Benayahu, Y., 2005, 'Recruitment of benthic organisms onto a planned artificial reef: shifts in community structure one decade post deployment', *Marine Environmental Research*, Vol 59: 79-99.

Perkol-Finkel, S. and Benayahu, Y., 2007, 'Differential recruitment of benthic communities on neighbouring artificial and natural reefs', *Journal of*

Experimental Marine Biology and Ecology, Vol 340: 25-39.

Pournou, A., Jones, A.M. and Moss, S.T., 2001, 'Biodeterioration dynamics of marine wreck-sites determine the need for their *in situ* protection', *The International Journal* of *Nautical Archaeology,* Vol 30(2): 299-305.

Quinn, R., Forsythe, W., Breen, C., Boland, D., Lane, P. and Omar, A.L., 2007, 'Process-based models for port evolution and wreck site formation at Mombasa, Kenya', *Journal of Archaeological Science*, Vol 34: 1449-1460.

Rees, S.E., Boyd, M.S. and Murray, L.A., 2006, 'Role of benthic indicators in regulating human activities at sea', *Environmental Science and Policy*, Vol 9(5): 496-508.

Robinson, J.E., Newell, R.C., Seiderer, L.J., Simpson, N.M., 2005, 'Impacts of aggregate dredging on sediment composition and associated benthic fauna at an offshore dredge site in the southern North Sea', *Marine Environmental Research*, Vol 60(1): 51-68.

Russell, M.A., Conlin, D.L., Murphy, L.E., Johnson, D.L., Wilson, B.M. and Carr, J.D., 2006, 'A minimum-impact method for measuring corrosion rate of steel-hulled shipwrecks in seawater', *The International Journal of Nautical Archaeology*, Vol 35(2): 310-318.

Smith, R., Boyd, S.E., Rees, H.L., Dearnaley, M.P. and Stevenson, J., 2006, 'Effects of dredging activity on epifaunal communities: surveys following cessation of dredging', *Estuarine Coastal and Shelf Science*, Vol 70(1-2): 207-223.

Szymelfenig, M., Kotwicki, L. and Graca, B., 2006, 'Benthic re-colonization in post-dredging pits in the Puck Bay (Southern Baltic Sea)', *Estuarine Coastal and Shelf Science*, Vol 68(3-4): 489-498.

Steimele, F., Foster, K. and Conlin, B., 2002, 'Benthic macrofauna productivity enhancement by an artificial reef in Delaware Bay, USA', *ICES Journal of Marine Science*, Vol 59: 100–105.

UK Marine SACs Project, 2008, *Environmental requirements of Sabellaria spinulosa,* www.ukmarinesac.org.uk/communitites/biogenic-reefs/br3_2.htm

Van Der Veer, H.W., Bergman, M.J.N and Beukema, J.J., 1985, 'Dredging activities in the Dutch Wadden Sea: Effects on macrobenthic infauna', *Netherlands Journal of Sea Research*, Vol 19(2): 183-190.

Watzin, M.C., Cohn, A.B. and Emerson, B.P., 2001, *Zebra mussels, shipwrecks and the environment*, Final report to the Argosy Foundation, Lake Champlain Maritime Museum, Vergennes, 55 pp.

Wessex Archaeology, 2006a, *HMS/m Holland No. 5, East Sussex, Designated Site Assessment: Archaeological Report*. A report prepared for English Heritage under the Archaeological Services in Relation to The Protection of Wrecks Act (1973) Contract.

Wessex Archaeology, 2006b, Aggregate Levy Sustainability Fund (ALSF) Marine aggregates and the historic environment: *Wrecks on the Seabed R2; assessment, evaluation and recording*. Year 1 report prepared for English

Heritage, Wessex Report reference 57453.02.

Wessex Archaeology, 2007, *HMS/m Holland No. 5, East Sussex, Designated Site Assessment: Archaeological Report*. A report prepared for English Heritage under the Archaeological Services in Relation to The Protection of Wrecks Act (1973) Contract.

Wheeler, A.J., 2002, 'Environmental Controls on Shipwreck Preservation: The Irish Context', *Journal of Archaeological Science,* Vol 29:1149–1159.

Wilson, K.D.P., Leung, A.W.Y and Kennish, R., 2002, 'Restoration of fisheries through deployment of artificial reefs in marine protected areas', *ICES Journal of Marine Science*, Vol 59: 157-163.

Zinten, V., Norro, A., Massin, C. and Mallefet, J., 2008, 'Temporal variation of *Tubularia indivisa* (Cnidaria, Tubulariidae) and associated epizoites on artificial habitat communities in the North Sea', *Marine Biology*, Vol 153: 405-420.

LITERATURE USED BUT NOT CITED

Advisory Committee on Historic Wreck Sites (ACHWS), 2007, *Annual report 2006*, Report submitted to Department of culture, Media and Sport: Architecture and Historic Environment Division.

Great Britain Department for Culture, Media and Sport, Great Britain Welsh Assembly Government, 2007, *Heritage protection for the 21st century*, The Stationary Office, London.

LITERATURE SOURCED BUT NOT FULLY REVIEWED DUE TO TIME CONSTRAINTS

Abelson, A., and Denny, M., 1997, 'Settlement of marine organisms in flow', *Annual Review of Ecological Systems*, Vol 28: 317-339.

Airoldi, L., Fabiano, M., and Cinelli, F., 1996, 'Sediment deposition and movement over a turf assemblage in a shallow rocky coastal area of the Ligurian Sea', *Marine Ecology Progress Series*, Vol 133: 241-251.

Ambrose, R.F. and Swarbrick, S.L., 1989, 'Comparison of fish assemblages on artificial and natural reefs off the coast of southern California', *Bulletin of Marine Science*, Vol 44(2): 718-733.

Anderson, R., 2005, *Analysis of Commonwealth Environmental Protection and Biodiversity Act 1999 in relation to Western Australian maritime heritage sites*, A report to the Department of Maritime Archaeology, WA Maritime Museum No. 23.

Andrews Survey, 2004, *Seabed characterisation and the effects of marine aggregate dredging*, Mineral Industry Research Organisation, Project Ref. No. 0548/analysis(01).

Ardizzone, G.D., Gravina, M.F. and Belluscio, A., 1989, 'Temporal development of epibenthic communities on artificial reefs in the central Mediterranean Sea', *Bulletin of Marine Science*, Vol 44(2): 592-608.

Badalamenti, F., Chemello, R., D'Anna, G., Henriquez Ramos, P. and Riggio, S., 2002, 'Are artificial reefs comparable to neighbouring natural rocky areas? A mollusc case study in the Gulf of Castellammare (NW Sicily)', *ICES Journal of Marine Science*, Vol 59: S127–S131.

Baynes, T.W. and Szmant, A.M., 1989, 'Effect of current on the sessile benthic community structure of an artificial reef', *Bulletin of Marine Science*, Vol 44(2): 545-566.

Bevilacqua, S., Terlizzi, A., Fraschetti, S., Russo, G.F., and Boero, F., 2006, 'Mitigating human disturbance: can protection influence trajectories of recovery in benthic assemblages?', *Journal of Animal Ecology*, Vol 75(4):908-20.

Bierne, N., Bonhomme, F. and David, P., 2003, ‚Habitat preferences and the marine speciation paradox', *Proceedings: Biological Sciences*, Vol 270(1522): 1399-1406.

Boyd, S.E., 2002, *Guidelines for the conduct of benthic studies at aggregate dredging sites*, CEFAS report for the Department for Transport, Local Government and the Regions.

Boyd, S., Limpenny, D.S., Rees, H.L., Cooper, K.M. and Campbell, S., 2003, 'Preliminary observations of the effects of dredging intensity on the recolonisation of dredged sediments off the south east coast of England (Area 222)', *Estuarine and Coastal Shelf Science*, Vol 57: 209-223.

Browning, L., 2002, *The biodiversity of South East England*, A report for the Wildlife

Trusts South East Marine Programme.

Brown, C.J., Hewer, A.J., Meadows, W.J., Limpenny, D.S., Cooper, K.M. and Rees, H.L., 2004, 'Mapping seabed biotopes at Hastings Shingle Bank, eastern English Channel. Part 1. Assessment using sidescan sonar', *Journal of the Marine Biological Association of the UK*, Vol 84: 481-488.

Coastline Surveys Ltd., 1999, *Marine aggregate and mining benthic and surface plume study*, Final report to US Department of the Interior Mineral Management Service and Plume Research Group, MMS OCS Study No. 99-0029.

Connor, D.W., Breen, J., Champion, A., Gilliland, P.M., Huggett, D., Johnston, C., Laffoley, D. d'A., Lieberknecht, L., Lumb, C., Ramsay, K., and Shardlow, M., 2002, *Rationale and criteria for the identification of nationally important marine nature conservation features and areas in the UK, Version 02.11*, Peterborough, Joint Nature Conservation Committee (on behalf of the statutory nature conservation agencies and Wildlife and Countryside Link) for the Defra Working Group on the Review of Marine Nature Conservation.

Cooper, K., 2005, *Cumulative effects of marine aggregate extraction in an area east of the Isle of Wight – a fishing industry perspective*, CEFAS Science Series Technical Report No. 126.

Cooper, K., Boyd, S., Aldridge, J. and Rees, H. 2007, 'Cumulative impacts of aggregate extraction on seabed macro-invertebrate communities in an area off the east coast of the United Kingdom', *Journal of Sea Research*, Vol 57(4):288-302.

van Dalfensen, J.A. *et al*., 2000, 'Differential response of macrozoobenthos to marine sand extraction in the North Sea and Western Mediterranean', *ICES Journal of Marine Science*, Vol 57:1439-1445.

Danovaro, R., Gambi, C., Mazzola, A. and Mirto, S., 2002, 'Influence of artificial reefs on the surrounding infauna: analysis of meiofauna', *ICES Journal of Marine Science*, Vol 59: 356–362.

ECA, 2003, *Regional environmental assessment for aggregate extraction in the eastern English Channel*, Non-technical summary.

ECA, 2007, *The East Channel Region interim regional environmental monitoring and management report 2006-2007*.

Einbinder, S. *et al*., 2006, 'Effects of artificial reefs on fish grazing in their vicinity: evidence from algae presentation experiments', *Marine Environmental Research*, Vol 61: 110-119.

European Commission, 2006, *Science for environment policy*, DG environment news alert service (28 June 2006).

European Commission, 2007, *Natura 2000: Interpretation manual of EU habitats*, Report No. EUR 27.

Fabi, G. and Fiorentini, L., 1994, 'Comparison between an artificial reef and a control site in the Adriatic Sea: analysis of four years of monitoring', *Bulletin of*

Marine Science, Vol 55(2-3): 538-558.

Grantham, B.A., Eckert, G.L. and Shanks, A.L., 2003, 'Dispersal potential of marine invertebrates in diverse habitats', *Ecological Applications*, Vol 13(1): 108-116.

Gubbay, S., 2006, 'Marine Protected Areas. A review of their use for delivering marine biodiversity benefits', *English Nature Research Reports*, No 688.

Gubbay, S., 2007, *Defining and managing Sabellaria spinulosa reefs*: Report of an inter-agency workshop 1-2 May, 2007, JNCC Report No. 405.

Guichard, F. and Bourget, E., 1998, 'Topographical heterogeneity, dynamics, and benthic community structure: a scale-dependant cascade', *Marine Ecological Progress Series*, Vol 171: 59-70.

Halpern, B.S., 2003, 'The impact of marine reserves: do reserves work and does size matter?', *Ecological Applications*, Vol 13(1): 117-137.

Hastings, A. and Botsford, L.W., 2003, 'Comparing designs of marine reserves for fisheries and for biodiversity', *Ecological Applications*, Vol 13(1): 65-70.

Hitchcock, D.R. and Bell, S., 2004, 'Physical impacts of marine aggregate dredging on seabed resources in coastal deposits', *Journal of Coastal Research*, Vol 20(1): 101-114.

Kaiser, M.J., Spence, F.E. and Hart, P.J.B., 2000, 'Fishing gear restrictions and conservation of benthic habitat complexity', *Conservation Biology*, Vol 14(5): 1512-1525.

Lieberknecht, L.M., Carwardine, J., Connor, D.W., Vincent, M.A., Atkins, S.M. and Lumb, C.M., 2004, *The Irish Sea Pilot - Report on the identification of nationally important marine areas in the Irish Sea*, JNCC report no. 347. www.jncc.gov.uk/irishseapilot.

Maughan, B.C. and Barnes, D.K.A., 2000, 'Epilithic boulder communities of Lough Hyne, Ireland: the influences of water movement and sediment', *Journal of the Marine Biological Association of the UK*, Vol 80: 767-776.

M.E.S., 2007, *Dissemination and raised awareness of the recoverability of Sabellaria spinulosa following aggregate extraction*, Marine ALSF delivery partners joint work in progress meeting 04.10.2007 (MAL0027). www.seasurvey.co.uk

M.E.S., 2007, *Predictive framework for assessment of recoverability of marine benthic communities following cessation of aggregate extraction*. Preparation of a Genus Trait Handbook. www.seasurvey.co.uk

Miller, M.W., 2002, 'Using ecological processes to advance artificial reef goals', *ICES Journal of Marine Science*, Vol 59: 27-31.

Miller, D.C., Muir, C.L. and Hauser, O.A., 2002, 'Detrimental effects of sedimentation on marine benthos: what can be learned from natural processes and rates?', *Ecological Engineering*, Vol 19: 211-232.

Mouillot, D., Culioli, J.M., and Chi, T., 2002, 'Indicator species analysis as a test of non-random distribution of species in the context of marine protected areas',

Environmental Conservation, Vol 29(3): 385-390.

Muxika, I., Borja, A. and Bonne, W., 2005, 'The suitability of the marine biotic index (AMBI) to new impact sources along European coasts', *Ecological Indicators*, Vol 5: 19-31.

Newell, R.C., Hitchcock, D.R. and Seiderer, L.J., 1999, *Organic enrichment associated with outwash from marine aggregates dredging: A probable explanation for surface sheens and enhanced benthic production in the vicinity of dredging operations*, Final report to US Department of the Interior Mineral Management Service and Plume Research Group.

Nicoletti, L., Marzialetti, S., Paganelli, D., and Ardizzone, G.D., 2007, 'Long-term changes in a benthic community associated with artificial reefs', *Hydrobiologia*, Vol 580(1): 233-240.

Nieuwaal, M., 2001, *Requirements for sediment plumes caused by dredging*, Final thesis report, Delft University of Technology, Faculty of Civil Engineering and Geosciences, Department of Civil Engineering, Section Hydraulics, December 2001.

Olsgard, F., Brattegard, T. and Holthe, T., 2003, 'Polychaetes as surrogates for marine biodiversity: lower taxonomic resolution and indicator groups', *Biodiversity and Conservation*, Vol 12(5): 1033-1049.

Powers, S. P., Grabowski, J.H., Peterson, C.H. and Lindberg, W.J., 2003, *Estimating enhancement of fish production by offshore artificial reefs: uncertainty exhibited by divergent scenarios*.

Perkol-Finkel, S. *et al.,* 2005, 'Fouling reefal communities on artificial reefs: does age matter?', *Biofouling*, Vol 21(2): 127-140.

Petersen, J.K., and Malm, T., 2006 'Offshore Windfarms: Threats to or possibilities for the marine environment?', *Ambio*, Vol 35(2): 75-80.

Qiu, J.W., Thiyagarajan, V., Leung, A.W.Y. and Qian, P.Y., 2003, 'Development of a marine subtidal epibiotic community in Hong Kong: Implications for deployment of artificial reefs', *Biofouling*, Vol 19(1): 37-46.

Quinn, R. and Breen C., (date unknown), *The role of scour in shipwreck site formation processes – analysis of marine geophysical data from a mixed tide-wave environment*, MRes Thesis, University of Ulster, Centre for Maritime Archaeology, Environmental Sciences Research, Institute School of Environmental Sciences.

Relini, G. *et al.,* 2002, 'Trophic relationships between fishes and an artificial reef', *ICES Journal of Marine Science*, Vol 59: S36-S42.

Rilov, G. and Benayahu, Y., 2000, 'Fish assemblage on natural versus vertical artificial reefs: the rehabilitation perspective', *Marine Biology*, Vol 136: 931-942.

Russ, G.R. and Alcala, A.C., 1996, 'Marine reserves: rates and patterns of recovery and decline of large predatory fish', *Ecological Application*, Vol 6(3): 947-961.

Sanders, H.L., 1958, 'Benthic studies in Buzzards Bay: Animal-sediment relationships', *Limnology and Oceanography*, Vol 3(3): 245-258.

Seaman, W., 2007, 'Artificial habitats and the restoration of degraded marine ecosystems and fisheries', *Hydrobiologia*, Vol 580(1): 143-155.

Simonini, S*. et al*., 2007, Re-colonisation and recovery dynamics of the macrozoobenthos after sand extraction in relict sand bottoms of the northern Adriatic Sea', *Marine Environmental Research*, Vol 64: 574-589.

Seiderer, L.J. and Newell, R.C., 1999, 'Analysis of the relationship between sediment composition and benthic community structure in coastal deposits: Implications for marine aggregate dredging', *ICES Journal of Marine Science*, Vol 56: 757-765.

Smith, R., Boyd, S.E., Rees, H.L., Dearnaley, M.P. and Stevenson, J., 2006, 'Effects of dredging activity on epifaunal communities: surveys following cessation of dredging', *Estuarine Coastal and Shelf Science*, Vol 70(1-2): 207-223.

Thrush, S.F., Hewitt, J.E., Norkko, A., Cummings, V.J. and Funnel, G.A., 2003, 'Macrobenthic recovery processes following catastrophic sedimentation on estuarine sandflats', *Ecological Applications*, Vol 13(5): 1433-1455.

Ward, T.J., Vanderklift, M.A., Nicholls, A.O. and Kenchington, R.A., 1999, 'Selecting Marine Reserves Using Habitats and Species Assemblages as Surrogates for Biological Diversity', *Ecological Applications,* Vol. 9(2): 691-698.

Wilding, T.A., 2006, 'The benthic impacts of the Loch Linnhe artificial reef', *Hydrobiologia*, Vol 555(1): 345-353.

Zinten, V., 2006, 'Epifaunal inventory of two shipwrecks from the Belgian continental shelf', *Marine Biodiversity*, Vol 183: 207-219.

APPENDIX A: LIST OF STAKEHOLDERS AND CONTEXT IN WHICH THEY WERE CONTACTED

Organisation	Contact as at February 2008	Address	Dialogue achieved?	Engagement context (Objectives)
Industry				
British Marine Aggregate Producers Association (BMAPA)	Mark Russell	Gillingham House 38-44 Gillingham Street London SW1V 1HU Tel: 020 7963 8000 Email: bmapa@qpa.org www.bmapa.org	Y, although limited due to time constraints	1, 2, 7, 8, 9
Marine Archaeological Monitoring and Conservation				
EH Maritime Archaeological Team	Mark Dunkley	Fort Cumberland Eastney Portsmouth PO4 9LD Tel: 023 9285 6768 Email: mark.dunkley@english-heritage.org.uk www.english-heritage.org.uk/	Y	1, 5, 6, 7, 8, 9
Hampshire and Wight Trust for Maritime Archaeology (HWTMA)	Julie Satchell	Room W1/95, National Oceanography Centre, Empress Dock, Southampton SO14 3ZH Tel: 023 8059 3290/023 8023 7300 Email: julie.satchell@hwtma.org.uk www.hwtma.org.uk	Y, although limited due to time constraints	1, 5, 4, 7, 8, 9, 10
Hastings Shipwreck and Coastal Heritage Centre	Peter Marsden	Shipwreck & Coastal Heritage Centre, Rock-a-Nore Road, Hastings, East Sussex TN34 3DW Tel: 01424 437452 Email: peter.marsden@tiscali.co.uk www.shipwreck-heritage.org.uk/	Y	1, 5, 7, 8, 9
Nautical Archaeological Society (NAS)	Mark Beattie-Edwards	The Nautical Archaeology Society Fort Cumberland Fort Cumberland Road Portsmouth PO4 9LD	Y	1, 5, 7, 8, 9, 10

		Tel: 023 9281 8419 Email: mark@nasportsmouth.org.uk www.nasportsmouth.org.uk		
West Sussex local government archaeological offices	Mark Taylor	West Sussex County Council, County Hall, West Street, Chichester, West Sussex, PO19 1RQ mark.taylor@westsussex.gov.uk Tel: 01243 756858 www.westsussex.gov.uk	N, due to time constraints	1, 5, 7, 8, 9
East Sussex local government archaeological offices	Casper Johnson, County Archaeologist	Environment Group County Hall St Anne's Crescent Lewes East Sussex BN7 1SG Tel: 01273 481608 Email: www.eastsussex.gov.uk	N, due to time constraints	1, 5, 7, 8, 9
Sussex Archaeological Society (Sussex Past)	?Lynn Gayford, Education & Outreach Officer	Barbican House & Lewes Castle, 169 High Street, Lewes, BN7 1YE educ@sussexpast.co.uk http://www.sussexpast.co.uk	N, due to time constraints	1, 5, 7, 8, 9
Marine Ecological Monitoring and Conservation				
Natural England SE Region, E & W Sussex (NE)	Jon Curson	Natural England, Phoenix House, 32-33 North Street, Lewes, East Sussex, BN7 2PH Tel: 01273 476595/407944 Email: jon.curson@naturalengland.org.uk	Attempted but no response.	1, 2, 3, 4, 6, 8, 9
Centre for Environment, Fisheries and Aquaculture Science (CEFAS)	Keith Cooper	Lowestoft Laboratory, Pakefield Road Lowestoft Suffolk NR33 0HT Tel: 01502 562244	Y	1, 2, 3, 4, 7, 8, 9
Joint Nature Conservation Committee (JNCC)	Annabelle Aish (Marine Habitats Advisor)	JNCC Monkstone House City Road, Peterborough PE1 1JY Tel:01733 866837/562626 Email: Annabelle.Aish@jncc.gov.uk	Y	3, 4, 8, 9

East Sussex County Council (ESCC)	Dr Kate Cole, Biodiversity Officer	Transport & Environment, County Hall, St Anne's Crescent, Lewes, E. Sussex BN7 1UE Tel: 01273 481677 kate.cole@eastsussex.gov.uk www.eastsussex.gov.uk/environment/conservation/coastaldiversity	Y	1, 3, 4, 6, 7, 8, 9, 10
Hampshire Wildlife Trust (HWT)	Vicky Swales Jolyon Chesworth	Head Office Beechcroft House, Vicarage Lane, Curdridge, Hampshire SO32 2DP Tel: 01489 774400 Email: JolyonC@hwt.org.uk www. hwt.org.uk	Y	1, 3, 4, 6, 7, 8, 9, 10
Sussex Seasearch	Dr Kate Cole	Transport & Environment, County Hall, St Anne's Crescent, Lewes, E. Sussex BN7 1UE Tel: 01273 481677 kate.cole@eastsussex.gov.uk www.eastsussex.gov.uk/environment/conservation/coastaldiversity	Y	1, 3, 4, 6, 7, 8, 9, 10
Booth Museum of Natural History	Dr Gerald Legg	194 Dyke Road Brighton East Sussex United Kingdom BN1 5AA Tel: 01273 292781 Email: Gerald.Legg@brighton-hove.gov.uk www.booth.virtualmuseum.info/	Y	1, 3, 4, 6, 7, 8, 9, 10
Hampshire & Isle of Wight Seasearch	Vicky Swales Jolyon Chesworth	Hampshire Wildlife Trust Head Office Beechcroft House, Vicarage Lane, Curdridge, Hampshire SO32 2DP Tel: 01489 774400	Y	1, 3, 4, 6, 7, 8, 9, 10

		Email: JolyonC@hwt.org.uk www. hwt.org.uk		
National Marine Aquarium, Plymouth	Deborah Snelling, Scientific Officer	National Marine Aquarium Rope Walk Coxside Plymouth Devon PL4 0LF UK Tel: 01752 600301 (ext 212) Email: deborah.snelling@national-aquarium.co.uk> *www.national-aquarium.co.uk*	Y	1, 3, 4, 6, 7, 8, 9
Other sea-users (local)				
Sussex Sea Fisheries District Committee (SSFC)	Rob Clark, Scientific Officer	Unit 6 Highdown House Shoreham Airport Shoreham-by-Sea West Sussex BN43 5PB Tel. 01273 454407 Email: admin@sussex-sfc.gov.uk www.sussex-sfc.gov.uk	Y	1, 3, 4, 8, 9
Dive Connection Dive Charter		www.tdc-dive.co.uk	N – info obtained via Hampshire and Isle of Wight Wildlife Trust	8, 9, 10
Wreck licensees/adoptees/nominated archaeologists				
Holland V Licensee Nominated Archaeologist	 Innes McCartney Mark Beattie-Edwards	 innes@periscopepublishing.com mark@nasportsmouth.org.uk	 Attempted but no response. Y	1, 5, 7, 8, 9, 10
Norman's Bay Licensee Nominated Archaeologist	 Paul Stratford Adrian Barak	 strats@resolutionproject.co.uk abarak@freezone.co.uk	 Y Attempted but no response	1, 5, 7, 8, 9, 10
Portland Stone	None	-	-	-

Bottle Wreck	None	-	-	-
General scientific community				
Western Australia Maritime Museum. Maritime Archaeology Dept.	Jeremy Green Head of Maritime Archaeology Susan Cox Contact for science and culture	Susan.cox@museum.wa.gov.au	Attempted but no response	3, 4, 5, 7, 8, 9
Northwestern Hawaiian Islands MultiAgency Education Project (NOWRAMP) & Maritime Heritage, NOAA	Dr. Hans Van Tilburg, Maritime Heritage Coordinator	www.hawaiianatolls.org/research/NOWRAMP2002/features/ship_ecol.php	Y	1, 3, 4, 5, 7, 8, 9
ERT Scotland Ltd	Dr Iain Dixon – Senior Environmental Consultant	Research Park South Heriot-Watt University EDINBURGH EH14 4AP Tel: 0131 449 5030 Email: iain.dixon@ert.co.uk www.ert.co.uk	Y	1, 8, 9
University of Ulster. 1.Centre for Maritime Archaeology, Environmental Sciences Research Institute School of Environmental Sciences 2. Coastal and Marine Research Group, School of Environmental Sciences	1.Rory Quinn 2.Dr Andrew Cooper	University of Ulster Coleraine Co. Derry BT52 1SA Northern Ireland Email: (1) rj.quinn@ulster.ac.uk (2) jag.cooper@ulster.ac.uk (1)www.science.ulster.ac.uk/cma/ (2)www.science.ulster.ac.uk/ccmr/cmr/	Y	1, 3, 5, 7, 8, 9
SULA Diving	Robert Forbes	SULA Diving Old Academy Back Road STROMNESS KW16 3AN 01856 850285 bobby@suladiving.com	Y	1, 6, 7, 8, 9
Scientific Diving Supervisory Committee (SDSC)	Robert Forbes	SULA Diving Old Academy Back Road	Y	7, 8

		STROMNESS KW16 3AN 01856 850285 bobby.forbes@uk-sdsc.com www.uk-sdsc.com/		
The National Oceanographic Centre (NOC)	1. Dave Lambkin, Postdoctoral Research Fellow 2. Justin Dix,	National Oceanography Center, Southampton, European Way, Southampton. U.K. SO14 3ZH. 1. School of Ocean and Earth Science, Tel: 023 80596499 Email: D.O.Lambkin@noc.soton.ac.uk 2. Tel: (0) 23 80593057 Email: jkd@noc.soton.ac.uk www.noc.soton.ac.uk	Y	1, 2, 3, 7, 8, 9
ABPMer	Ray Drabble, Senior Environmental Consultant.		Y	1, 3, 4, 8, 9
General diving public				
Marine Quest Dive Charter (specialising in wreck diving)	Iain Easingwood	'The Harbourside' 33 Harbour Road Eyemouth, Berwickshire Scotland, TD14 5HY Tel: 01890 752444 Email: info@marinequest.co.uk. www.marinequest.co.uk	Y	8, 9, 10

APPENDIX B: WRECK SITE SUMMARY

Wreck site	Position	Designations		Description	Nearest Aggregate Extraction Area(s)	Available-Data Acquisition History
		Heritage	Nature Conservation			
Holland V	Bow 50°41.649N 000°30.896E Stern 50°41.653N 000°30.882E	PWA 1973	None	Metal. Structure exposed. 31m.	366-370, Hastings Shingle Bank	*2000 – photographic dive (Innes McCartney, wreck licensee) 2000 – geophysical survey (ADU) 2001 – geophysical survey (ADU) 2005 – multibeam survey (ADU, ALSF contract), 2005 - diver recorder training (NAS led group), *2005 - level 2a & 3a diving investigation (WA PWA 1973) 2006 – diving investigation (NAS led group) 2007 – diving investigation (NAS led group) *2007 – level 3a diving investigation (WA, PWA 1973)
Norman's Bay	Site 50°48.1767N 000°24.6380E	PWA 1973	None	Wood. Structure buried but with components exposed. 7-14m.	366-370, Hastings Shingle Bank	*2005 – level 2a diving investigation (WA, PWA 1973) *2006 – level 3a diving investigation (WA, PWA 1973) *2007 – level 3a diving investigation (WA, PWA 1973)
Bottle Wreck (*Wrecks on the Seabed* site #5013)	Site 50°40.919N 000°36.557W	None	None	Wood. Structure buried but cargo exposed. 20m.	396/1 & 435/1, Owers Bank	2002 – geophysical survey (WA, ALSFR1) 2003 – geophysical survey (WA, ALSFR1) *2003 – level ? diving investigation (WA, ALSFR1) *2005 – ROV survey (WA, ALSFR2) *2005 – level 3b diving investigation (WA, ALSFR2)
Portland Stone (*Wrecks on the Seabed* site #5011)	Site 50°42.874N 000°41.135W	None	None	Wood. Structure buried but cargo exposed. 8m.	396/1 & 435/1, Owers Bank	2002 – geophysical survey (WA, ALSFR1) *2002 – level ? diving investigation (WA, ALSFR1) 2003 – geophysical survey (WA, ALSFR1) *2003 – level ? diving investigation (WA, ALSFR1) *2005 – level ? diving investigation (WA,?ALSFR2) *2005 – ROV survey (WA, ALSFR2)
HMS *Northcoates*	Site 50°39.71N 000°35.40W	None	sMNCI	SMNCI, metal wreck, structure exposed, 26m	Areas 396/1 and 435/1, Owers Bank	Site surveyed by Seasearch divers – do data available
City of Waterford	Site 50°40.57N 000°06.69W	None	sMNCI	SMNCI, metal wreck, structure exposed, 30m	Areas 122/1 A&B, 123 A&B, and 124/1 A&B, Owers Bank	Site surveyed by Seasearch divers – do data available

Outer Mulberry	Site 50°44.76N 000°42.18W	None	sMNCI	SMNCI, concrete structure, exposed, 9m	Areas 396/1 and 435/1, Owers Bank	Site surveyed by Seasearch divers – do data available

* denotes archaeological site survey from which video and stills image data was acquired and used for review in current study.

Key: ADU (Archaeological Diving Unit, University of St Andrews)
WA (Wessex Archaeology)
NAS (Nautical Archaeological Society, Portsmouth)
PWA 1973 (Contract for Archaeological Services in Support of The Protection of Wrecks Act 1973)
ALSFR1 (Aggregates Levy Sustainability Fund Round 1 Contract: *Wrecks on the Seabed*)
ALSFR2 (Aggregates Levy Sustainability Fund Round 2 Contract: *Wreck on the Seabed*)
? = No data

APPENDIX C: SUMMARY OF ARCHAEOLOGICAL SURVEY EFFORT FOR EACH WRECK SITE

Wreck Site	No. of days diving (incl. ROV)	No. of archaeological dives (total bottom time in mins)	Total amount of video footage acquired (mins)	Total no. of stills images acquired	Species/habitat data acquired?
Holland V	*2001 – photographic dive (Innes McCartney) - 1 2005 - level 2a & 3a diving investigation (WA PWA contract) - 6 2007 – level 3a diving investigation (WA, PWA contract) - 4	2001 – no data PWA 2005 – 11 (307) PWA 2007 – 4 (95)	2001 - 0 PWA 2005 - 307 PWA 2007 - 95	IM 2001 - 8 PWA 2005 - 259 PWA 2007 - 127	IM 2001 - none PWA 2005 - limited PWA 2007 – limited Seasearch – 1 dive
Norman's Bay	PWA 2005 - 8 PWA 2006 - 5 PWA 2007 - 15	PWA 2005 – 10 (589) PWA 2006 – 11 (664) PWA 2007 - 22 (1446)	PWA 2005 - 589 PWA 2006 - 664 PWA 2007 - 1446	PWA 2005 - 39 PWA 2006 - 120 PWA 2007 - 79	PWA 2005 - limited PWA 2006 - limited PWA 2007 - limited Seasearch - none
Bottle Wreck (Wrecks on the seabed site # 5013)	ALSF R1 2003 - 1 ALSF R2 2005 (incl. ROV) – 9 (incl. 1 ROV)	ALSF R1 2003 – 1 (26) ALSF R2 2005 (incl. ROV) – 31 (1365)	ALSF R1 2003 - 26 ALSF R2 2005 (incl. ROV) – 1365	ALSF R1 2003 – no data ALSF R2 2005 (incl. ROV) - 181	ALSF R1 2003 - limited ALSF R2 2005 (incl. ROV) - limited Seasearch - none
Portland Stone (Wrecks on the seabed site # 5011)	ALSFR1 2002 – 6 ALSF R1 2003 - 6 ALSF R2 2005 (incl. ROV) – no data available	ALSFR1 2002 – 3 ALSF R1 2003 – 10 (~500) ALSF R2 2005 (incl. ROV) – no data	ALSFR1 2002 – no data ALSF R1 2003 – ~500 ALSF R2 2005 (incl. ROV) – no data	ALSFR1 2002 – no data ALSF R1 2003 – 0 (video only) ALSF R2 2005 (incl. ROV) – no data	ALSFR1 2002 - limited ALSF R1 2003 - limited ALSF R2 2005 (incl. ROV) – none Seasearch - none

No data = not possible to determine from the field logs and associated files within the time constraints of the current study.

APPENDIX D: SPECIES AND HABITAT DATA: *HOLLAND V*

Wreck	*Holland V*	*Holland V*	*Holland V*	*Holland V*	*Holland V*	*Holland V*	*Holland V*
Year	2001	2001	2001	2001	2001	2001	2001
Zone	Main wreck	Main wreck	Main wreck	Main wreck	Main wreck	Main wreck	Main wreck
Zone features	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Image location (waypoint OR in relation to wreck features) with a view for future relocation	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dive No.	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Frame No.	0	1	2	3	4	5	6
No. of habitats present for feature	1						
Habitat # (1/1 = 1 of 1)	1/1	1/1	1/1	1/1	1/1	1/1	1/1
Habitat (physical characteristics)	Metal wreck structure with variable relief including protruding features, vertical and horizontal faces. Horizontal faces with layer of sediment/silt.	Metal wreck structure with variable relief including protruding features, vertical and horizontal faces. Horizontal faces with layer of sediment/silt.	Metal wreck structure with variable relief including protruding features, vertical and horizontal faces. Horizontal faces with layer of sediment/silt.	Metal wreck structure with variable relief including protruding features, vertical and horizontal faces. Horizontal faces with layer of sediment/silt.	Metal wreck structure with variable relief including protruding features, vertical and horizontal faces. Horizontal faces with layer of sediment/silt.	Metal wreck structure with variable relief including protruding features, vertical and horizontal faces. Horizontal faces with layer of sediment/silt.	Metal wreck structure with variable relief including protruding features, vertical and horizontal faces. Horizontal faces with layer of sediment/silt.
Habitat (characterising taxa)	Dense robust hydroid turf	Dense robust hydroid turf	Dense robust hydroid turf	Dense robust hydroid turf	Dense robust hydroid turf	Dense robust hydroid turf	Dense robust hydroid turf

Taxa	Indication of biogenic impacts	Abundance (SACFOR/P)						
PORIFERA								
Porifera spp. indet	**Biofouling**							
CNIDARIA								
Alcyonium digitatum	**Biofouling**							
Actinothoe sphyrodeta	**Biofouling**							
Hydroid spp. indet (robust)	**Biofouling**	S	S	S	S	S	S	S
Hydroid spp. indet (fine)	**Biofouling**							
Nemertesia antennina	**Biofouling**							
Tubularia indivisa	**Biofouling**	P	P	P	P	P	P	P
Urticina Sp. indet	**Biofouling**							
ANNELIDA								
Pomatoceros Spp. indet	**Accretion**							
Sabellaria spinulosa	**Accretion**							

CRUSTACEA								
?Atelecyclus rotundus	**Bioturbation**							
Cirripedia Spp. indet. empty shells	**Biofouling**							
?Cancer pagurus	**Bioturbation**							
Homarus gammarus	**Bioturbation**							
Necora puber	**?Bioturbation**							
Pagurus Sp. indet								
BRYOZOA								
Bryozoa spp. indet. (turf)	**Biofouling**							
Bryozoa spp. indet (crust)	**Biofouling**							
?Crisia/Cellaria Sp. indet (stills/video not clear enough)	**Biofouling**							
Flustra foliacea	**Biofouling**							
TUNICATA								

Ascidiacea Spp. indet (colonial)	**Biofouling**							
Ascidiacea Spp. indet (solitary)	**Biofouling**							
PISCES								
Parablennius gattorugine								
Dogfish/Smooth hound egg case								
Biotope (or rock equivalent if biotope recorded on wreck feature)		CR.HCR.FaT.CTub and/or CR.HCR.XFa and/or CR.MCR.CSab.Sspi.Byb	CR.HCR.FaT.CTub and/or CR.HCR.Xfa and/or CR.MCR.CSab.Sspi.Byb	CR.HCR.FaT.CTub and/or CR.HCR.Xfa and/or CR.MCR.CSab.Sspi.Byb	CR.HCR.FaT.CTub and/or CR.HCR.Xfa and/or CR.MCR.CSab.Sspi.Byb	CR.HCR.FaT.CTub and/or CR.HCR.Xfa and/or CR.MCR.CSab.Sspi.Byb	CR.HCR.FaT.CTub and/or CR.HCR.Xfa and/or CR.MCR.CSab.Sspi.Byb	CR.HCR.FaT.CTub and/or CR.HCR.Xfa and/or CR.MCR.CSab.Sspi.Byb

Year	2001	2001	2005	2005	2005	2005	2005
Zone	Main wreck	Main wreck	Wreck	Wreck	Wreck	Wreck	Wreck
Zone features	N/A	N/A	Bow Cap (H&V faces)	Bow Cap (H&V faces)	Conning Tower (H only)	Conning Tower (V face)	Exhaust system hatch (H face)
Image location (waypoint OR in relation to wreck features) with a view for future relocation	N/A	N/A	Bow Cap	Bow Cap	Conning tower	Conning tower	Exhaust system hatch

	Dive No.	N/A	N/A	395x	399	392x	395x	395x
	Frame No.	7	8	5139	5171&5172	5032	5130	5121
	No. of habitats present for feature			1	1		1	1
	Habitat # (1/1 = 1 of 1)	1/1	1/1	1/1	1/1		1/1	1/1
	Habitat (physical characteristics)	Metal wreck structure with variable relief including protruding features, vertical and horizontal faces. Horizontal faces with layer of sediment/silt.	Metal wreck structure with variable relief including protruding features, vertical and horizontal faces. Horizontal faces with layer of sediment/silt.	Protruding metal wreck feature	Protruding metal wreck feature. Some silt accumulation apparent.	Protruding metal wreck feature with covering of rope/net.	Protruding metal wreck feature with covering of rope/net.	Protruding metal wreck feature with covering of rope/net. Covering of sediment.
	Habitat (characterising taxa)	Dense robust hydroid turf	Dense robust hydroid turf	Dense hydroid turf (& possibly bryozoa turf?)	Dense hydroid turf (& possibly bryozoa turf?)	Thin, patchy crust of Sabellaria spinulosa		Thin, patchy crust of Sabellaria spinulosa and moderately dense turf of robust hydroids
Taxa	**Indication of biogenic impacts**							
PORIFERA								
Porifera spp. indet	**Biofouling**			P	P		O	
CNIDARIA								
Alcyonium digitatum	**Biofouling**							
Actinothoe sphyrodeta	**Biofouling**							
Hydroid spp. indet	**Biofouling**	S	S	P (Loc. S on V	P (Loc. S on V		Loc. A on V	C

(robust)				faces)	faces)		face	
Hydroid spp. indet (fine)	**Biofouling**					P	P	P
Nemertesia antennina	**Biofouling**							
Tubularia indivisa	**Biofouling**	P	P				P	C
Urticina Sp. indet	**Biofouling**							
ANNELIDA								
Pomatoceros Spp. indet	**Accretion**			C		P	C	F
Sabellaria spinulosa	**Accretion**					?C	P	C
CRUSTACEA								
?Atelecyclus rotundus	**Bioturbation**			P				
Cirripedia Spp. indet. empty shells	**Biofouling**					P	P	
?Cancer pagurus	**Bioturbation**			P				
Homarus gammarus	**Bioturbation**							
Necora puber	**?Bioturbation**							
Pagurus Sp. indet						P		C
BRYOZOA								
Bryozoa spp. indet. (turf)	**Biofouling**			?P	?P			
Bryozoa spp. indet (crust)	**Biofouling**							
?Crisia/Cellaria Sp. indet (stills/video not clear enough)	**Biofouling**							R
Flustra foliacea	**Biofouling**							
TUNICATA								
Ascidiacea Spp. indet (colonial)	**Biofouling**							
Ascidiacea Spp. indet (solitary)	**Biofouling**							
PISCES								
Parablennius gattorugine								

Dogfish/Smooth hound egg case								
Biotope (or rock equivalent if biotope recorded on wreck feature)		CR.HCR.FaT.CTub and/or CR.HCR.Xfa and/or CR.MCR.CSab.Sspi.Byb	CR.HCR.FaT.CTub and/or CR.HCR.Xfa and/or CR.MCR.CSab.Sspi.Byb	CR.HCR.FaT.CTub	CR.HCR.FaT.CTub	CR.MCR.CSab.Sspi.Byb	CR.HCR.FaT.CTub and CR.MCR.CSab.Sspi.Byb	CR.HCR.FaT.CTub and CR.MCR.CSab.Sspi.Byb

Year	2005	2005	2005	2005	2005	2005	2005
Zone	Wreck	Wreck	Wreck	Wreck	Surrounding seabed	Surrounding seabed	Surrounding seabed
Zone features	Hole in pressure hull (V face)	Propeller and stern (V faces)	Propeller and stern (V faces)	port side stern vertical face and overhang near seabed	Stern stbd	Stern stbd	Bow stbd
Image location (waypoint OR in relation to wreck features) with a view for future relocation	Stern port side	Stern	Stern	Stern port side	No data	No data	No data
Dive No.	395x	395x	395x	393	392x	392x	392x
Frame No.	5155	5153	5150	1 (0:09:00-0:10:00)	5086	5086	5054
No. of habitats present for feature	1	1	1	1	2	2	2
Habitat # (1/1 = 1 of 1)	1/1	1/1	1/1	1/1	1/2	2/2	1/2

	Habitat (physical characteristics)	Vertical face on portside wreck with hole. Some silt accumulation apparent.	Vertical faces on propeller and stern.	Vertical faces on propeller and stern	Vertical face and overhang on main wreck near seabed	Silty medium sand with small ripples and fine shell debris	Occasional cobbles and small boulders on sand.	Silty medium sand with small ripples and fine shell debris
	Habitat (characterising taxa)	Dense cover (>90%) of mixed hydroid and bryozoan turf with sponges and ?ascidians	Dense cover (>90%) of mixed hydroid and bryozoan turf with sponges and ?ascidians	Dense cover (>90%) of mixed hydroid and bryozoan turf with sponges and ?ascidians	Dense cover (>70%) of hydroid (?& bryozoan) turf	No conspicuous biota on sand.	Mixed hydroids, bryozoans and anthozoans on cobbles	No conspicuous biota on substrate
Taxa	**Indication of biogenic impacts**							
PORIFERA								
Porifera spp. indet	**Biofouling**	F	P	F				
CNIDARIA								
Alcyonium digitatum	**Biofouling**						Loc. P on cobbles	
Actinothoe sphyrodeta	**Biofouling**						Loc. P on cobbles	
Hydroid spp. indet (robust)	**Biofouling**	A	S	S			Loc. P on cobbles	
Hydroid spp. indet (fine)	**Biofouling**	P	P	P			Loc. P on cobbles	
Nemertesia antennina	**Biofouling**		R					
Tubularia indivisa	**Biofouling**	P	S	S				
Urticina Sp. indet	**Biofouling**							
ANNELIDA								
Pomatoceros Spp. indet	**Accretion**		C	C				
Sabellaria spinulosa	**Accretion**	?P						
CRUSTACEA								

?Atelecyclus rotundus	**Bioturbation**							
Cirripedia Spp. indet. empty shells	**Biofouling**							
?Cancer pagurus	**Bioturbation**							
Homarus gammarus	**Bioturbation**							
Necora puber	**?Bioturbation**							
Pagurus Sp. indet								
BRYOZOA								
Bryozoa spp. indet. (turf)	**Biofouling**	P	P	P			Loc. P on cobbles	
Bryozoa spp. indet (crust)	**Biofouling**							
?Crisia/Cellaria Sp. indet (stills/video not clear enough)	**Biofouling**						Loc. P on cobbles	
Flustra foliacea	**Biofouling**							
TUNICATA								
Ascidiacea Spp. indet (colonial)	**Biofouling**							
Ascidiacea Spp. indet (solitary)	**Biofouling**	?P	?P	?P				
PISCES								
Parablennius gattorugine				F				
Dogfish/Smooth hound egg case								
Biotope (or rock equivalent if biotope recorded on wreck feature)		CR.HCR.FaT.CTub	CR.HCR.FaT.CTub			?SS.SSA.CFiSa	CR.HCR.FaT.CTub	?SS.SSA.CFiSa

	Year	2005	2005	2005	2005	2005	2005	2005
	Zone	Surrounding seabed	Surrounding seabed	Surrounding seabed	Surrounding seabed	Surrounding seabed	Surrounding seabed	Seabed at base pf wreck
	Zone features	Bow stbd	(60m SW of wreck outwith area of scour)	(60m SW of wreck outwith area of scour)	(60m SW of wreck outwith area of scour)	(60m SW of wreck outwith area of scour)	between anomaly 1 and wreck	Ledge on stbd side
	Image location (waypoint OR in relation to wreck features) with a view for future relocation	No data	Anomaly 1	Anomaly 1	Anomaly 1	Anomaly 1	No data	No data
	Dive No.	392x	398	398	398	398	398	393
	Frame No.	5054	5163	5163	1 (0:16:40-0:20:30)	1 (0:14:10-0:16:00)	1 (0:16:40-0:20:30)	5092
	No. of habitats present for feature	2	2	2	2	2	1	1
	Habitat # (1/1 = 1 of 1)	2/2	1/2	2/2	1/2	2/2	1/1	1/1
	Habitat (physical characteristics)	Mixed sediment	Silty medium sand with small ripples and fine shell debris	Large boulder (1x1x1m) on sand. Some silt accumulation apparent.	Silty medium sand with small ripples and fine shell debris	Large boulder (1x1x1m) on sand. Some silt accumulation apparent.	Rippled silty sand with fine shell debris. Occassional ribbons of gravel.	Silty sand with possible underlying hard/compact substrate
	Habitat (characterising taxa)	No conspicuous biota on substrate	No conspicuous biota on sand.	Dense (>90%) mixed hydroid and bryozoan turf, and Sabellaria spinulosa (confirmed with video)	No conspicuous biota on sand.	Dense (>90%) mixed hydroid and bryozoan turf, and Sabellaria spinulosa	No conspicuous biota.	Dense mixed hydroid and bryozoan turf.
Taxa	**Indication of biogenic**							

	impacts							
PORIFERA								
Porifera spp. indet	**Biofouling**							
CNIDARIA								
Alcyonium digitatum	**Biofouling**					P		
Actinothoe sphyrodeta	**Biofouling**							
Hydroid spp. indet (robust)	**Biofouling**					P		Loc. S along ledge
Hydroid spp. indet (fine)	**Biofouling**							
Nemertesia antennina	**Biofouling**							
Tubularia indivisa	**Biofouling**							P
Urticina Sp. indet	**Biofouling**			Loc. F on boulder		F		
ANNELIDA								
Pomatoceros Spp. indet	**Accretion**							
Sabellaria spinulosa	**Accretion**			Loc. C-A on boulder		C-A		
CRUSTACEA								
?Atelecyclus rotundus	**Bioturbation**							
Cirripedia Spp. indet. empty shells	**Biofouling**							
?Cancer pagurus	**Bioturbation**							
Homarus gammarus	**Bioturbation**							
Necora puber	**?Bioturbation**							
Pagurus Sp. indet						P		
BRYOZOA								
Bryozoa spp. indet. (turf)	**Biofouling**							S
Bryozoa spp. indet (crust)	**Biofouling**							
?Crisia/Cellaria Sp. indet (stills/video not clear enough)	**Biofouling**			Loc. A on boulder		Crisia Sp. - P		P
Flustra foliacea	**Biofouling**			Loc. C on		P		

				boulder				
TUNICATA								
Ascidiacea Spp. indet (colonial)	**Biofouling**							
Ascidiacea Spp. indet (solitary)	**Biofouling**							
PISCES								
Parablennius gattorugine								
Dogfish/Smooth hound egg case						P		
Biotope (or rock equivalent if biotope recorded on wreck feature)		SS.SMX.CMx	?SS.SSA.CFiSa	CR.MCR.CSab.Sspi. Byb & CR.HCR.Xfa				CR.HCR.FaT.CTub

Year	2005	2005	2005	2005	2007	2007
Zone	Seabed at base of wreck	Seabed at base of wreck	Seabed at base of wreck	Seabed at base of wreck	Wreck	Wreck
Zone features	beneath stern (portside)	stbd side	stbd side	port side	Bow Cap	Hole in pressure hull (V face)
Image location (waypoint OR in relation to wreck features) with a view for future relocation	no data	No data	No data	No data	Bow Cap	
Dive No.	393	390	390	393	412	411
Frame No.	5104	1 (0:07:50-0:15:00)	1 (0:07:50-0:15:00)	1 (0:08:09-0:10:50)	0019	0009

	No. of habitats present for feature	1	2	2	1	1	1
	Habitat # (1/1 = 1 of 1)	1/1	1/2	2/2	1/1	1/1	1/1
	Habitat (physical characteristics)	Course mixed sediment of sand, pebbles and cobbles	Mixed silty sand, gravel, pebbles and cobbles	Rippled medium silty sand	Slightly sandy and silty, gravel, pebbles and cobbles	Protruding metal wreck feature. Silt accumulation apparent.	Vertical face on portside wreck with hole. Silt accumulation apparent.
	Habitat (characterising taxa)	Sparse barnacles and/or Pomatoceros Sp. and possible hydroid/brozoan 'fluff' on pebbles and cobbles. No other conspicuous benthos.	No conspicuous biota	No conspicuous biota	Sparse bryozoan/hydroid cover, sponges and colonial ascidians on stones (limited view of species)	Dense hydroid turf (& possibly bryozoa turf?) with sponges and Actinothoe sphyrodeta	Moderate cover of hydroids, Actinothoe sphyrodeta, Pomatoceros Sp. and few ?encrusting bryozoa.
Taxa	**Indication of biogenic impacts**						
PORIFERA							
Porifera spp. indet	Biofouling				P	P	
CNIDARIA							
Alcyonium digitatum	Biofouling						
Actinothoe sphyrodeta	Biofouling						A
Hydroid spp. indet (robust)	Biofouling					P (Loc. S on V faces)	F
Hydroid spp. indet (fine)	Biofouling	?P			P		
Nemertesia antennina	Biofouling						
Tubularia indivisa	Biofouling					P (Loc. S on V faces)	P

Urticina Sp. indet	Biofouling						
ANNELIDA							
Pomatoceros Spp. indet	Accretion	?P				P	C
Sabellaria spinulosa	Accretion						
CRUSTACEA							
?Atelecyclus rotundus	Bioturbation						
Cirripedia Spp. indet. empty shells	Biofouling	?P					
?Cancer pagurus	Bioturbation						
Homarus gammarus	Bioturbation				P		
Necora puber	?Bioturbation				P	P	P
Pagurus Sp. indet							
BRYOZOA							
Bryozoa spp. indet. (turf)	Biofouling	?P			P	?P	
Bryozoa spp. indet (crust)	Biofouling						?R
?Crisia/Cellaria Sp. indet (stills/video not clear enough)	Biofouling						
Flustra foliacea	Biofouling						
TUNICATA							
Ascidiacea Spp. indet (colonial)	Biofouling				P		
Ascidiacea Spp. indet (solitary)	Biofouling						
PISCES							
Parablennius gattorugine							
Dogfish/Smooth hound egg case							

Biotope (or rock equivalent if biotope recorded on wreck feature)		SS.SMX.CMx				CR.HCR.FaT.CTub	CR.HCR.FaT.CTub

APPENDIX E: SPECIES AND HABITAT DATA: NORMAN'S BAY

Wreck	Norman's Bay	Norman's Bay	Norman's Bay	Norman's Bay	Norman's Bay
Year	2005	2005	2005	2005	2006
Zone	No data	No data	No data	No data	No data
Zone features	Cannons, upright from seabed	Exposed ?brick artefacts lying on seabed	Cannons, upright from seabed	Cannons, upright from seabed	Unknown wreck artefacts lying on seabed
Image location (waypoint OR in relation to wreck features) with a view for future relocation	No data	No data	No data	No data	No data
Dive No.	404	404	404	404	1011
Frame No.	0010	0022	0035	0037	4012
No. of habitats present for feature	1	1	1	1	1
Habitat # (1/1 = 1 of 1)	1/1	1/1	1/1	1/1	1/1
Habitat (physical characteristics)	Cannon substrate with some silt accumulation	Seabed comprising of compact ?brick artefacts with a layer of sand/silt	Cannon substrate with some silt accumulation	Cannon substrate with some silt accumulation	Silty,wreck artefact on seabed of gravelly, shelly sand
Habitat (characterising taxa)	Dense mussels with robust hydroids.	Patchy mussels with occasional Asterias and ?Porifera sp	Dense mussels with robust hydroids.	Dense mussels with robust hydroids.	Robust hydroids

Taxa	**Indication of biogenic impacts**	**Abundance (SACFOR/P)**				
PORIFERA						
Porifera spp. indet	Biofouling		?P			?P
CNIDARIA						
Hydroid spp. indet (robust)	Biofouling			P	P	P
Nemertesia antennina	Biofouling	P				
Tubularia indivisa	Biofouling	P				P

ANNELIDA						
Pomatoceros Spp. indet	Accretion	P				P
CRUSTACEA						
Cirripedia spp. indet	Biofouling					
Homarus gammarus	Bioturbation					P
MOLLUSCA						
Mytilus edulis	Biofouling, ?corrosion	P	P	P	P	
ECHINODERMATA						
Asterias rubens	unknown	P				
Biotope (or rock equivalent if biotope recorded on wreck feature)		Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data

Year	2006	2006	2006	2006	2006
Zone	No data	No data	No data	No data	No data
Zone features	Unknown,prominent wreck feature	Exposed wooden artefact on seabed with some overlying sediment	Exposed brick artefact lying on seabed	Exposed brick artefact lying on seabed	Exposed lead ingot on seabed
Image location (waypoint OR in relation to wreck features) with a view for future relocation	No data	No data	No data	No data	No data
Dive No.	1011	1011	1011	1011	1011
Frame No.	4050	4058	4076	4099	4112
No. of habitats present for feature	1	1	1	1	1
Habitat # (1/1 = 1 of 1)	1/1	1/1	1/1	1/1	1/1

	Habitat (physical characteristics)	Unknown prominent wreck feature with some silt accumulation	Low lying wooden feature. Clean with little epibenthic growth. Patchy sand and gravel overlying	Low lying silty brick feature with few hydroids.	Low lying silted brick feature with few hydroids and Pomatoceros. Some gravel also overlying	Low lying lead artefact and other unknown hard substrate. Notable silt accumulation.
	Habitat (characterising taxa)	Dense Tubularia indivia and Asterias rubens	No obvious biota	Little biota obvious. Few hydroids.	Few robust hydroids and sparse Pomatoceros	Relatively dense Tubularia indivisa with few other robust hydroids. Barnacles present on lead surfaces.
Taxa	**Indication of biogenic impacts**					
PORIFERA						
Porifera spp. indet	Biofouling					
CNIDARIA						
Hydroid spp. indet (robust)	Biofouling			P		P
Nemertesia antennina	Biofouling				P	?P
Tubularia indivisa	Biofouling	P		P	P	P
ANNELIDA						
Pomatoceros Spp. indet	Accretion				P	
CRUSTACEA						
Cirripedia spp. indet	Biofouling					P
Homarus gammarus	Bioturbation					
MOLLUSCA						
Mytilus edulis	Biofouling, ?corrosion					
ECHINODERMATA						
Asterias rubens	unknown	P				

Biotope (or rock equivalent if biotope recorded on wreck feature)		Insufficient data Insufficient data	Insufficient data	Insufficient data	Insufficient data

APPENDIX F: SPECIES AND HABITAT DATA: BOTTLE WRECK

Wreck	Bottle wreck	Bottle wreck	Bottle wreck	Bottle wreck	Bottle wreck	Bottle wreck
Year	2005	2005	2005	2005	2005	2005
Zone	No data	No data	No data	No data	No data	No data
Zone features	Seabed with low lying wreck artefacts.	Seabed with low lying wreck artefacts.	Seabed with low lying wreck artefacts.	Seabed with low lying wreck artefacts.	Seabed with low lying wreck artefacts.	Seabed with low lying wreck artefacts.
Image location (waypoint OR in relation to wreck features) with a view for future relocation	No data	No data	No data	No data	No data	No data
Dive No.	101	103	103	106	109	109
Frame No.	10_31_01_25	17_00_45_20	17_00_45_21	17_23_02_10	13_56_50_04	14_10_06_21
No. of habitats present for feature	1	1	1	1	1	1
Habitat # (1/1 = 1 of 1)	1/1	1/1	1/1	1/1	1/1	1/1
Habitat (physical characteristics)	Seabed of sandy gravel with much shell (Crepidula) debris and occasional cobbles and pebbles. Low lying wreck artefacts present also.	Seabed of sandy gravel with much shell (Crepidula) debris and occasional pebbles. Low lying wreck artefacts present also.	Seabed of sandy gravel with much shell (Crepidula) debris and occasional pebbles. Low lying wreck artefacts present also.	Seabed of silty sandy gravel. Low lying wreck artefacts present.	Seabed of sandy, shelly gravel. Low lying wreck artefacts present.	Seabed of sandy, shelly gravel. Low lying wreck artefacts present.
Habitat (characterising taxa)	No obvious biota	Flustra foliacea and lowing ?bryozoan/hydroid turf on wreck artefacts. Drift algae present (not attached/living)	Hydroids, colonial ascidians, Pomatoceros and barnacles on wreck artefacts.	No obvious biota.	Sparse hydroid turf.	Sparse sponges and Flustra foliacea.

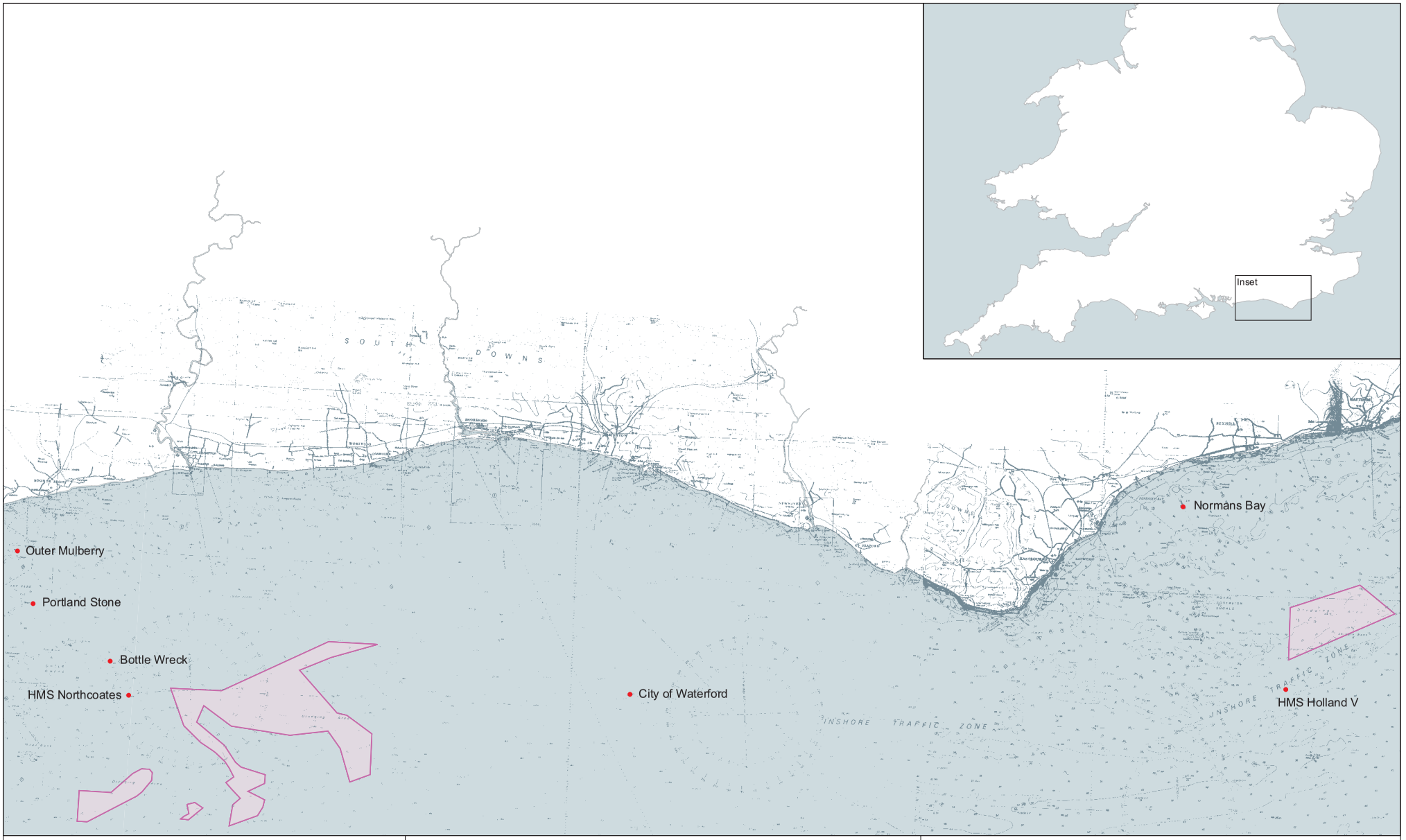
Taxa	Indication of biogenic impacts	Abundance (SACFOR/P)					
PORIFERA							
Porifera spp. indet	Biofouling						P
CNIDARIA							
Hydroid spp. indet (robust)	Biofouling		?P		?P	P	
Hydroid spp. indet (fine)	Biofouling			P			
Nemertesia antennina	Biofouling			P			
ANNELIDA							
Pomatoceros Spp. indet	Accretion			P			
CRUSTACEA							
Cirripedia Spp. indet.	Biofouling			P			
BRYOZOA							
Bryozoa spp. indet. (turf)	Biofouling		?P				
Flustra foliacea	Biofouling		P				P
TUNICATA							
Botryllus schlosseri	Biofouling			P			
Biotope (or rock equivalent if biotope recorded on wreck feature)		Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data

APPENDIX G: SPECIES AND HABITAT DATA: PORTLAND STONE WRECK

Wreck	Portland Stone	Portland Stone	Portland Stone	Portland Stone	Portland Stone
Year	2003	2003	2003	2003	2003
Zone	Main wreck	No data	No data	No data	No data
Zone features	Anchor	Exposed iron support with overlying sediments	Exposed, low lying wreck features with overlying sediments	Exposed, low lying wreck features with overlying sediments	Exposed, low lying wreck features with overlying sediments
Image location (waypoint OR in relation to wreck features) with a view for future relocation	No data	No data	No data	No data	No data
Dive No.	No data	11	9	6	6
Frame No.	Video footage - MPEG4 clips (no counter time)	Video footage - MPEG4 clips (no counter time)	Video footage - MPEG4 clips (no counter time)	Video footage - MPEG4 clips (no counter time)	Video footage - MPEG4 clips (no counter time)
No. of habitats present for feature	1	1	1	1	1
Habitat # (1/1 = 1 of 1)	1/1	1/1	1/1	1/1	1/1
Habitat (physical characteristics)	Ships anchor	Exposed iron support feature with mixed sand, gravel and shell overlying.	Exposed, low lying wreck features with overlying mixed gravel, pebbles, sand and shell debris.	Exposed iron support feature with mixed sand, gravel and shell overlying.	Exposed stove feature with mixed sand, gravel, pebbles and cobbles and shell overlying.
Habitat (characterising taxa)	Much of growth removed by divers to measure artefact. Species remaining noted below.	Foliose red algae and some Flustra. Little other obvious biota.	Foliose red algae. Little other obvious biota	Foliose red algae. Little other obvious biota	Foliose red algae. Little other obvious biota.

Taxa	**Indication of biogenic impacts**	**Abundance (SACFOR/P)**				
CNIDARIA						
Actinothoe sphyrodeta	Biofouling	P				
Alcyonium digitatum	Biofouling	P				
BRYOZOA						
Flustra foliacea	Biofouling	P	P			

RHODOPHYTA						
Filamentous red algae spp. indet.		P				
Foliose red algae spp. indet.			P	P	P	P
?Calliblepharis Sp. indet			P			
Biotope (or rock equivalent if biotope recorded on wreck feature)		Insufficient data	Insufficient data	Insufficient data	Insufficient data	Insufficient data
		Quality of video	Quality of video	Quality of video	Quality of video	Quality of video



Aggregate extraction areas

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Drawing in projection UTM Zone 31N

Date:	25/02/08	Revision Number:	0
Scale:	1:250,000	Illustrator:	KMN
Path:	W:\Projects\57456\DO\RepFigs\Ecology\08_02_25		

Site location

Figure 1

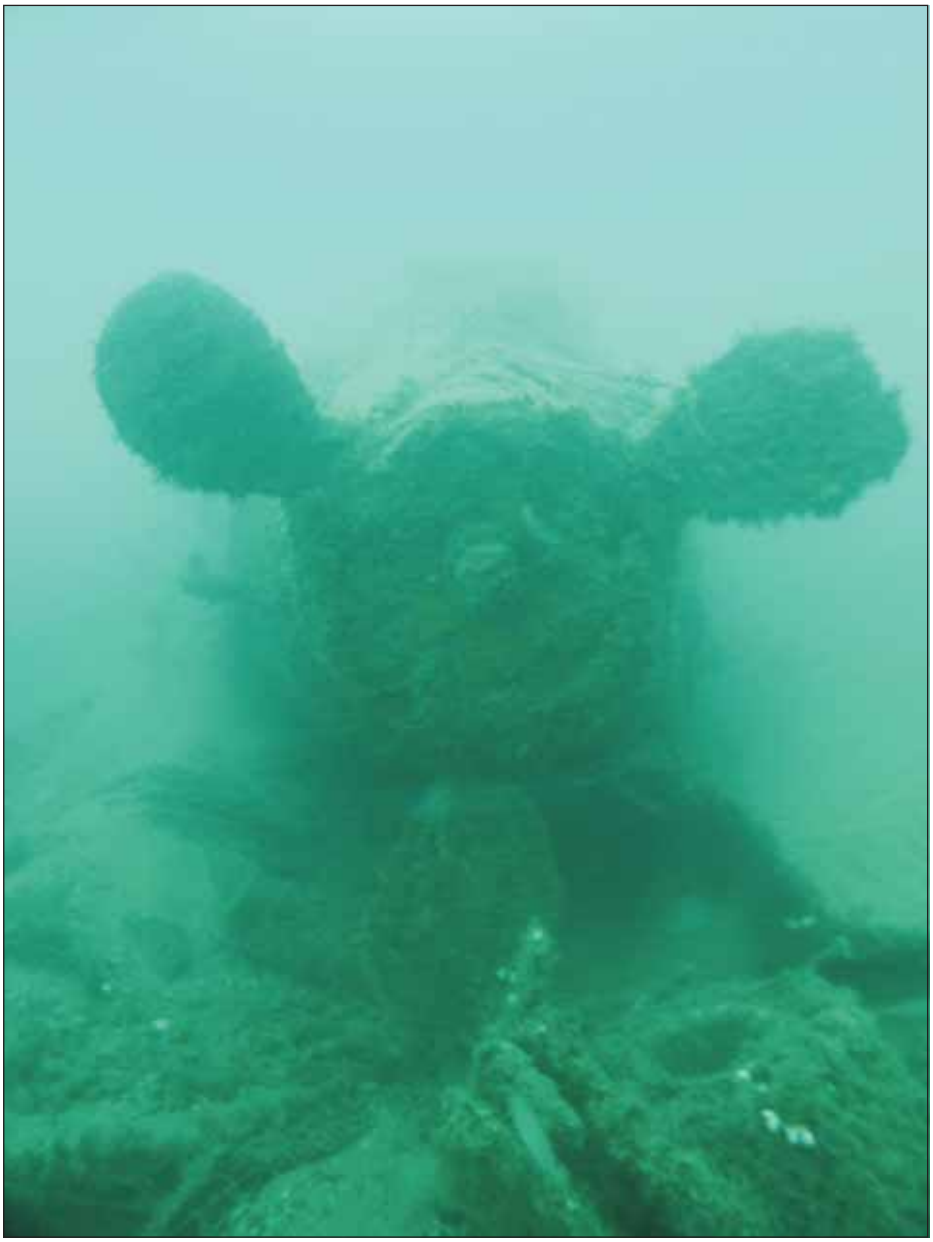

Plate 1: Example of stills images collected for archaeological purposes
(Holland V 2005 Dive 392x, frame no. 5009)

Date:	28/02/08	Revision Number:	0
Scale:	N/A	Illustrator:	KMN
Path:	W:\Projects\57456\DO\RepFigs\Ecology\08_02_25		

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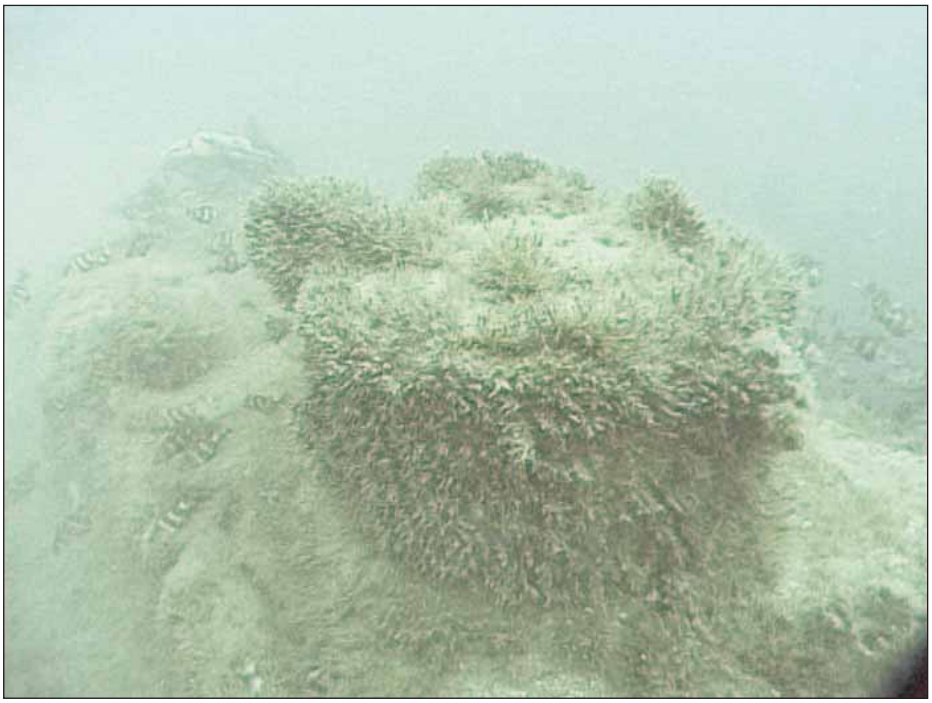

Plate 2a: Holland V: Main wreck structure, 2001
Conning tower (with horizontal surfaces also visible).

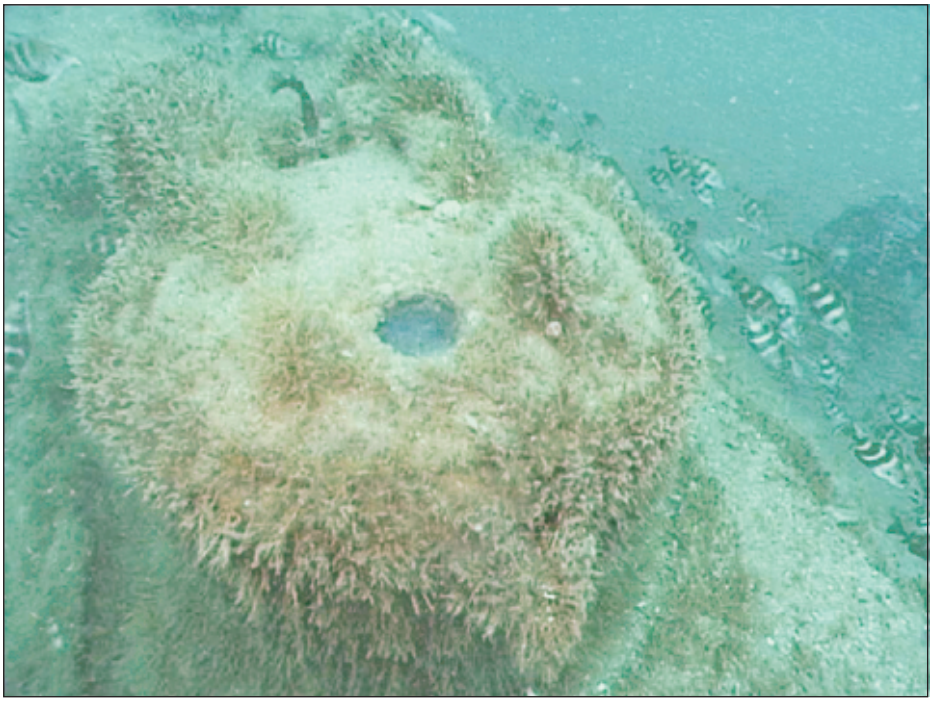

Plate 2b: Holland V: Main wreck structure, 2001
Conning tower (with horizontal surfaces also visible).

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Scale:	N/A	Illustrator:	KMN
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Plate 3: Holland V: Main wreck structure, 2001
Bow cap (with horizontal surfaces also visible).

Plate 4: Holland V: Main wreck structure, 2001
Propeller (showing vertical surfaces).

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Scale:	N/A	Illustrator:	KMN
Path:	W:\Projects\57456\DO\RepFigs\Ecology\08_02_25		

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Plate 5: Holland V: Main wreck structure, 2001
Horizontal and vertical surfaces (orientation: bow cap to stern).

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Plate 6a: Holland V:
Main wreck structure, 2005.
Bow cap

Plate 6b: Holland V: Main wreck structure, 2005. Bow cap (showing horizontal surfaces)

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Scale:	N/A	Illustrator:	KMN
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Plate 7a: Holland V:
Main wreck structure, 2005.
Conning tower (horizontal surfaces)

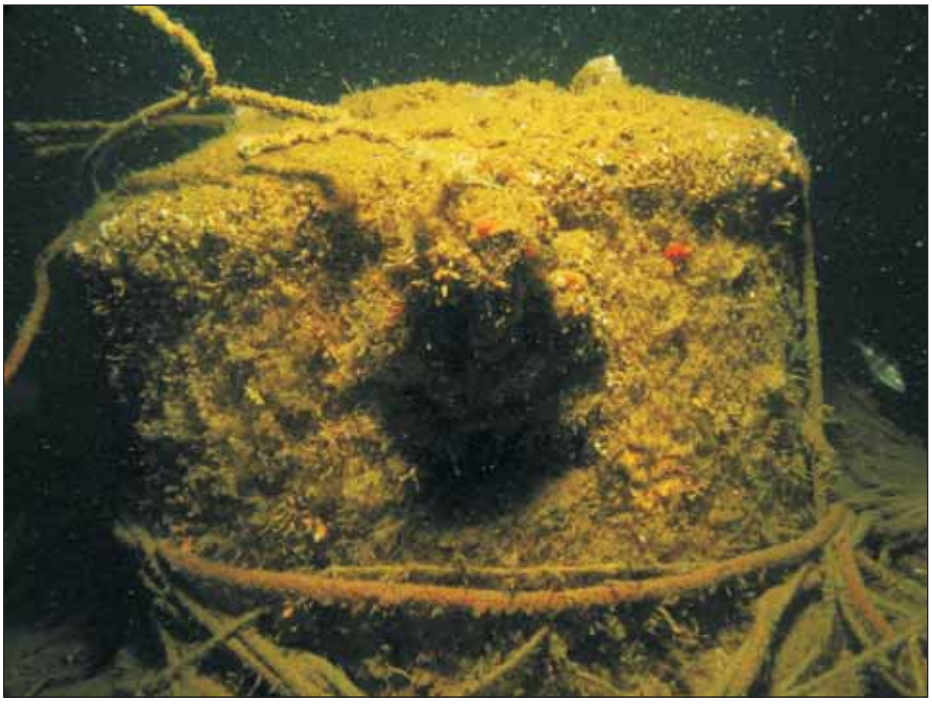

Plate 7b: Holland V: Main wreck structure, 2005. Conning tower (vertical surfaces)

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Plate 8: Holland V: Main wreck structure, 2005.
Exhaust system hatch (horizontal surface)

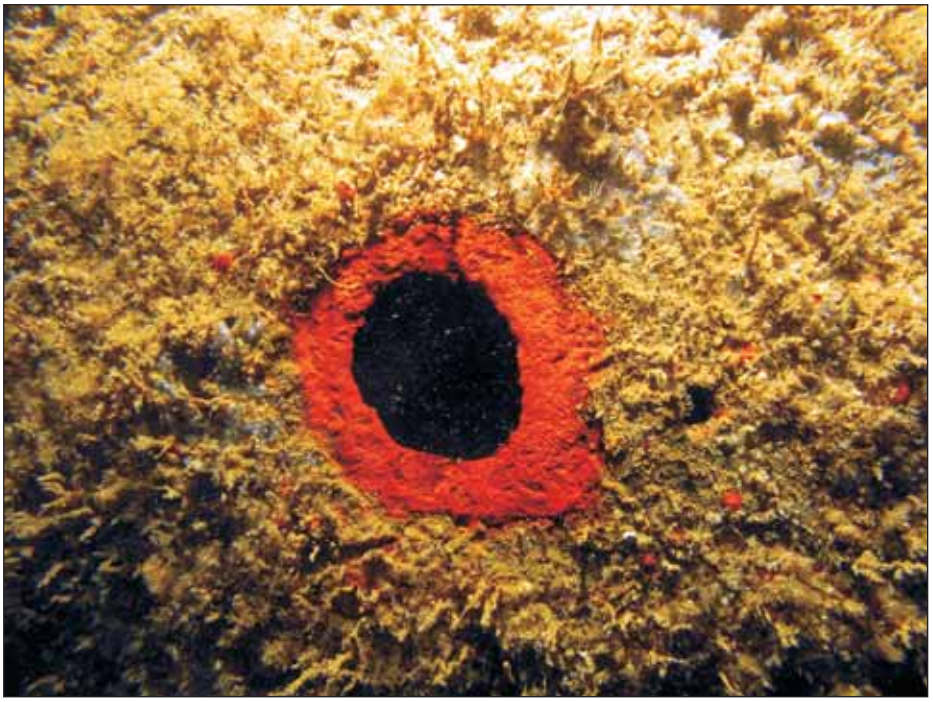

Plate 9: Holland V: Main wreck structure, 2005.
Hole in pressure port side hull (vertical surface)

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Plate 10: Holland V: Main wreck structure, 2005.
Propeller blade (vertical surface with horizontal surfaces also visible)

Plate 11: Holland V: Main wreck structure, 2005.
Propeller and stern (vertical surfaces)

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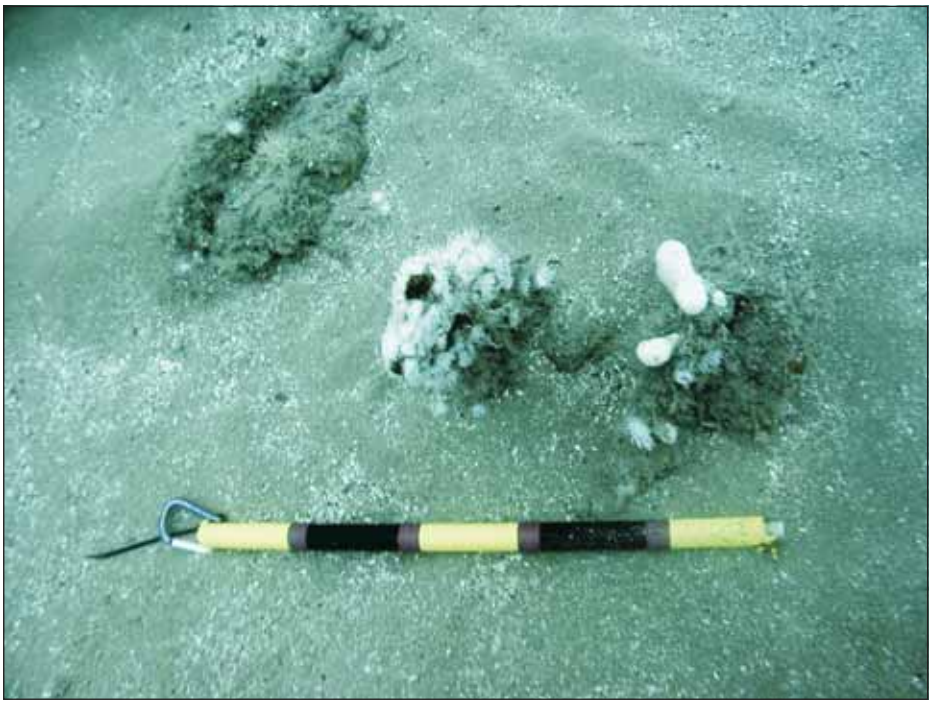

Plate 12: Holland V: Surrounding seabed within immediate proximity to wreck, 2005. Stern upstream

Plate 13: Holland V: Surrounding seabed within immediate proximity to wreck, 2005. Bow upstream

Date:	28/02/08	Revision Number:	0
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Plate 14: Holland V: Surrounding seabed within immediate proximity to wreck, 2005. Stern upstream

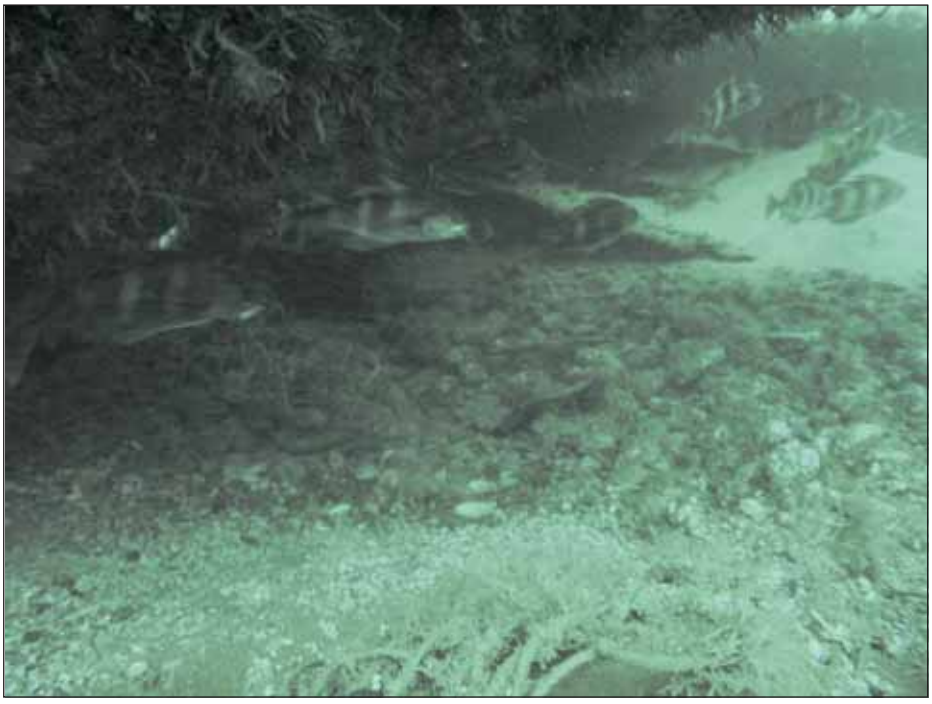

Plate 15: Holland V: Surrounding seabed within immediate proximity to wreck, 2005. Bow upstream

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Plate 16: Holland V: Seabed outwith influence of wreck, 2005.
Seabed substrates and boulder

Plate 17: Holland V: Main wreck structure, 2007.
Bow cap (horizontal surfaces visible)

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Plate 18: Holland V: Main wreck structure, 2007.
Hole in pressure port side hull (vertical surface)

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