MILFORD HAVEN WATERWAY
ENVIRONMENTAL SURVEILLANCE GROUP

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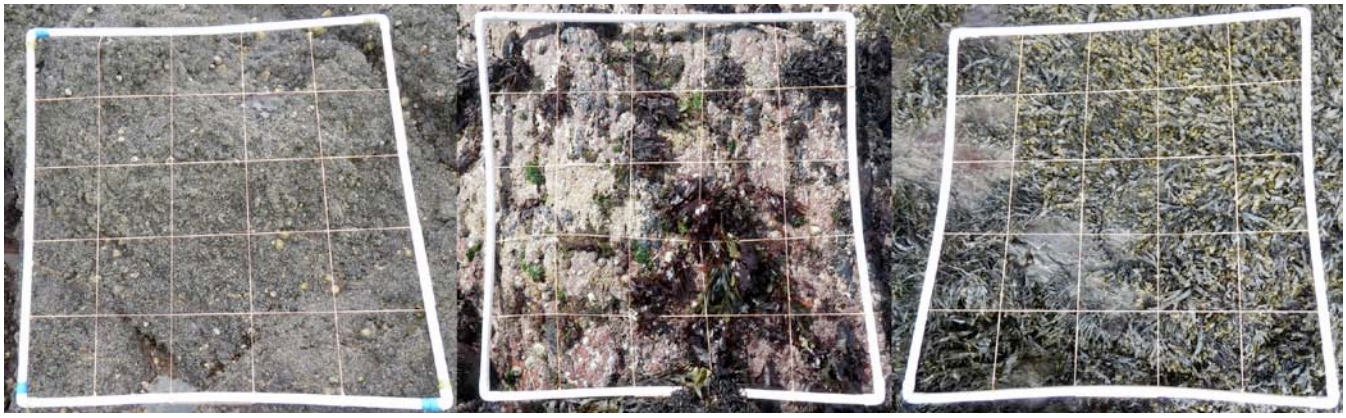

Business Report 2013

MILFORD HAVEN WATERWAY ENVIRONMENTAL SURVEILLANCE GROUP

BUSINESS REPORT 2013

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Valero Energy Ltd

Wildlife Trust West Wales (corresponding)

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COVER IMAGES

Front: rocky shore quadrats illustrating some of the range of communities present at the Milford Haven Waterway surveillance sites.

Rear: distribution of the invasive non-native slipper limpet *Crepidula fornicata* in Sediment Profile Imaging survey sample images.

Milford Haven Waterway Environmental Surveillance Group
Report 2013

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CHAIRMAN'S FOREWORD

On 4 July 2014 the BBC website revealed that research concerning African cichlid fish appears to demonstrate a memory that lasts 12 days as opposed to the 'few seconds' that has been so popularly believed for fish. This is a salutary reminder that there is much we do not know about the natural world which we inhabit.

One of the challenges to building our knowledge is gathering of data and whilst this is accelerating across the world the existence of particularly long data sets remains limited.

The Milford Haven Waterway Environmental Surveillance Group has been gathering information on the environmental status of the Waterway since it's inception in 1992.

I am delighted to introduce our 2013 report setting out the considerable achievements during the last year.

The Group's membership consists of representatives from both industry and the public sector working together to co-ordinate and optimise the ongoing monitoring that takes place daily by individual member organisations, with more extensive surveys commissioned by the Group itself.

The continued success of the Group is largely down to the commitment, enthusiasm and effort put in by our members over and above their day to day roles. Indeed member organisations can be rightly pleased as to the positive contributions their representatives make in optimising the work programme.

In Blaise Bullimore we have a dedicated and enthusiastic Project Officer who works tirelessly in support of the Group.

I am truly thankful and immensely proud to have worked with such a positive and talented team.

Captain Mark Andrews

Milford Haven Port Authority

Chairman

RHAGAIR Y CADEIRYDD

Ar 4 Gorffennaf 2014 roedd gwefan y BBC yn datgelu bod ymchwil i bysgod ciclid Affricanaidd yn awgrymu bod gallu ganddynt i gofio am hyd at 12 diwrnod, ac nid am 'ychydig eiliadau', fel y credid yn gyffredin am bysgod. Mae hyn yn rhybudd amserol i'n hatgoffa fod cymaint, o hyd, na wyddom am y byd naturiol o'n cwmpas.

Wrth geisio ehangu ein gwybodaeth, casglu data yw un o'r heriau a wynebwn; ac er bod y gwaith hwnnw'n cyflymu ledled y byd, mae setiau data sy'n ymestyn dros gyfnodau arbennig o hir yn parhau'n brin.

Mae Grŵp Goruchwylio Amgylcheddol Dyfrffordd Aberdaugleddau wedi bod yn casglu gwybodaeth am statws amgylcheddol y Ddyfrffordd er pan sefydlwyd y Grŵp ym 1992.

Pleser mawr i mi yw cyflwyno ein hadroddiad am 2013, sy'n nodi'r gwaith sylweddol y llwyddwyd i'w wneud yn ystod y flwyddyn ddiwethaf.

Mae aelodaeth y Grŵp yn cynnwys cynrychiolwyr o fyd diwydiant ac o'r sector cyhoeddus, yn cydweithio â'i gilydd i gydgysylltu a gwella'r monitro parhaus a gyflawnir yn ddyddiol gan ein haelod-sefydliadau unigol, ynghyd â'r arolygon ehangach a gomisiynir gan y Grŵp ei hunan.

Mae llwyddiant parhaus y Grŵp yn dibynnu'n helaeth ar ymroddiad, brwdfrydedd ac ymdrechion ein haelodau, dros ben a thu hwnt i'w swyddi beunyddiol. Yn wir, gall y cyrff sy'n aelodau fod yn hynod falch o gyfraniad eu cynrychiolwyr tuag at wella gwaith y rhaglen i'r eithaf.

Yn Blaise Bullimore ei hunan mae gennym Swyddog Prosiect ymroddedig a brwdfrydig sy'n gweithio'n ddiflino i gefnogi'r Grŵp.

Rwy'n wirioneddol ddiolchgar, ac yn falch aruthrol, o fod wedi cydweithio â thîm mor gadarnhaol a dawnus.

Y Capten Mark Andrews

Awdurdod Porthladd Aberdaugleddau

Cadeirydd

1. INTRODUCTION

This is the fourteenth business report of the Milford Haven Waterway Environmental Surveillance Group (formerly the Milford Haven Waterway Environmental Monitoring Steering Group). It covers the period January to December 2013.

As a change from the usual introduction, over the following five pages this report reproduces an article from the Autumn 2013 Porcupine Marine Natural History newsletter 'Milford Haven Waterway Environmental Surveillance Group: Twenty years of partnership surveillance' by the Group's project manager Blaise Bullimore. The article was based on presentations made to the March 2013 Porcupine annual conference and the Problems of Small Estuaries symposium at Swansea University and Field Studies Council Dale Fort marine research symposium both held in April 2013.

Milford Haven Waterway Environmental Surveillance Group: Twenty years of partnership surveillance

Blaise Bullimore

Milford Haven Waterway Environmental Surveillance Group (MHWESG) Project Manager

The drowned river valley - ria - of Milford Haven and the Cleddau estuaries was formed about 80,000 years ago as the sea rose and flooded deep channels created by glacial erosion during the last ice age maximum. It is the only ria in Wales and one of the most biologically diverse and important marine inlets in the UK, where marine wildlife penetrates deep inland in almost fully saline conditions but nearly completely sheltered from wave action.

Milford Haven has a long and distinguished history. Iron Age promontory forts are scattered on headlands at the entrance and along the course of the Haven and the Daugleddau. Several settlements bear names derived from Viking visitors. In his play *Cymbeline*, Shakespeare asks "how far it is to this same blessed Milford: and by the way tell me how Wales was made so happy as to inherit such a haven". Henry Tudor landed at Dale in 1485 before marching to defeat Richard III at the Battle of Bosworth. In his 1603 *The Description of Pembrokeshire*, George Owen claimed that Milford Haven was the most famous port of Christendom, and Nelson later described it as the next best natural harbour to Trincomalee in Sri Lanka and "the finest port in Christendom".

Human pressures in the Haven began long ago, most likely starting with fishing along the shores - Mesolithic tools believed to be limpet or shellfish scoops have been found near Dale - and late Bronze Age forest clearances for farming would have disturbed soils, causing erosion and flushing silt into the waterway.

Coal was exported from the 13th century and herring from the 14th; mine waters would have contaminated the Haven's sediments and water, and expanding fisheries moved exploitation from the shores into the waterway. Quays, jetties and landing places sprang up to serve the coal-mines and the large limestone quarries, claiming foreshore habitat and locally modifying sediment transport. The waterway was a hive of industry from the Medieval period, with saw-mills, paper mills, tanneries and limestone-burning on shores all contributing to the contaminant load; evidence of metal workings found during the construction of an LNG terminal in the late 2000s hints at a level of industrialization around 800AD[1].

The use of sheltered deep areas as anchorages from at least the 16th century would have caused localized seabed disturbance; steam pumping to de-water coal-mines in the 1800s increased the input of contaminants to waterway, and by 1830 silt accumulation at Havefordwest had limited access for trading vessels.

Major habitat losses began with the claiming of mudflats to build a naval dockyard in the 1820s and a ship-breaking yard contributed increasingly persistent pollutants between the 1880s and 1970s.

Many thousands of vessels and aircraft used the Haven during the second World War, and in August 1940 the bombing of the Navy's fuel oil storage depot at Pembroke Dock started the largest 'single-seat' fire in the UK's history. The estimated 132,000 tons of oil that burned was about ten times that which went up in flames in the Buncefield fire in Hertfordshire in 2005. Not all the oil burned; some spilled into the Haven and the 'asphalt pavement' formed as it soaked into the sediments is still visible in places at the top of the foreshore below the former tank complex, while some soaked into the ground from where traces are still emerging in ground water and are captured in an interceptor to prevent it entering the Haven.

Although possibly not the first invasive non-native species to gain a foothold in the Haven, the slipper limpet *Crepidula fornicata*, a serious pest, was first found there in 1953. Assumed to have been introduced with cultivated oysters, it is now a dominant species in some locations.

Clearly, by the time Milford Haven's oil port era began in 1960, the waterway had already acquired a legacy of human impacts. However, oil importing got off to a shaky start when the

[1] Medieval Works Found At LNG Site BBC News, 5 April 2005. Retrieved 12 February 2013

first vessel to offload at the new Esso refinery terminal in 1960, *Esso Portsmouth*, suffered structural failure when unloading which caused an explosion and fire that severely damaged the ship and released oil into the Haven.

Over subsequent years, further, mostly minor, pollution incidents followed and in 1967 the Field Studies Council established the Oil Pollution Research Unit (OPRU) to undertake research into the effects of oil contamination in estuaries and coastal waters. OPRU undertook many experimental and surveillance studies in the Haven and these provided a firm foundation for the MHWESG's later work programme.

However, despite the pollution incidents, it wasn't until 1991 that a one-day conference to address pollution affecting the Milford Haven waterway was convened by the local authority. A key presentation by the Shetland Oil Terminal Environmental Advisory Group (SOTEAG) undoubtedly sowed the seed for the establishment of the MHWESG. Representatives of SOTEAG's forerunner had visited Milford Haven in the mid 1970s to learn from what was being done in West Wales; ironically they came back in 1991 to enable Milford Haven to learn from them!

The Milford Haven Waterway Environmental Monitoring Steering Group was established just a few months later as a consequence of discussions prompted by the conference. Membership comprised the major industries around the Haven, the Port Authority, local government and statutory environmental agencies.

The Group's stated vision was: "To provide high quality environmental information to enable members of the Group, and other authorities and industry working in and adjacent to the Waterway, to contribute to the maintenance and enhancement of the rich and diverse marine environment of the Waterway." It planned to achieve this by considering existing monitoring and future needs, collating and interpreting data and information for its members and funding future monitoring not being undertaken by others by contributing to a shared common resource. Members share common ownership of the Group's outputs and are free to use them as they wish; outputs are also placed in the public domain through local and academic libraries.

Members agreed to focus the Group's attention on scientific and technical issues only; political and management issues were to be explicitly excluded. This agreement has proved instrumental in contributing to the continuous cordial working relationship between the partners.

The first task undertaken by the Group was a review of the then current state of environmental knowledge of the Waterway. The comprehensive report, compiled by OPRU, included a Foreword by the then Secretary of State for Wales who welcomed and endorsed the collaborative approach demonstrated by the Group's membership. The review provided a detailed snapshot of the history of the Waterway, the physical, chemical and biological environments, the Waterway's industry, commerce and fisheries, environmental designations and responsibilities, and past and current research monitoring. It remains a valuable reference document despite now being over 20 years old.

Having developed a ten-year work plan, the Group commenced routine water quality sampling, annual wetland bird survey reporting and, in 1993, a series of major surveys. The first was a comprehensive investigation of metals in sediments (at 93 stations) and sublittoral sediment macrobenthos, particle size distribution, organic matter and hydrocarbons (40 stations; a subset of stations previously surveyed by OPRU in the 1970s and 80s), followed by an equally thorough survey of macrobenthos in sediment shores in 1994 (65 stations on 15 shores). Rocky shores were resurveyed the following year at 31 permanently marked sites, many of which had been established by Swansea University researchers in the 1960s and OPRU in the 1970s.

The surveys reconfirmed the high biological diversity of sediment communities and the heterogeneous distribution of sediment habitats. It revealed that sediment metal concentrations were elevated, though comparable with other estuaries in SW Britain, there was measurable organic enrichment and hydrocarbons were present, particularly in sediment sinks.

The rocky shore re-survey collected semi-quantitative data from discontinuous down-shore belt transects and was able to detect declines in some molluscs and the alga *Ascophyllum nodosum*. Some of the mollusc declines were considered likely to be attributable to TBT contamination from antifouling paints on both commercial and recreational craft.

The data collected during these surveys proved invaluable in the investigation of the environmental effects of the *Sea Empress* Oil Spill (SEOS) in 1996, although the semi-quantitative rocky shore data proved relatively insensitive. Studies commissioned by the *Sea Empress* Environmental Evaluation Committee (SEEEC) used the Group's established sampling sites since they provided robust pre-spill data. As a consequence of SEEEC's work, and also because of increasing obligations on the statutory environmental agencies to undertake monitoring to assess progress toward European environment Directive targets, the Group modified its planned work programme earlier than anticipated.

Nevertheless, several other major projects were completed in the late 1990s, including establishing and surveying permanently-marked sublittoral rock sites (which showed rock communities were also highly biodiverse, with high densities and biomass of many species) and the extensive eelgrass, *Zostera marina*, between Milford Haven and South Hook Point which had previously been surveyed by OPRU in the late 1970s and mid 80s. The area and footprint of the bed – the largest in Wales – had changed little since previous surveys; there was a welcome absence of green algal 'mats' (which are an indicator of elevated nutrient levels) and low levels of hydrocarbon contamination (particularly welcome just three years after the SEOS) though also a suspicion of evidence for the 'wasting disease' that had caused great loss of eelgrass beds in Northern Europe and North America in the late 1920s and early 1930s.

Other survey data collected by members during this time was made available to the Group as contributions in kind, including intertidal eel grass populations and annual shelduck surveys by the Pembrokeshire Coast National Park Authority and water quality monitoring data from the Environment Agency Wales (EAW).

In 2000, with a change in Chairmanship, the Group paused to review and reflect. A technical review was contracted out to scrutinise the Group's outputs to date, the outputs from SEEEC and the work programme in the context of the increased monitoring being begun by the EAW and Countryside Council for Wales (CCW). The reviewer endorsed most of the projects though recommended some adjustments in priorities and a revised work programme.

The Group also took the opportunity to review its governance, establishing a formal Memorandum of Agreement between the partners, and, acknowledging that it did not conduct monitoring in the strict sense of the word and neither did it steer others to do so, members agreed to changing the name, replacing 'Monitoring Steering' with 'Surveillance'.

The Group began the new millennium by mopping up some of the outstanding priorities from the original work programme that had been endorsed in the 2000 Review.

A very comprehensive re-survey of the Haven's salt-marshes was undertaken, building on surveys in 1970, 1982 and, following the SEOS, 1997-98. Whilst the survey estimated that there had been a 15% decrease in total salt-marsh area since 1982, there had been a roughly 25% increase in salt-meadow (the more biodiverse upper-salt marsh). It concluded that the marshes were no longer influenced by the oil spill but reported areas of active erosion, algal mats, litter and negative influences of livestock grazing and poaching.

The first step toward meeting the Group's aspiration for an inputs budget for the Haven was taken with an inventory of available inputs data. Whilst this identified data sources and provided a snapshot of the data available, it also suggested that developing a budget would be a significant and expensive task not to be undertaken lightly, particularly given its vulnerability to becoming rapidly outdated.

One of the most significant recommendations in the 2000 Review was to undertake more reviews, including detailed and critical reviews of the time-series data that existed and expert opinions on which work should be maintained so as best to meet the Group's goals.

The first of these reviews was conducted by the Plymouth Marine Laboratory (PML) on the eight macrobenthic datasets available to the Group. Although there were difficulties comparing some of the datasets, it concluded that the "data are of exceptionally high quality and value", that the studies showed higher than average values of biodiversity, there was "no indication of long term changes over the study period in eight spatial subtidal studies" and that "most of the stations are of Good or Moderate ecological status". However it also inferred that there had been "detrimental effects of the {dredging} outfall from the marina at Neyland."

The review made recommendations for re-establishing subtidal macrobenthic surveillance but for omitting intertidal sediment surveillance since it was a less sensitive indicator. These recommendations have been implemented (beginning in 2008) and integrated with Countryside Council for Wales (CCW) and EAW macrobenthic monitoring programmes for the European Habitats and Water Framework Directives respectively.

The second review was a very detailed appraisal of available sediment contaminants and transport data and studies. The time series data were even more difficult to compare than the macrobenthic datasets, with some being incomparable because of changes in laboratory techniques over time. Nevertheless, the review concluded that there had been no major qualitative changes in the status of contaminants since the 1980s, with decreases in some contaminants in some locations and increases in others, and that sediments had largely recovered from major spills. It also found that the data reviewed broadly confirmed the 1980s findings concerning sediment and contaminant transport.

Recommendations were made to undertake a forensic examination of sediment contaminants in samples from sediment sinks in comparison with a range of potential contemporary and legacy contaminant sources, including the only remaining samples of *Sea Empress* cargo and fuel oil; to recommence routine sediment contaminant surveillance, analysing the first round of samples using both contemporary and historical laboratory methods to provide a cross-calibration measure to enable better comparison with older datasets; and to undertake a comprehensive sediment facies survey using sediment profile imaging.

Thirdly, 25 years of wetland birds data were reviewed and reported in the context of UK trends. The annual abundance of each species was found to be variable, with some overall declines and increases. Declines in some species were not considered a result of pressures in the Haven but were attributed to milder winters resulting in less migratory birds moving to the far west from mainland Europe or the eastern UK.

A series of what are planned to be regular surveillance projects were commenced in 2008. The first was re-establishing subtidal macrobenthic sampling at the sites recommended in the PML review.

An initial round of contaminant bioaccumulation sampling and analysis, developed from previous work undertaken by EAW's predecessor body the National Rivers Authority (NRA), was also undertaken in 2007 - 08. The Marine Biological Association (MBA) collected samples of five species from 13 locations along the length of the Waterway and from two reference sites and analysed them for 42 determinands (13 metals, 6 organotins, 16 PAHs, 7 PCBs plus biometrics); the work was repeated and slightly expanded in 2010 to establish a robust baseline. The data were compared with the earlier NRA data where appropriate and set in a UK context.

There was considerable variation in bioaccumulated contaminants between species and locations in the waterway, reflecting differences in feeding strategy and habitat preference, physiological and ecological attributes, and chemical properties of the different determinands. Metal concentrations in the majority of biota samples (94%) were at the lower-middle part of the UK range. Metals data revealed a number of changes between surveys, both increases and decreases. All TBT concentrations were above the lower Environmental Assessment Criteria for mussels (sub-lethal effects possible) but below thresholds considered by OSPAR to be acutely toxic. The majority of PAHs in mussels were above OSPAR background levels, but not excessively so.

Long overdue, rocky-shore surveillance was re-established in 2010. In an attempt to improve it's sensitivity for detecting change,

the sampling methodology was substantially modified, adopting the method developed at the Skomer Marine Nature Reserve in the mid 2000s. Replicate, quantitative (rather than semi-quantitative) samples are collected at three selected shore heights (rather than a semi-continuous belt transect) to provide statistically robust data which may still be compared with the earlier semi-quantitative data. A subset of six of the historical sites was selected to integrate with CCW's Habitats Directive rocky-shore monitoring which is based on a further six of the historical OPRU / Group sites. Additional data were collected using MarClim (UK wide marine biodiversity and climate change project) protocols.

Once again, it proved difficult to compare the data collected with historical data: methods had varied, not all data were statistically valid, and some sites had been relocated. Nevertheless, it was concluded that the rocky intertidal communities were structurally and functionally healthy. Temporal changes and increasing abundance trends of several species were generally in line with wider UK responses to climate warming, though modified by local factors. Dogwhelks, *Nucella lapillus*, were noted to have increased in abundance at some sites since the use of TBT antifoulants had been prohibited. Non-native species were recorded at every site with the highest number of non-natives ever recorded during a MarClim survey.

Two of the sediment-review recommendations were taken forward in 2011 – 12. The forensic investigation of sediment contaminants from sediment sink areas found that 5-15% of total hydrocarbon (THC) residues were of biogenic origin; 2-6% of THC residues were PAHs, about half each recent petrogenic and older pyrogenic sources with recent contributions from refinery waste water and potentially African crudes; the remaining 70-85% of THC was heavily-weathered petrogenic residues from historic spills. SEOS cargo was undetectable but *Sea Empress* heavy fuel oil was detected further up the Waterway than previously recorded. The 'fingerprints' of the Iranian crude oil spilled by the *El Omar* in 1988 and fuel oil from the wartime bombing at Pembroke Dock were also tentatively identified.

The sediment facies survey proved to be the most ambitious and expensive project undertaken by the Group. It was carried out by the developer of the sediment profile imaging technique and involved flying half a ton of equipment from his base in Seattle, Washington. Over a period of twelve days in May 2012 more than 550 stations, with three replicates at each, were successfully sampled using the seabed penetrating camera system. Sediment surface images were also obtained by a 'plan view' camera at a higher than anticipated proportion of the sites. The final outputs from the survey are eagerly anticipated.

Throughout the life of the Group there have been changes in membership as industries come and go from the Haven or change hands, and major change is anticipated in 2013 as CCW and EAW are dissolved and replaced by a single body, Natural Resources Wales.

The future is certain to bring new developments to the Waterway and new pressures to the environment necessitating more and new information. The Group has an ambitious, costed, work programme including the maintenance of routine sublittoral macrobenthic, rocky shore and bioaccumulation surveillance; recommencing sediment and water-column contaminant surveillance; and potentially finally developing an inputs budget and, if substantial resources become available, extending the bioaccumulation work to include the use of sublethal effects indicator tools.

The outputs from the Group send several 'take home' messages about surveillance to detect change. Apart from the obvious – timing (allowing for seasonality), site relocation (comparing like with like), the value and utility of replicated, quantitative data being considerably greater than single, semi-quantitative samples – the value of integration between projects in the Waterway to maximise the possible signals of change and to provide context for interpreting change, and of integration with projects elsewhere to place the Milford Haven findings in context have become very clear. Perhaps the strongest message is the need to ensure that, as methods evolve, measures are taken to ensure that new data remains "backwards-compatible" and comparable with historical data so that the objective of detecting change has a fighting chance of being realised.

2. GROUP ACTIVITY 2013

2.1 Introduction

The Group commenced a forensic investigation into the source of hydrocarbons in Waterway sediments in 2011. Fugro-ERT reported on the analyses undertaken, the data generated and an initial interpretation in early 2013 (Fugro-ERT 2012, listed in Appendix 3). A further, more detailed and specialised forensic evaluation and interpretation of the data was commissioned from David Little, formerly of the Oil Pollution Research Unit, Pembroke, who carried out a review of sediment contaminants and transport for the Group in 2007-09 (Little, 2009) and specialist forensic hydrocarbon chemist Yakov Galperin, EGC Consulting, California. The summary of the resultant report is included as section 2.2.

The rocky shore surveillance programme recommenced in 2010 was repeated in 2013. The contract was awarded to the Field Studies Council's Dale Fort Field Centre resulting in the work being completed by locally based marine biologists with considerable knowledge and experience of the Waterway. The summary of their report is included as section 2.3.

A further round of macrobenthic sampling was conducted at the suite of sites recommended in the review of macrobenthic studies in the Haven (Warwick 2006). The sites were previously sampled in 2008 and 2010 and the data reported in the 2011 business report. The 2013 samples have been analysed and the data is currently being analysed for inclusion in the next report.

Wetland bird surveillance continued as in previous years and synopses from the Wetland Birds Surveys (WeBS) and Pembrokeshire Coast National Park Authority shelduck surveys are included (sections 2.4 & 5).

A presentation on a mapping application for the data collected by the Sediment Profile Imaging survey reported in the 2012 business report was given by the contractor to the Mapping European Seabed Habitats (MESH) project conference *Mapping Atlantic Area Seabed Habitats for Better Marine Management* in Alvero, Spain. A paper is being prepared for publication in a special edition of the Journal of Coastal Research.

This report also includes guest contributions from Dr Steve Morrell, Dale Fort Field Centre, describing his personal rocky shore monitoring work since 1996, and the summary from an NRW placement student's thesis that draws heavily on the images collected by the SPI project.

2.2 Forensic evaluation of Milford Haven sediment hydrocarbon contamination

Yakov Galperin & David I. Little

Executive Summary

This supplemental environmental forensic investigation is based on data generated by Fugro ERT (2012) under contract to MHWESG from sampling conducted by Group members during 2010. The study interprets and compares findings with prior and more recent chemistry data from the Milford Haven Waterway (MHW). Current and historic petroleum-related activities in the estuary contribute to the hydrocarbon contamination of surficial sediments in the study area. The fate of the contaminant inputs involves fine-grained sediment transport over long time periods. The forensic study demonstrates that the sediment hydrocarbons have three main components:

- Aliphatic hydrocarbons (n-alkanes) of a predominantly biogenic nature represent about 5-15% of total hydrocarbons (THC) in sediment.
- Polycyclic aromatic hydrocarbon (PAH) compounds of mixed more recent petrogenic and older pyrogenic sources are about 2-6% of THC, of which about half are petrogenic including the present contribution from refinery waste water and increasingly from African crude oils.
- Unresolved complex mixture (UCM) predominantly attributed to heavily-weathered petrogenic sources; the historic spill-related contamination may represent as much as 70-85% of THC in sediments of MHW.

In spite of the size of the *Sea Empress* spill in 1996 (72,000 t), the Forties Blend crude oil cargo was not able to be distinguished forensically. However, inputs of heavy fuel oil (HFO) from *Sea Empress'* bunkers (480 t spilled) were detected 2 km further upstream than reports at the time of the spill. Geochemical signals from refinery waste-water inputs are ubiquitous in low concentrations (<2% of THC). Inputs of Iranian crude oil spilled by *El Omar* in 1988 and fuel oil from WW2 bombing at Llanreath fuel depot have also been tentatively identified. The evaluation of PAH source ratios demonstrates that the older pyrogenic PAH compounds in the surficial sediments come mainly from biomass (grass and wood) and coal combustion. The PAH consist of broadly similar pyrogenic PAH at most stations, and are similar to material from maintenance dredging of MHW before 2006. Sediment PAHs at some stations appear to have become more pyrogenic since 1996, as if still 'recovering' from the more petrogenic signature lingering from the *Sea Empress.* Recent CEFAS data for 2008-2012 have ratios with a wider scatter. This is partly because they are from a wider range of dredging sites in MHW, but they also overlap with 1993 pre-*Sea Empress* and with 1996 non-petrogenic post-*Sea Empress* ratios, suggesting resuspension of un-dredged older material by construction activities. These main PAH findings discussed in this report were reasonable when compared with other PAH surveys: (1) before and after the *Sea Empress* spill in 1996, (2) CEFAS maintenance dredging licensing, (3) external annual surveys since 1999 for CSEMP of sediment PAH off Cosheston Point, (4) DEFRA air quality since 1999 in South Wales and (5) bioaccumulation data for mussels and ragworms at Dale, Angle and Pennar in 2010.

Recommendations include forensic analyses of groundwater from the former Llanreath fuel depot, from adjacent to Angle Bay, and of coal from Hook colliery. Increased efforts are needed to coordinate monitoring methods within and across media, and to improve sample archiving and the quality of forensic analyses. A focussed core study that uses radionuclide-dating and advanced chemical fingerprinting, as proposed by Little (2009) is also recommended for MHWESG.

2.3 Rocky shore surveillance 2013

Steve Morrell, Dale Fort Field Centre

Executive Summary

Six rocky shores within the Milford Haven Waterway were surveyed by staff from The Field Studies Council on behalf of the Milford Haven Waterway Environmental Surveillance Group. Field surveys were carried out between 25th July and 6th of September 2013. These repeated the work carried out by the Marine Biological Association of the UK in 2010 and used the same methodology.

The results were analysed and compared with the results of the 2010 investigation.

Over three times the number of algal species was found at Dale Point than in the 2010 survey.

At Gelliswick, high frequencies of *Melarhaphe neritoides* were found. The introduced red alga *Caulacanthus okamurae* was also found. Neither of these species was reported in 2010.

The non-native sea squirt *Corella eumyota* was not found in either the $1m^2$ frequency quadrats or in the MarClim SACFOR survey at Gelliswick. This species was reported as being present in high densities on the underside of cobbles in 2010.

At Llanreath one live *Mytilus edulis* was found. The 2010 survey reported them to be Super-abundant.

The 2010 survey reported large numbers of the non-native sea squirt *Corella eumyota* on the lower shore at Llanreath. This survey found one lower shore specimen.

At Cosheston Folly seven lower shore algal species were found that were not listed in the 2011 report.

At Great Castle Head a large population of the introduced brown alga *Sargassum muticum* was found. This was not reported by the 2010 survey.

At Sawdern Point twice as many species of algae were found as the 2010 survey.

The barnacle *Perforatus perforatus* was found at Dale Point, Great Castle Head and Sawdern Point. The 2010 survey found it only at Dale Point.

Limpet density decreased with shelter. The 2010 survey did not find this pattern.

With the exception of Llanreath, all the sites were in as good as or better condition compared to the 2010 survey.

Recommendations, made include annual surveys, some changes in methodology and consistency in personnel.

2.4 Annual summer shelduck survey 2013

J E Hodges, PCNPA Ecologist

Executive summary

The Daugleddau Estuary and Milford Haven Waterway hold nationally important numbers of shelducks during the winter months. In addition there is a small summer population which had been the subject of annual summer boat surveys carried out between 1991 and 2012. The summer boat surveys were repeated in 2013 as part of a coordinated programme of environmental surveillance in the estuary system. The aims, objectives and methods used, together with the data obtained are described in this report.

The results indicate that in terms of the numbers of broods of ducklings seen on the water, 2013 (along with 2012) was the poorest year for breeding shelducks in the estuary since the current sequence of annual surveys began in 1991. Predation is thought to have been a major factor affecting the number and size of broods recorded in 2013. Disturbance may also have been a contributory factor, although there is little hard evidence on which an assessment of the importance of this as a factor affecting the population can be based.

Since the mid-1990 s there has been a steady decline in the numbers of shelduck overwintering in the UK. This decline has been mirrored by the data for shelduck from the WeBS counts: the local and national declines are probably linked to an increasing tendency for birds to “short-stop” on mainland Europe in response to the recent run of mild winters. The decline in the over wintering population has led to fewer birds remaining within the estuary system to breed.

Data collected for other wetland birds once again underlined the importance of the estuary system during the autumn migration period, especially for species such as curlew and green and redshank.

Data collected for other wetland birds once again underlined the importance of the estuary system during the autumn migration period, especially for species such as curlew and green and redshank.

The report concludes with a recommendation for the continuation of the annual surveillance of summer shelduck populations in the estuary system as part of the Milford Haven Waterway Environmental Surveillance Group’s annual work programme.

2.5 Wildfowl and wader counts on the Milford Haven Waterway 2013-14

Annie Haycock, Pembrokeshire WeBS Coordinator

Executive Summary

The Wetland Bird Survey was carried out on the Cleddau Estuary system between September 2013 and March 2014, with additional counts for June and July 2013 made by Jane Hodges during the annual survey of summer shelduck populations.

The methodology used followed that set out in the BTO WeBS Counters Handbook.

A total peak count of 21,123 birds between November and February confirms that the estuary system is still of international importance for its waterfowl populations. This peak count was slightly higher than 2012-13, but these two years are still the lowest since 1996-97 when gulls were included in the counts.

The levels of "National Importance" for many water birds have been revised, and only three species now qualify (based on a five-year mean): wigeon (max. 3800 in October), greenshank (max 19 in November), and curlew (1795 in July). Shelduck (375 in February), dunlin (1555) in February) and little egret (25 in October) were well below the qualifying level in 2013-14 but only just short based on the 5-year average.

Of the species that have declined, wigeon may be of particular concern as the decline, over the past two seasons, is large and in a single area of the estuary – Pembroke River. The reason for the decline is not yet known.

Winter 2013-14 was somewhat warmer than the long-term average, but this was offset by the extreme winds experienced between October and March, and the flooding in many parts of the country (Met Office data). This undoubtedly affected bird distribution and movements across the country, and the continent.

The total number of birds recorded each month was lower than the average recorded during the past decade, this was largely due to low numbers of wigeon in the early part of the winter, and to the relative lack of dunlin later on. Gull numbers were also low throughout the winter.

Comparison of counts with the national report for 2011-12 (the most recent that is available) shows that for most species, the local trends in populations are similar to those experienced nationally.

2.6. NRW assessment of environmental pressures on the Milford Haven Waterway

Natural Resources Wales, January 2014

Executive summary

The purpose of this report is to describe the general environmental pressures on the Milford Haven waterway and estuary system, with a particular focus on nutrients. The report reviews available data and compliance with relevant European directives, in particular the Water Framework Directive (WFD). It also provides evidence to inform decisions regarding potential designation under the Nitrates Directive and Urban Waste Water Treatment Directive. A separate review of the condition of the Pembrokeshire Marine Special Area of Conservation (SAC) is being undertaken. The intention, once that report becomes available, is that the two reports will be integrated to provide a comprehensive report on the state of the environment of the Milford Haven waterway.

The Milford Haven waterway is a ria estuary (drowned river valley) comprising a central waterway with numerous shallow embayments, tributaries and pills. It is the largest estuary in Wales and the catchment area includes a large proportion of Pembrokeshire. For WFD purposes, the waterway has been divided into two separate water bodies: Milford Haven Inner (a transitional water body) and Milford Haven Outer (a coastal water body). The entire Milford Haven waterway is within the Pembrokeshire Marine SAC, which is considered to be one of the best areas in the UK for a number of habitats and species, all of which can be affected by effluent disposal and diffuse pollution impacting on water quality. Nutrient enrichment, in particular, has been cited as a threat to the integrity of the SAC.

A comprehensive review of all Environment Agency-regulated discharges potentially impacting on the SAC was completed in 2006 under the EU Habitats Regulations. 160 discharge consents were identified as having a potentially significant impact on site integrity; therefore an Appropriate Assessment was completed for these discharges in Stage 3 of the Review of Consents process, using best available knowledge at the time of the review. The Stage 3 assessment concluded that there was no adverse impact on the integrity of the SAC from consented discharges.

Since the Review of Consents was completed there has been increasing concern about the occurrence of opportunistic macroalgae on inter-tidal mudflats and sandflats within sheltered bays and inlets in the waterway, prompting further investigations and more rigorous assessment of new discharges. In line with Habitats Regulations, any new discharges deemed to have a likely significant effect on the SAC have been subject to an appropriate assessment, including the new Pembroke Power Station in 2011.

There are 71 WFD water bodies adjudged to comprise the catchment area of the waterway, excluding the waterway itself. Fishery impairment and nutrient enrichment are the main problems affecting compliance with WFD in these freshwater bodies. Whilst water industry point discharges and abstractions contribute to these issues, agricultural land is considered to be the primary source of diffuse pollutants impacting on both water and fishery quality within the catchment area. Other pressures on the

waterway, including thermal impacts, port activities, development, fishing and recreation are also briefly discussed in this report.

Results of monitoring in the waterway and its catchment area are used to assess compliance with a number of European directives, including the WFD, which will assimilate the requirements of a number of other directives by the end of 2013. Data analysis carried out for this report focused on nutrients, as this is the water quality issue most likely to affect compliance with European directives in the waterway.

Evidence is being gathered to inform a review of the waterway in 2013 to assess its suitability as a candidate Polluted Water (eutrophic) under the Nitrates Directive and candidate Sensitive Area (eutrophic) under the Urban Waste Water Treatment Directive (UWWTD). These designations would have the following implications:

Land draining to a Polluted Water (eutrophic) would become designated as a Nitrate Vulnerable Zone and restrictions would apply to reduce nitrate leaching from agricultural activities.

Sensitive Area (eutrophic) designation would require discharges from larger sewage treatment works, including Pembroke Dock and Merlin's Bridge, to meet the UWWTD standards for the removal of nutrients, unless we could show this will have no effect on the degree of eutrophication.

These candidacies were last reviewed in 2009, but at the time there was insufficient evidence of adverse ecological impacts to justify designation. The Environment Agency's decision was to continue monitoring and review the case for designation in late 2013.

Evidence from WFD monitoring in the Milford Haven Inner water body shows that dissolved inorganic nitrogen (DIN) levels are Moderate and this appears to be reflected in the opportunistic macroalgae classification, which also achieves Moderate status. Therefore, this transitional water body is currently failing to meet the Good standard that will be required for WFD compliance by 2027. Further investigations will be required to identify reasons for failure and a programme of measures to achieve Good ecological status will need to be put in place by 2014.

The DIN classification demonstrates that the waters of the Milford Haven Outer water body are also hyper-nutrified according to WFD standards, but WFD assessments did not demonstrate evidence of phytoplankton blooms or excessive macroalgal growth in this coastal water body as a whole. Therefore, the current evidence indicates that although the water body is classifying as Moderate for DIN, all other classifications meet Good status or higher. The nutrients are not causing adverse ecological impacts at water body reporting level and this water body is not currently of concern. Therefore, no further investigations are required for this water body in relation to WFD requirements. However, Habitats Directive requirements may be more stringent and will be assessed further. There are also localised areas of excessive macroalgal growth that may need to be addressed.

Analysis of monitoring data has indicated a slight overall decrease in DIN and a slight overall increase in dissolved inorganic phosphorus (DIP) in the Milford Haven waterway over the last 14 years. However, these trends are very minor compared with other

sources of variation in the data and they may simply reflect the influence of random variation in the weather. The contribution of both DIN and DIP from the 5 largest sewage treatment works discharges has decreased over the same period.

Sewage treatment works effluents discharging directly to the waterway account for approximately 34% of the total DIP load and 5% of the total DIN load to the waterway (excluding exchange with seawater). Environmental Permitting Regulation (EPR) installation discharges account for no more than 2% of the total DIN load, including deposition of their aerial emissions and discharges to water. DIP loads from EPR-installation discharges are of no likely significance. Losses from agricultural land are almost certainly the dominant source of DIN from the catchment area, but further source apportionment work is required to give a more detailed breakdown of DIN sources and also to apportion sources of DIP. A number of other data gaps and recommendations for further work are highlighted in this report.

As the lead organisation in dealing with this matter, Natural Resources Wales (NRW) will consider the outputs of this report with a view to providing a plan of action to ensure compliance is maintained across the catchment area and across all relevant directives.

Copies of this report, reference A&R/SW/14/1, are available from:

Email: paul.edwards@cyfoethnaturiolcymru.gov.uk /
paul.edwards@naturalresourceswales.gov.uk

Tel: 01792 325610

2.7 Rocky Shore Monitoring at Dale Fort Field Centre 1996 - 2014

Steve Morrell, Senior Teaching / Project Officer, Dale Fort Field Centre.

Introduction

Dale Fort is a marine field centre located near the entrance to Milford Haven. It has operated as part of The Field Studies Council, an educational charity, since 1947. It was the world's first marine field centre and quickly gained an international reputation for high quality environmental education and scientific research, which it retains to this day. Its mission is to promote environmental understanding for all and its activities are heavily dependent upon the high quality of the marine environment that surrounds it.

The work reported below began in February 1996 as a response to the *Sea Empress* oil spill on 15 February 1996. The spill stimulated the author to begin a programme of seashore monitoring which still continues.

Sites and methods

Three sites were selected near Dale Fort: Dale Fort Jetty Beach, Castle Beach and Monkhaven. Dale Fort Jetty and Castle Beaches were chosen because of their close proximity to Dale Fort (located either side of Dale Point) and their vital importance to the work of the field centre. Monkhaven was selected as a more exposed site located opposite Dale Fort on the north side of the Haven.

Jetty and Castle Beaches were both heavily oiled. The upper rocky shore of Castle Beach was most oiled, with oil in crevices, on rock platforms and in upper shore rock pools. Monkhaven was less heavily oiled, but with thick oil on upper shore rock faces, though it persisted for less time that at the other sites.

Jetty Beach and Monkhaven transects are surveyed annually using 0.25m^2 quadrats at permanently marked 1m height intervals; the Castle Beach transect is sampled at 0.5m height intervals.

The numbers of individuals of each species present within the quadrats are recorded on each visit. The percentage covers of algae, lichens, small barnacles and colonial animals (*eg* sponges) within the quadrat frame are visually estimated and the numbers of small periwinkle species are counted from within 10 cm square sub-quadrats. All quadrats are photographed at each sampling event.

Selected results

1. Species diversity

The number of species at Jetty Beach was relatively low immediately after the oil spill though this was unrelated to the spill as the first survey of this transect was carried out before the beach became oiled. However, by one year after the spill the number of species had increased, and peaked in 1999 – 2000 after which it remained fairly stable

After reductions in species numbers in 1996 and 1998, diversity at Castle Beach stabilised and has remained consistent until 2014 when the number peaked at 39 species.

No effects of the oil spill on total species numbers at Monkhaven were evident and for the last decade species number has shown negligible variation.

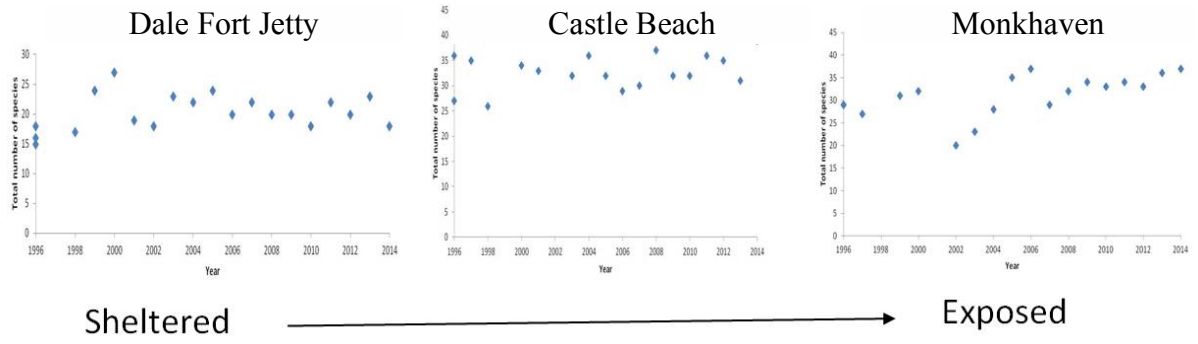

Figure 1. Total numbers of species found on all 3 sites, 1996 - 2014

The general pattern seems to be one of increasing stability with increasing exposure despite it being counterintuitive that the more stressful environments appear to support the most consistent number of species. Therefore, a species with a naturally variable abundance was examined to establish whether the pattern of stability with increasing exposure was repeated at a single species level.

Melaraphe neritoides is a small snail that lives on the upper parts of rocky shores, browsing on micro-algae and lichens. It favours exposed conditions but is also found at the sheltered Dale Fort Jetty site. Its abundance varies considerably from year to year. Similar patterns of stability in this species' abundance to the patterns of stability seen for all species at the thee monitoring sites suggest that these patterns are real and not sampling artefacts: Jetty Beach was by far the most variable and Castle Beach and Monkhaven were mostly stable, though with an unexplained peak in numbers at both Castle Beach and Monkhaven in 2003.

2. Limpets

Limpets are conspicuous, common, large, long-lived mainly herbivorous animals that occupy an extensive vertical range on rocky shores of all degrees of exposure. Although robust they are sensitive to hydrocarbon pollution and as they are keystone community structuring species they are considered ideal subjects for rocky shore monitoring.

The first year of monitoring on Jetty Beach recorded the lowest numbers, particularly in the middle shore. Coupled with evidence of limpet casualties evident during 1996 the low numbers were assigned to the effect of oil deposition.

However, following an increase in abundance over the following four to six years numbers fell before increasing again, suggesting a cycle of 10 - 12 years from peak to minimum abundance (Figure 2). Data from the coming years may provide evidence that either this is a natural cyclic phenomenon or a delayed response from the oil spill.

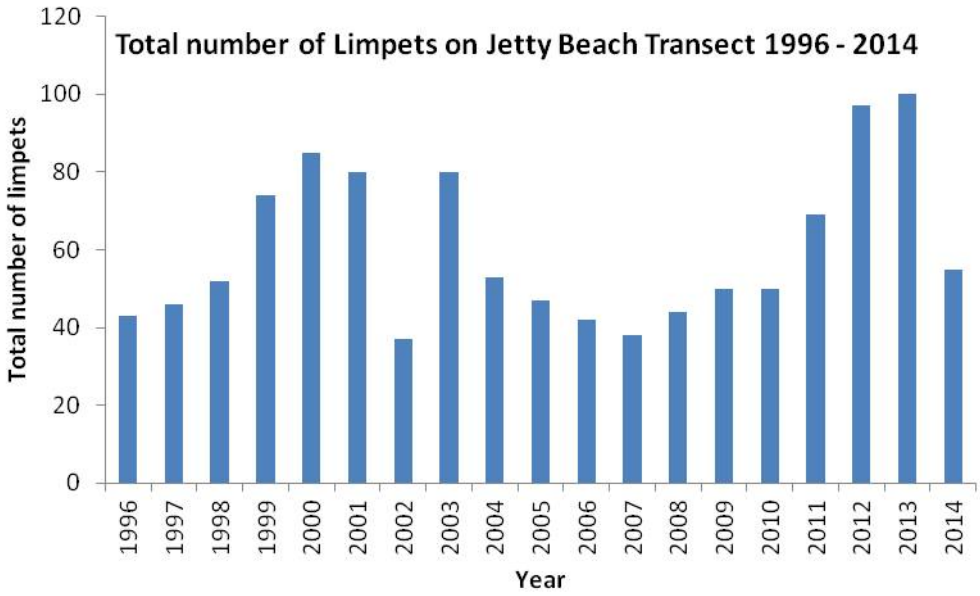

Figure 2. Total Number of limpets on Jetty Transect 1996 - 2014

Low numbers of limpets were present at Castle Beach in 1996, 97 and 1999. Numbers increased in 1998 and from 2000 but have remained very variable since 2000. There is less evidence of a cycle of abundance though there may be a shorter one of 5 - 7 years (Figure 3). This may be a reflection of increased exposure and intra-specific competition resulting in reduced longevity for the population as a whole at Castle Beach.

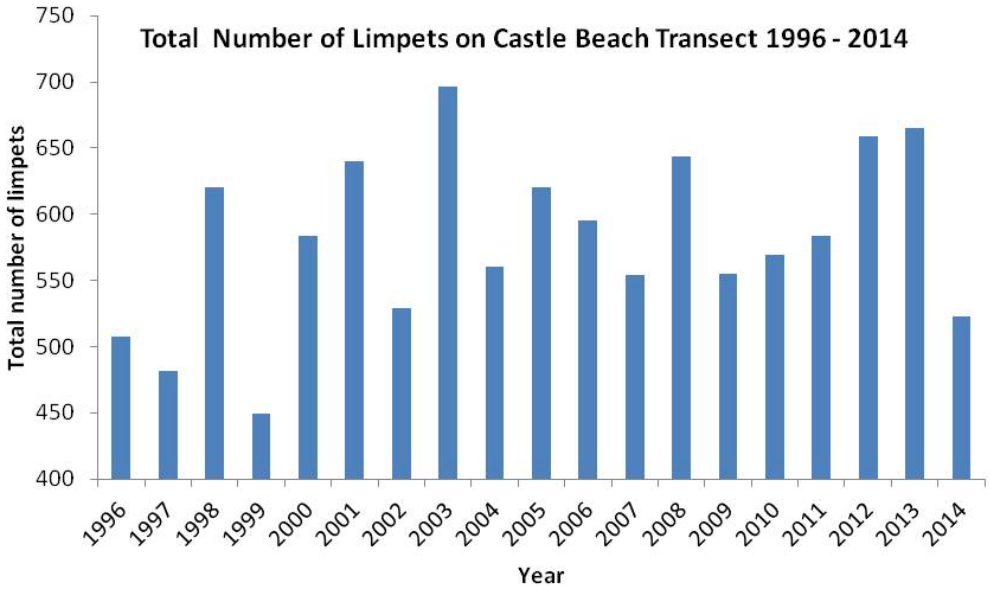

Figure 3. Total number of limpets on Castle Beach Transect 1996 - 2014

Following reduction in number and very wide variations in abundance between 1996 and 2003 at the Monkhaven, limpet numbers stabilised from 2004, although possibly showing some evidence for a 4 - 5 years cycle (Figure 4).

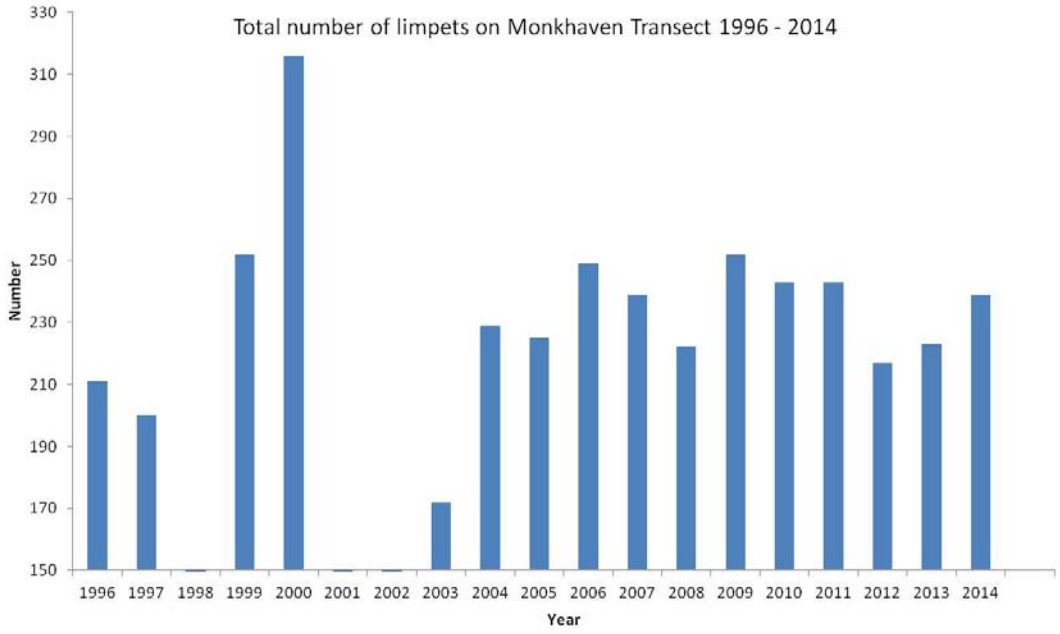

Figure 4. Total number of limpets on Monkhaven Transect 1996 - 2014

Across the three sites there would appear to have been a trend of decrease in length of cycle and degree of variation with increasing exposure.

As all sites are recorded photographically to enable to maintain a visual record and enable additional future analysis, a middle shore station at Castle Beach was chosen for a detailed limpet-size investigation.

The mean maximum diameter of limpets at the sample station appear to show an 8 - 10 year cycle between the largest and smallest mean maximum diameter. Initial comparison of the mean maximum diameter with limpet density suggested a negative correlation similar to that reported for limpets from West Angle Bay (Crump et al [1]): "A Spearman's rank correlation coefficient of -0.84 confirms that the inverse relationship between mean limpet size and limpet density was significant at the 1% level." However, regression analysis of the data showed this not to be the case, and found no correlation between limpet size and density, a conclusion similar to that drawn by Ballantine (1961[2]): " There is no direct relationship between mean size and population density (expressed as weight per occupied area) in *P. vulgata."* It is reasonable to suppose that there is no simple relationship between limpet size and density and that inter-specific

[1] Robin G. Crump, Andrew D. Williams & John H. Crothers 2003. West Angle Bay, a case study: the fate of limpets. Field Studies, 10: 579-599

[2] Ballantine WJ (1961) The population dynamics of Patella vulgata and other limpets. PhD Thesis, University of London

biotic interactions are probably important as interactions with the physical environment.

3. *Gibbula umbilicalis* (purple topshell) at Castle Beach

Gibbula umbilicalis is a small herbivorous snail that occupies the middle to lower parts of sheltered to moderately exposed rocky shores. It is a warm water species that is currently extending its range northwards which is regarded as evidence of rising sea temperatures.

Purple topshell numbers fell to a single individual a year after the oil spill, followed by a gradual but fluctuating increase for 10 years. However, numbers decreased again in 2007 -2009, then rapidly increased in 2010 and 2011 although the winter of 2009–10 was the coldest for decades. Since then numbers have fluctuated very widely from year to year. The population size in the sampled area is, however, small and it is unclear whether the variations are real changes in population size or an artefact resulting from the great mobility of *G. umbilicalis*. For example, weather conditions at the time of sampling are likely to have a major influence on count data; during dry, warm weather topshells seek shelter in crevices making them very difficult to detect.

4. *Pelvetia canaliculata* (channelled wrack)

P. canaliculata is a brown alga that typically lives on the upper parts of sheltered rocky shores all around the coast of Britain. It is remarkable for its ability to withstand desiccation (up to 95% water loss) and is the only alga that actually requires a period of drying out. It persists for years and in mature form is large, obvious and unmistakable. These properties render it a useful species for inter-tidal monitoring.

Pelvetia occupied very little space at Dale Fort Jetty beach for the first 9 years of the monitoring period and there were no noticeable effects of the oil spill in 1996. In 2005 it began to increase, until by 2009 it was occupying almost half the upper shore quadrat. This continued until 2011 when an even more dramatic decline began. Within one year its abundance had dropped to very low levels, comparable to pre-2005.

The reason for these changes was not obvious. There was no physical change in the structure of the site. The only animals at the shore height of *Pelvetia* that might have grazed on it were *Littorina saxatilis* (rough winkle), small, herbivorous snails that dwell mainly on the upper parts of rocky seashores.

L. saxatilis is a highly mobile species and its density varies with highly variable factors such as the weather. In wet weather they browse on open rock and in dry weather will seek the safety of moist crevices or other appropriate microhabitats. Similarly to *G. umbilicalis*, this renders them more or less visible to shore surveyors and consequently consistency of counts can be variable. Nevertheless, the density of *L. saxatilis* over time inversely mirrors the density of *Pelvetia* suggesting that grazing might be a factor in change in the abundance of the alga. If this is a real effect, it is likely that the rate of change in algal cover is regulated by *L. saxatilis* grazing tiny, recently settled, immature

algae rather than large mature specimens, thereby slowing re-colonisation of young *Pelvetia* plants as older plants die off.

A similar pattern of *Pelvetia* abundance increase and subsequent decrease was recorded on the more exposed (south) side of Dale Point at Castle Beach, though the increase and decrease began a year later than at Jetty Beach. Although the number of *L. saxatilis* at Castle Beach was not so convincingly the reciprocal of the abundance of *P. canaliculata* compared with Jetty Beach, there were generally larger numbers of winkles present when the cover of *Pelvetia* was least.

Conclusions

There is considerable, apparently natural, variation in intertidal species abundance in what are usually considered stable shores and a paucity of long-term, reliable, quantitative data even from shores that have been studied for decades.

As perhaps the most important variable in most data sets is the people that collect the data, methodologies should strive for consistency and repeatability to try to reduce the effects of personnel changes. This data set has the unusual feature that the same person has collected the data from the beginning that should ensure maximum consistency in observation and eliminate any effect from inter-worker variability.

If another major oil spill occurs this dataset will able much more definite statements to be made about its effects, particularly for limpets but also for several other species. Continuing to add to this long-term data set will improve the ability to recognise and interpret any anthropogenic or other changes in the future.

Seashores are one of the few natural habitats that remain in the UK. Their inhabitants indicate the state of the seas and, since humanity depends on the sea for our existence, they are worthy of study.

2.8 Do alien invaders always destroy the native ecology? The case of *Crepidula foricata* in Milford Haven

Jan Verbeek, University of Liverpool

Abstract from undergraduate First Class Honours Marine Biology research project

The introduction of non-native species (NNS) is considered one of the main factors driving global biodiversity loss and requires the development of appropriate management procedures after successful introductions. This must be based on a detailed understanding of the processes and patterns involved in species establishment.

The American slipper limpet, *Crepidula fornicata,* is an invasive non-native gastropopd mollusc that has spread around UK coastlines and along the European coasts from the Mediterranean to Norway, sometimes severely impacting the native ecosystem. This study aimed to establish the current spread and investigate any recent change in the distribution of *C. fornicata* in the subtidal zone of the Milford Haven Waterway (MHWW), South Wales, and examined whether habitat substratum type determines adult *Crepidula* abundance.

The impact of *Crepidula* on sedimentary processes and condition of the colonised areas (measured on proxies describing benthic quality – aRPD, amount of unconsolidated material, bioturbation indicators and successional stage) was investigated using sediment profile imagery (SPI). The ecological impact of *C. fornicata* on the native epibenthic biota was investigated by examining the relationship between *Crepidula* density and associated epibenthic species composition.

It was found that *C. fornicata* exhibited a well-established population in the MHWW, predominantly found in muddy bottom habitats, but contracted in its distribution since 2009-2010. *Crepidula* affected the community structure and the abundance of several organisms without significantly impacting overall epifaunal abundance, species richness, species diversity and species evenness. *Crepidula*-induced changes were habitat and density dependent, primarily observed in relatively homogenous, muddy bottom habitats at high *Crepidula* density. The overall neutral effect of *C. fornicata* highlights that, against the popular view of the detrimental impacts of NNS, species invasions may not necessarily pose a threat to recipient systems and can become incorporated into the ecology of an ecosystem.

Note: much of the data used in this study was obtained from the images collected by the MHWESG Sediment Profile Imaging study.

3. FUTURE WORK PROGRAMME

The Group undertook a detailed review of its medium term work programme at the end of the 2012. Priority projects were agreed but, because the Group's budget had been substantially depleted by the expensive SPI survey, insufficient resources were available within the Group's current annual income to undertake all these at either the necessary intervals or, in some cases, potentially at all. For example, the cost of a single round of bioaccumulation surveillance significantly exceeds the Group's annual income contributions; to repeat this work would therefore necessitate avoiding expenditure one year to carry it forward to the next to fund this project, at the expense of one or more other routine projects which would have to be postponed or abandoned.

The planned major project for 2014 is to commence routine sediment contaminants surveillance as recommended by Little (2009), beginning with paired analysis of sediment samples using current and 'historical' (1970s – 80s) analytical techniques to enable integration and comparison of currently incomparable datasets. The annual summer shelduck breeding surveillance and wetland bird data collation and reporting will also be continued.

Scheduling the frequency of repeating projects within the rolling surveillance programme remains a challenge to the Group. Whilst members of the Group are conscious of the reduced value of datasets caused by failing to sample at appropriate intervals, the Group's income precludes revisiting projects as frequently as members would wish.

Several projects were postponed or added to a wish-list to be addressed as and when resources become available. These include:

- recommencing routine water quality surveillance following the NRW review of environmental pressures on the Milford Haven Waterway (section 2.6);
- repeating bioaccumulation surveillance (recommended interval 5 - 6 yr);
- eelgrass *(Zostera)* surveillance (recommended interval 6 yr);
- saltmarsh vegetation surveillance (recommended interval 3 yr);
- repeat broadscale macrobenthic survey.

In recent years the Group has welcomed additional members from new industries around the Haven who have brought an increase in Group annual income through their contributions. Nevertheless, although some existing members modestly increased their contributions for 2013-14, the Group's income has remained about the same as when it was established in 1992 even though the cost of surveillance work has increased substantially since then, and the scope, sophistication and, consequently, the cost of the projects undertaken by the Group have developed considerably.

APPENDICES

Appendix 1: Purpose and terms of reference

Preamble

The Milford Haven Waterway[3] is an extensive natural inlet of the sea with a long and distinguished maritime history. Its deep waters provide a natural harbour of significant economic importance. It is one of the best examples of a ria system in Britain and supports a particularly diverse range of high quality marine and estuarine habitats and biological communities.

The identification and consideration of political and management issues or the setting of environmental standards are specifically excluded from these Terms of Reference. However, group members are free, and are expected to use the group's outputs to help meet their own requirements.

Purpose

To provide high quality environmental information to enable members of the Group, and other authorities and industry working in and adjacent to the Waterway, to contribute to the maintenance and enhancement of the rich and diverse marine environment of the Waterway.

Terms of Reference

The Milford Haven Waterway Environmental Monitoring Steering Group will:

1. Maintain surveillance of the quality of the marine physico-chemical environment, marine biology and ornithology of the Milford Haven Waterway

2. Undertake surveillance of the foreshore, seabed and waters of the Milford Haven Waterway from a line between St Anne's Head and Sheep Island to the tidal reaches of the Eastern and Western Cleddau Rivers and other tributaries to normal tidal limits by:

2.1 keeping under review all relevant survey, surveillance and monitoring;

2.2 commissioning surveys to fill gaps in knowledge and to establish baselines;

2.3 undertaking surveillance projects;

2.4 maintaining a literature and information database.

3. Jointly maintain, and keep under review, a prioritised programme of survey and surveillance projects.

4. Share technical output equally under joint ownership and copyright.

5. Function as a technical, science based, group.

6. Form and appoint specific sub-groups to undertake specific responsibilities as required.

7. Publish an annual report which will comprise a summary of work undertaken, the executive summaries from individual project reports, a financial statement and the planned work programme.

8. Make its output available to the wider community in addition to its membership.

Membership and Funding

[3] The term Waterway in this document specifically refers to the waters, seabed and foreshore of the Milford Haven Waterway and the Daugleddau Estuary from a line between St Anne's Head and Sheep Island to the tidal reaches of the Eastern and Western Cleddau Rivers and other tributaries to normal tidal limits.

Membership is comprised of statutory authorities, industry and others with an interest in the environmental quality of the Waterway. Membership will be at the invitation and discretion of the Group's existing members.

Each member will contribute to the functioning of the group, either in monetary terms or 'in kind'.

Appendix 2: Memorandum of Agreement

THIS AGREEMENT is made the 1st day of July 2004

BETWEEN:

(1) **ChevronTexaco Limited** whose principal office is at Pembroke Refinery, Pembroke SA71 5SJ

(2) **Countryside Council for Wales** whose principal office is at Llanion House, Llanion Park, Pembroke Dock, Pembrokeshire. SA72 6DY

(3) **Environment Agency (Wales)** whose principal office is at Rivers House, Hawthorn Rise, Haverfordwest, Pembrokeshire. SA61 2BQ

(4) **Milford Haven Port Authority** whose principal office is at Gorsewood Drive, Hakin, Milford Haven, Pembrokeshire SA73 3ER

(5) **Pembrokeshire Coast National Park Authority** whose principal office is at Llanion Park, Pembroke Dock, Pembrokeshire SA72 6DY

(6) **Pembrokeshire County Council** whose principal office is at County Hall, Haverfordwest, Pembrokeshire SA61 ITP

(7) **Petroplus Tankstorage (MH) Ltd** whose principal office is at Waterston, Milford Haven, Pembrokeshire SA71 IDR '

(8) **South Wales Sea Fisheries Committee** whose principal office is at Queens Buildings, Cambrian Place, Swansea SAl 1TW

(9) **Total Refinery** whose principal office is at PO Box 10, Milford Haven, Pembrokeshire SA73 3JD

(10) **Welsh Water-Dwr Cymru** whose principal office is at Pentwyn Road, Nelson, Treharris, Caerphilly. CF46 6LY

(11) **Wildlife Trust South and West Wales** whose principal office is at The Welsh Wildlife Centre, Cilgerran, Cardigan SA43 2TB

Here and after referred to as "the Parties"

RECITAL

The parties have agreed to enter into this agreement to record and regulate the terms of their co-operation in order to provide high quality environmental information to the parties so enabling the parties to contribute to the maintenance and enhancement of the rich and diverse marine environment of the Waterway (as hereinafter defined) and to perform the objects set out in clause 2.2 under the terms of this Agreement

AGREEMENT

The parties agree as follows:

1. INTERPRETATION

1.1 In this agreement unless there be anything in the context inconsistent therewith the following expressions shall have the following meanings:

"Committee" has the meaning ascribed to it by clause 3.1 1. "Group" means the Milford Haven Waterway Environmental Surveillance Group created by this agreement and any agreement supplemental to it

"Group Members" means all of the parties listed above or some of them as the context admits and Group Member shall have a corresponding meaning

"Objects" means the objects of the Group more particularly itemised in clause 2.2

"Waterway" means the waters, seabed and foreshore of the Milford Haven Waterway and the Daugleddau Estuary from a line between St Anne's Head and Sheep Island to the tidal reaches of the Eastern and Western Cleddau Rivers and other tributaries to the normal tidal limits.

2. SCOPE OF THE JOINT VENTURE

2.1 The Group Members agree with one another to enter into this Agreement to provide high quality environmental information to enable the Group Members to contribute to the maintenance and enhancement of the rich and diverse marine environment of the Waterway and to perform the objects set out in clause 2.2 under the terms of this agreement

2.2 The Objects of the Group are:

2.2.1 to maintain surveillance of the quality of the marine physico-chemical environment and marine biology, and ornithology, of the Waterway;

2.2.2 to undertake surveillance of the Waterway by:

2.2.2.1 keeping under review all relevant survey, surveillance and monitoring as well as undertaking surveillance projects when necessary;

2.2.2.2 commissioning surveys to improve current knowledge and establish baselines; and

2.2.2.3 maintaining a literature and information database.

2.2.3 to share technical output equally under joint ownership and copyright

2.2.4 to function as a technical, science based, group

2.2.5 to make its findings available to the wider community in addition to Group Members

2.3 For the avoidance of doubt, nothing in this Agreement shall be deemed to override or in any way restrict the statutory duties or obligations of any of the Group Members

3. CONTROL AND MANAGEMENT

3.1 A committee ("the Committee") comprising of a representative nominated by each of the Group Members will be established for the purposes of:

3.1.1 discussing determining and approving the purpose, Terms of Reference and work programme of the Group

3.1.2 exchanging information

3.1.3 reporting on progress to include publishing an annual report that comprises of a summary of all work undertaken for the year, a financial statement and planned work programme for the forthcoming year

3.1.4 preparing an annual business plan

3.2 Each Group Member shall notify the Chairperson, or Secretary, in writing of their nominated representative and shall be entitled to appoint alternative representatives

3.3 The Committee shall appoint a Chairperson from its number to chair Committee meetings and a Vice Chairperson to chair committee meetings in the absence of the Chairperson. In the absence of both the Chairperson and the Vice Chairperson those nominated representatives present shall appoint one of their number present to act as Chairperson for that particular meeting. The term of office of the Chairperson and the Vice Chairperson will be subject to an annual review

3.4 The quorum for meetings of the Committee shall be 5 nominated representatives of the Group Members. Minutes of all meetings of the Committee shall be taken and kept in designated minute books by the Milford Haven Port Authority and copies of such minutes circulated to Group Members as soon as practicable after each meeting

3.5 Questions arising at a meeting of the Committee, that cannot be resolved by consensus, shall be decided by a majority of votes and each nominated representative shall have one vote. In the case of an equality of votes the Chairperson of the meeting shall have a casting vote. The nominated representatives may regulate the conduct of the meetings of the Committee as they consider appropriate

3.6 The Committee shall be entitled to delegate any of its functions to sub-committees or to other persons as it considers appropriate for the task; provided that the delegation and the reasons therefore are recorded in writing

3.7 Group Members shall not make any decisions on matters of principle relevant to the Terms of Reference of the Group without consulting the Committee

3.8 The Committee will meet as often as necessary or desirable for the purposes of achieving the objects set out in clause 2.2 at a convenient time and venue and any Group Member may call such a meeting by giving to the other Group Members 14 days prior notice in writing to that effect designating the time venue and items for the agenda of the meeting

3.9 The Group Members shall at all times co-operate with each other and act in good faith to enable the Group objects to be attained

4. RESOURCING

4.1 Each of the Group Members will provide either a monetary contribution or some other contribution eg services, premises that shall be agreed by all the Group Members for the furtherance of the Objects of the Group in accordance with the annual business

plan referred to in clause 3.1.4. The contributions are to be provided promptly within the time frame agreed for contributions

4.2 Milford Haven Port Authority shall receive all financial contributions by Group Members and shall keep such monies in a separate interest bearing bank account in trust for the Group. Milford Haven Port Authority shall make payments on behalf of the Group in respect of commitments agreed at clause 4.3 below but may not make any other payments or commitments on behalf of the Group without the prior approval of the Committee. Milford Haven Port Authority shall provide quarterly statements to the Committee in respect of such account

4.3 Under the terms of this Agreement Milford Haven Port Authority shall have the authority to enter into contracts including, without limitation, for the appointment of professionals, advisers and consultants on behalf of the Group subject to the prior approval of the Committee

4.4 No contracts shall be entered into unless there are sufficient funds available within the interest bearing bank account referred to in clause 4.2 to meet the obligations under the contract

5. INTELLECTUAL PROPERTY RIGHTS

5.1 All rights which may now or in the future subsist in respect of or derived from any intellectual property including without limitation all copyright, design rights, registered designs, trade and service marks (whether registered or not) and moral rights (including in all such cases any applications for any such rights or protections and any rights to apply therefore and all renewals continuations extensions renewals and divisions)(the "IP Rights") developed or generated by the Group in pursuance of the Objects shall be owned by the Group Members jointly

5.2 Any Group Member shall be entitled to use any IP Rights free of charge provided that any such use shall not compromise the Objects of the Group and provided further that if any Group Member wishes to license or authorise any third party to use or exploit any IP Rights, such third party shall be required to pay a licence fee calculated on an arms length basis

5.3 All costs and expenses and all receipts in respect of any intellectual property shall be shared equally by the Group Members

5.4 Each Group Member shall retain all IP Rights to all materials, information etc. contributed by that Group Member

6. LIABILITY

The Group Members agree that all losses, damages, costs and/or expenses incurred as a result of participation in the Group and/or any action taken in accordance with this Agreement shall be borne equally by all Group Members provided that if any such losses, damages, costs and/or expenses arise as a result of an act or omission attributable to one or more Group Members, for example a breach of clause 4.2 or if the action of one or more Group Members is not in proper pursuance of the Objects or if the action of one or more Group Members gives rise to a breach of a contract referred to in clause 4.3 or if any Group Member infringes the IP Rights of a third party, then that Group Member or those Group Members shall bear those particular losses, damages, costs and/or expenses and shall indemnify the other Group Members accordingly

7. TERM AND TERMINATION

7.1 The provisions of this Agreement shall come into force on the date stated above

7.2 A Group Member may at any time terminate its participation in respect of this Agreement subject to three months' notice in writing to the Chairperson with no right of return of contribution

7.3 In the event that any Group Member is in breach of this agreement which they fail to remedy within 14 days of written request by the Committee then such Group Member's involvement in the Group may be terminated by notice given to them by the Committee at any time following expiry of the said period of 14 days

7.4 Subject to clauses 7.2 and 7.3 this agreement will terminate on completion of the Objects stated in clause 2

7.5 Upon termination of this agreement the Group shall be terminated forthwith and the parties shall take such further steps as may be necessary in order to wind up the Group in a fair and reasonable manner. The assets of the Group at winding up should be distributed pro rata to the direct financial contributions by Group Members. If a Group Member's participation in the Group is terminated in accordance with clause 7.2 or 7.3 the provisions of clauses 5.1 to 5.3 shall no longer apply in respect of such Group Member

8. GOVERNING LAW

This agreement shall be governed by and construed in all respects in accordance with the laws of the European Union, England and Wales and all parties will submit to the jurisdiction of the courts of England and Wales

9. THIRD PARTIES

Nothing in this Agreement shall create any rights for third parties under the Contracts (Rights of Third Parties) Act 1999. No variation to this Agreement and no supplemental or ancillary agreement to this Agreement shall create any such rights unless expressly so stated in any such agreement by the parties to this Agreement. This does not affect any right or remedy of a third party that exists or is available apart from that Act

10. NO PARTNERSHIP

Nothing in this Agreement shall be construed as establishing or implying any partnership between the Parties hereto and nothing in this Agreement shall be deemed to constitute either of the Parties hereto as the agent of the other Party or authorize either Party (i) to incur any expenses on behalf of the other Party (ii) to enter into any engagement or make any representation or warranty on behalf of the other party (iii) to pledge the credit of or otherwise bind or oblige the other Party or (iv) to commit the other Party in any way whatsoever without in each case obtaining the other Party's prior written consent

11. SUCCESSORS

References in this Agreement to the parties shall include their respective heirs successors in title permitted assigns and personal representatives This Agreement shall be binding upon and enure to the benefit of the parties and their respective successors

12. ASSIGNMENT

No Member may assign its interests in this Agreement without prior approval of the Committee (not to be unreasonably withheld) except that no such approval is required for an assignment to a company in the same group as the Member

13. ARBITRATION

13.1 Any dispute or difference arising out of or in connection with this Agreement shall be referred to the arbitration of a sole arbitrator to be appointed in accordance with Section 16(3) of the Arbitration Act 1996 ("the Act") the seat of such arbitration being hereby designated as London England 13.2 In the event of failure of the parties to make the appointment pursuant to Section 16(3) of the Act the appointment shall be made by the President for the time being of the Chartered Institute of Arbitrators

13.3 The Arbitrator shall decide the dispute in accordance with the substantive laws of England and Wales

Appendix 3: Chronological list of MHWEMSG / MHWESG[4] reports

1992

Hobbs, G and Morgan, C I (eds.) (1992). *A review of the current state of environmental knowledge of the Milford Haven Waterway*. Report from Oil Pollution Research Unit; xi &140pp

Hobbs, G and Morgan, C I (eds.) (1992). *A review of the current state of environmental knowledge of the Milford Haven Waterway; Executive Summary*. Report from Oil Pollution Research Unit, 12pp

MHWEMSG (1992). *Report of the Milford Haven Waterway Environmental Monitoring Steering Group 1992*. 6pp

1993

Hodges, J E (1993). *Daugleddau Estuary and Milford Haven Waterway annual shelduck survey: report for 1993.* Report from Pembrokeshire Coast National Park Authority, 8pp + appendices

1994

Ellis, R & Poole, A (1994). *Cleddau Estuary wader and wildfowl counts 1993 – 94. 20* pp + appendices

Hodges, J E (1995). *Daugleddau Estuary and Milford Haven Waterway annual shelduck survey: report for 1995.* Report from Pembrokeshire Coast National Park Authority,8pp + appendices

Levell, D, Smith, J and Hobbs, G (1994). *Milford Haven macrobenthic survey October 1993*. Report from Oil Pollution Research Unit; xii, 26pp + figures, tables & data appendices.

MHWEMSG (1994). *Report of the Milford Haven Waterway Environmental Monitoring Steering Group 1993/94*. 20pp

Smith, J and Hobbs, G (1994). *Metal concentrations in Milford Haven sea bed sediments - data storage, analysis and initial interpretation*. Report from Oil Pollution Research Unit; v, 8pp + tables & maps

1995

Hodges, J E (1995). *Daugleddau Estuary and Milford Haven Waterway annual shelduck survey: report for 1995.* Report from Pembrokeshire Coast National Park Authority 10pp + appendices

Howe, M (1995). *Monitoring of eelgrass populations in the Milford Haven waterway and Daugleddau Estuary*. Report from Pembrokeshire Coast National Park Authority; 7pp

MHWEMSG (1995). *Report of the Milford Haven Waterway Environmental Monitoring Steering Group 1994/95.* 19pp

Poole, A & Ellis, R (1995). *Cleddau Estuary including Milford Haven Waterway: wildfowl and wader counts 1994 – 95.* 30pp

Rostron, D M (1995). *The macrobenthos of the foreshore soft sediments of Milford Haven, 1994*. Report from SubSea Survey; 2 vols, 17pp + maps, figures & data appendices

[4] The Group changed its name in 2000

1996

Hodges, J E (1996). *Daugleddau Estuary and Milford Haven Waterway annual shelduck survey: report for 1996.* Report from Pembrokeshire Coast National Park Authority, 8pp + appendices

MHWEMSG (1996). *Report of the Milford Haven Waterway Environmental Monitoring Steering Group 1995/96.* 14pp

Poole, A (1996). *Milford Haven and Cleddau Estuary wetland bird survey 1995-96*. 18pp

1997

Hodges, J E (1997). *Daugleddau Estuary and Milford Haven Waterway annual shelduck survey: report for 1997.* Report from Pembrokeshire Coast National Park Authority. 10pp + tables & appendices

MHWEMSG (1997). *Report of the Milford Haven Waterway Environmental Monitoring Steering Group 1996/97.* 36pp

Moore, J J (1997). *Rocky shore transect monitoring in Milford Haven, October 1995.* Report from Oil Pollution Research Unit. OPRU Report No OPRU/14/96. 36pp + appendices

Poole, A (1997). *Milford Haven Waterway and Cleddau Estuary bird survey 1996-97*. 13pp + appendices

1998

Hodges, J E (1998). *Daugleddau Estuary and Milford Haven Waterway annual shelduck survey – report for 1998.* Report from Pembrokeshire Coast National Park Authority. 9pp + tables & appendices

Munro, C (1999). *Monitoring of the rocky sub-littoral of Milford Haven: May-July 1998.* Report from Marine Biological Surveys. v, 38pp + appendices, photographs and videorecording

Poole, A (1998). *Milford Haven Waterway and Cleddau Estuary bird survey 1997-98*. 12pp + appendices

1999

Hodges, J E (1999). *Daugleddau Estuary and Milford Haven Waterway annual shelduck survey – report for 1999.* Report from Pembrokeshire Coast National Park Authority. 8pp + tables & appendices

Irving, R and Worley, A (1999). *Survey of sublittoral Zostera marina bed in Milford Haven. Field Report*. Report from Posford Duvivier. 4pp

Kitts, H (1999). *Quantification of inputs to Milford Haven*. Report from Hyder Ltd. 29pp + tables & appendices

MHWEMSG (1999). *Report of the Milford Haven Waterway Environmental Monitoring Steering Group 1997 - 1999*. 25pp

Poole, A (1999). *Milford Haven Waterway and Cleddau Estuary Bird Survey 1998-99*. 13pp + appendices

Posford Duvivier (2000). *A survey of subtidal Zostera beds in Milford Haven*. 36pp + appendices

2000

Bent, E J (2000). *A review of environmental studies in Milford Haven Waterway 1992 – 2000*. iv, 65 pp + tables & maps

Hodges, J E (2000). *Daugleddau Estuary and Milford Haven Waterway annual shelduck Survey – Report for 2000.* Report from Pembrokeshire Coast National Park Authority. 10pp + tables + appendices

MHWESG (2000). *Milford Haven Waterway Environmental Surveillance Group Annual Report 1999 - 2000*. 20pp & appendices

Poole, A (2000). *Milford Haven waterway and Cleddau Estuary Bird Survey 1999-2000*. 15pp + appendices

2001

Hodges, J E (2001). *Daugleddau Estuary and Milford Haven Waterway surveillance of summer shelduck populations: report for 2001.* Report from Pembrokeshire Coast National Park Authority. 8pp + appendices

Poole, A (2001). *Milford Haven Waterway and Cleddau Estuary bird survey 2000-01*. 14pp + appendices

2002

Hodges, J E (2002). *Daugleddau Estuary and Milford Haven Waterway surveillance of summer shelduck populations: report for 2002.* Report from Pembrokeshire Coast National Park Authority. 8pp + appendices

Poole, A (2002). *Milford Haven Waterway and Cleddau Estuary bird survey 2001-02.* 12pp + appendices

2003

Bent, E J (2003). *Milford Haven Waterway review of work programme 2000 – 2010*. 32pp

Hodges, J E (2004). *Daugleddau Estuary and Milford Haven waterway surveillance of summer shelduck populations: report for 2003.* Report from Pembrokeshire Coast National Park Authority. 9pp + appendices

Poole, A (2003). *Milford Haven Waterway and Cleddau Estuary bird survey 2002-03.* 16pp + appendices

Prosser, M V & Wallace H L (2003). *Milford Haven salt-marsh survey 2002.* Report from Ecological Surveys (Bangor). 2 vols. 58pp + appendices, photographs & maps

2004

Hodges, J E (2004). *Daugleddau Estuary and Milford Haven Waterway surveillance of summer shelduck populations: report for 2004.* Report from Pembrokeshire Coast National Park Authority. 7pp + appendices

Haycock, A (2004). *Milford Haven Waterway and Cleddau Estuary Bird Survey 2003-04.* 14pp + appendices

2005

Atkins (2005). *Development of an Inputs Budget for Milford Haven Waterway.* 68pp + cd database & GIS data

Hodges, J E (2005). *Daugleddau Estuary and Milford Haven Waterway surveillance of summer shelduck populations: report for 2005.* Report from Pembrokeshire Coast National Park Authority. 8pp + appendices

Haycock, A (2005). *Milford Haven Waterway and Cleddau Estuary Bird Survey 2004-05. 7*pp + appendices

2006

Hodges, J E (2006). *Daugleddau Estuary and Milford Haven Waterway surveillance of summer shelduck populations: report for 2005.* Report from Pembrokeshire Coast National Park Authority. 8pp + appendices

Haycock, A (2006). *Milford Haven Waterway and Cleddau Estuary Bird Survey 2004-05. 7*pp + appendices

Warwick, R (2006). *Review of benthic and intertidal sediment macrofauna data and development of a surveillance programme*. 105pp + electronic data annex

2007

Hodges, J E (2007). *Daugleddau Estuary and Milford Haven Waterway surveillance of summer shelduck populations: report for 2006.* Report from Pembrokeshire Coast National Park Authority. 8pp + appendices

2008

Haycock, A (2008). *Wildfowl and wader counts on the Milford Haven Waterway 2006-07* 20pp

Haycock, A (2008). *A review of the status of wetland birds in the Milford Haven waterway and Daugleddau estuary*. A report to the Milford Haven Waterway Environmental Surveillance Group. 122pp

Hodges, J E (2008). *Daugleddau Estuary and Milford Haven Waterway surveillance of summer shelduck populations: report for 2008*. Report from Pembrokeshire Coast National Park Authority. 26pp + appendices

2009

Haycock, A (2009). *Wildfowl and wader counts on the Milford Haven Waterway 2007-08* 20pp

Hodges, J E (2009). *Daugleddau Estuary and Milford Haven Waterway surveillance of summer shelduck populations: report for 2009*. Report from Pembrokeshire Coast National Park Authority. 9pp + appendices

Langston, W J, O'Hara, S, Imamura M & Pope, N D (2009) *Bioaccumulation surveillance in Milford Haven Waterway 2007-2008*. Report to the Milford Haven Waterway Environmental Surveillance Group from the Marine Biological Association Plymouth. 66pp + appendices

Little, D I (2009) *Sediment Contaminants & Transport Review*. A report to the Milford Haven Waterway Environmental Surveillance Group. 368pp + appendices

2010

Haycock A (2010). Wildfowl and wader counts on the Milford Haven Waterway, 2009-10. A report to the Milford Haven Waterway Environmental Surveillance Group. 24pp

Hodges, J E (2010). *Daugleddau Estuary and Milford Haven Waterway surveillance of summer shelduck populations: report for 2010.* Report from Pembrokeshire Coast National Park Authority. 8 pp + appendices

Mieszkowska, N. (2011). Reestablishment of intertidal rocky surveillance. A report to the MHWESG from the Marine Biological Association on ot the UK. 54pp + appendices.

2011

Haycock A (2011). Wildfowl and wader counts on the Milford Haven Waterway, 2010-11. A report to the Milford Haven Waterway Environmental Surveillance Group. 24pp

Hodges, J E (2011). Daugleddau Estuary and Milford Haven Waterway surveillance of summer shelduck populations: report for 2011. Report from Pembrokeshire Coast National Park Authority. 8pp + appendices

2012

Fugro-ERT (2012). Investigation into the source of hydrocarbons present in sediment samples from Milford Haven waterway. Report to the Milford Haven Waterway Environmental Surveillance Group from the Fugro-ERT (Fugro Geoconsulting). v&40pp + appendices

Hodges, J E (2012). Daugleddau Estuary and Milford Haven Waterway surveillance of summer shelduck populations: report for 2012. Report from Pembrokeshire Coast National Park Authority. 9pp + appendices

Langston, W J, O'Hara, S, Davey, M, Shortridge, E, Pope, N D, Harino, & Vane, C H. (2012) Bioaccumulation surveillance in Milford Haven Waterway Phase II (2010) Report to the MHWESG from the Marine Biological Association UK. 85pp + appendices

2013

Germano & Associates (2013). Sediment-Profile Imaging Survey of Milford Haven Waterway, Wales, UK - May 2012. Report to the Milford Haven Waterway Environmental Surveillance Group from Germano & Associates, Inc., Seattle, Washington, USA. vii&34pp + tables, figures and appendices

Haycock, A (2013). A review of the status of wetland birds in the Milford Haven Waterway and Daugleddau Estuary 2013 A report to the Milford Haven Waterway Environmental Surveillance Group. 123pp

Hodges, J E (2013). Daugleddau Estuary and Milford Haven Waterway surveillance of summer shelduck populations: report for 2013. Report from Pembrokeshire Coast National Park Authority. 9pp + appendices

2014

Galperin, Y & Little, D I (2014). Forensic Evaluation Of Milford Haven Sediment Hydrocarbon Contamination: Supplemental Report. Report to Milford Haven Waterway

Environmental Surveillance Group from EGC Consulting California USA & David I. Little; 60 pp.

Haycock, A (2014). A review of the status of wetland birds in the Milford Haven Waterway and Daugleddau Estuary 2013. A report to the Milford Haven Waterway Environmental Surveillance Group; 24 pp.

Morrell, S (2014). Rocky Shore Surveillance 2013. Report to Milford Haven Waterway Environmental Surveillance Group from the Field Studies Council Dale Fort Field Centre; 50 pp.