MILFORD HAVEN WATERWAY
ENVIRONMENTAL SURVEILLANCE GROUP

GRŴP CADW GOLWG AMGYLCHEDDOL
AR DDYFRFFORDD ABERDAUGLEDDAU

MILFORD HAVEN WATERWAY ENVIRONMENTAL SURVEILLANCE GROUP

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COVER IMAGES

Seagrass or eelgrass, *Zostera marina* © Swansea University

MILFORD HAVEN WATERWAY ENVIRONMENTAL SURVEILLANCE GROUP

Dragon LNG

Natural Resources Wales

Pembrokeshire Coast National Park Authority

Pembrokeshire County Council

Port of Milford Haven

Puma Energy Ltd

RWE Generation UK

Sem Logistics Milford Haven Ltd

South Hook LNG Ltd

Valero Energy Ltd

Wildlife Trust West Wales (corresponding)

Welsh Government Environment Division (observer)

Contact the MHWESG by e-mail at
mhwesg@gmail.com

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Milford Haven Waterway Environmental Surveillance Group
Report 2015 & 2016

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Chairman's Foreword

It's tempting to look back at the last two years of work as a frustrating pause in momentum for us as a group, but that would belittle the efforts by all parties to find an improved way forward. Our new Collaboration Agreement lays an essential foundation for the work that comes next, securing an enhanced ability to manage contracts and safety measures on a professional footing in order to go where the science and long term monitoring needs take us. This is no mean feat for what may outwardly appear a group of disparate interests, drawn together only by a common interest in the Milford Haven Waterway.

The challenge for the Group has not ended there, as again we have bid farewell to steadfast and dedicated Group members who embark on the next step in their professional and private lives; their input will be widely missed. Where new Group representatives have joined we welcome the viewpoints and understanding that new perspectives can bring.

Looking forward, I will be handing on the Chair's reins to Paul Howells of Dragon LNG. He not only brings a wealth of experience and common sense to the role but also a clear understanding of the principles of collaboration and goodwill which have served the Group so well to date. I have no doubt that this will continue.

I am left only to thank the members of the group for their resilience and perseverance in finding a way for us to work together going forward. I reserve particular thanks for our project manager, Blaise Bullimore. For someone who is happier exploring the underwater environment rather than the desktop one, he has been dogged in his determination in pursuing the administrative and long term needs of the group.

Roland Long

Pembroke Power Station

Chair

Rhagair y Cadeirydd

Mae'n demtasiwn i edrych yn ôl ar y ddwy flynedd ddiwethaf o waith fel saib rhwystredig mewn momentwm ar gyfer ni fel grŵp, ond byddai hynny'n bychanu'r ymdrechion gan bob plaid i ddod o hyd i ffordd newydd ymlaen. Mae ein cytundeb cydweithredu newydd yn gosod sylfaen hanfodol ar gyfer y gwaith sy'n dod nesaf, gan sicrhau gwell gallu i reoli contractau a mesurau diogelwch ar sail broffesiynol er i fynd lle y wyddoniaeth ac anghenion monitro hirdymor mynd â ni. Mae hyn yn dipyn o gamp ar gyfer yr hyn a allai ymddangos yn allanol grŵp o fuddiannau gwahanol, tynnu at ei gilydd yn unig gan diddordeb cyffredin yn y Ddyfrffordd Aberdaugleddau.

Yr her ar gyfer y Grŵp wedi dod i ben yno, fel y unwaith eto rydym wedi ffarwelio aelodau cadarn ac ymroddedig Grŵp sy'n cychwyn ar y cam nesaf yn eu bywydau proffesiynol a phreifat, bydd eu cyfraniad yn cael ei golli yn eang. Lle cynrychiolwyr grwpiau newydd wedi ymuno rydym yn croesawu safbwyntiau a dealltwriaeth y gall safbwyntiau newydd ddod.

Gan edrych ymlaen, byddaf yn dosbarthu ar yr awenau Cadeiryddion i Paul Howells o Dragon LNG. Mae'n nid yn unig yn dod â chyfoeth o brofiad a synnwyr cyffredin i'r rôl ond hefyd dealltwriaeth glir o egwyddorion cydweithredu ac ewyllys da sydd wedi gwasanaethu'r Grwp mor dda hyd yma. Nid oes gennyf unrhyw amheuaeth y bydd hyn yn parhau.

Yr wyf yn gadael yn unig i ddiolch i aelodau'r grŵp am eu gwydnwch a dyfalbarhad wrth ddod o hyd i ffordd i ni weithio gyda'n gilydd yn y dyfodol. Rwy'n cadw'r ddiolch yn arbennig ar gyfer ein rheolwr prosiect, Blaise Bullimore. Ar gyfer rhywun sydd yn hapusach archwilio'r amgylchedd tanddwr yn hytrach na'r un bwrdd gwaith, mae wedi bod yn llawn yn ei benderfyniad wrth fynd ar drywydd anghenion tymor gweinyddol a hir y grŵp.

Roland Long

Gorsaf Bŵer Penfro

Cadeirydd

1. Introduction

This is the sixteenth annual report of the Milford Haven Waterway Environmental Surveillance Group (formerly the Milford Haven Waterway Environmental Monitoring Steering Group). It covers the period January 2015 to December 2016.

A detailed history of the Group and it's outputs since its establishment in 1991 was included in the 2013 report and readers wishing to know more about the development of the Group and projects completed up to the end of 2013 are referred to that report which is available as a PDF document on request.

In early 2015, members agreed that the Memorandum of Agreement under which the Group had operated since 2004 had been overtaken by time. In addition to the Group having gained additional members, all the refineries had changed ownership, Milford Haven Port Authority had changed its trading name to the Port of Milford Haven, the Countryside Council for Wales and the Environment Agency Wales had been dissolved in 2014 and their functions subsumed into the newly created Natural Resources Wales, Welsh Water had withdrawn and the South Wales Sea Fisheries Committee had been dissolved; of the original MoA signatories only two retained their name or legal status.

To accommodate the views of the member organisations, it was agreed to replace the formal MoA with a less formal and non-binding knowledge collaboration agreement. Although it was hoped this could be accomplished easily and speedily, given the differences of the membership organisations and their differing appetites for the degree of informality or binding nature of an agreement, reaching a consensus took a considerable time. The new Collaboration Agreement is reproduced as Appendix 2.

Members agreed to suspend field-work during the negotiation of the Agreement, perhaps not anticipating the length of time it would take. However, although this stalled implementation of the Group's work programme, it provided an opportunity to complete the overdue desk study reviews which comprise the bulk of section 2.

The major project for 2015 was to initiate routine sediment contaminants surveillance as recommended by Little (2009), by undertaking paired analysis of sediment samples using current and 'historical' (1970s – 80s) analytical techniques so as to enable integration and comparison of currently incomparable datasets. This work resulted in two data feeder reports and a comprehensive analysis of their data and other data sources. The summary from the review from forms section 2.1 of this report.

Whilst it was the known inconsistencies between earlier and recent laboratory methods that stimulated the need for this project, David Little's thorough detective work unearthed several further issues.

In trying to clarify the laboratory methods used over time, not only in studies for the Group, but in other's surveys, environmental impact and compliance assessments and so forth, Dr Little discovered that documentation of methods, particularly sample preparation, was often inadequately reported. He made enquiries with several laboratories and individuals, often using his network of personal contacts, to unearth methods statements going back over 30yrs. Since many laboratories had changed ownership and/or staff had retired, this was challenging and in some cases the best information that could be obtained was laboratory staff's personal

recollections. His investigations suggest there have been substantial differences between sample preparation and laboratory methods over time, though there appear to have been improvements since 2000. The significance of the differences to the data is not known (and probably cannot be known) but, through this contract, MHWESG is in the advantageous position of having had these potential inconsistencies identified and resolved or explained in respect of the data available to the Group. Nevertheless, it appears that inter-comparability of long-term metals data may be compromised to some degree in wider UK monitoring programmes.

The Port of Milford Haven's former Environment Manager and one of the Port's representatives on the Group for many years, Dave Levell, had taken a particular interest in David Little's suite of projects and their reports and had regularly provided robust constructive critical reviews which David Little always acknowledged led to the reports being improved. Despite having retired, Dave was invited and agreed to review this most recent report; his general comments were particularly valuable and illuminating, and are reproduced almost in their entirety:

> "This is a comprehensive and complex report which answers some of the longstanding uncertainties concerning the variety of analytical methods and confidence that can be placed in the comparability and results of monitoring studies (in this case of sediment contaminants) that have been used through the long history of environmental studies throughout the waterway.
>
> It is a report that could probably only have been compiled by a person who has also had a long-term involvement and understanding of the Waterway, its industrial history, variety of studies and their objectives, along with a personal interest and commitment to wider understanding of the sediment related uncertainties and processes within the Waterway. It is an exemplar of the benefits of having a fully interpretative report, rather than the simple presentation of a set of analytical results that, although of course less costly, generally provides little basis for confident decision making unless the technical specialist is available within the client group for further understanding and context.
>
> It is a complex subject and requires a determined effort on the part of the reader to grasp the Daedalian complexities that arise from the diversity of methodologies employed historically both within the field sampling and particularly the subsequent laboratory analyses.
>
> I particularly liked the section which illustrates the difficulties arising from the above, and also the dangers of the blind comparison of data sets.
>
> There is an awful lot of concentrated reading required and I have made relatively few significant comments – reflecting the thorough nature of this well constructed report.
>
> Although there is a natural reluctance to highlight the inadequacies or limitations imposed by previous work, this does not detract from the value of this comprehensive review of the long-term comparability and confident identification of trends in the monitoring of MHW sediment hydrocarbons and metals."

Since all the then available macrobenthic data was reviewed in 2006 by Richard Warwick, Plymouth Marine Laboratory, three rounds of macrobenthic sampling has been undertaken by the Group and several other macrobenthic datasets have been collected by Group members. Richard was invited to update his review using the Group's data plus data provided from NRW and RWE Npower monitoring programmes. The summary of this work forms section 2.2

The Group previously provided support for analysis of seagrass, *Zostera marina,* tissue samples from Gelliswick Bay as contribution to a Swansea University MSc student project investigating the potential of seagrass as an ecological status indicator. Following this, Swansea University were commissioned to undertake a review of all known and available seagrass data from the Haven; the summary of this work forms section 2.3.

The established annual wetland bird surveillance projects continued and are summarised in sections 2.4 and 2.5.

2. Group activity 2015-16

2.1 Sediment contaminant concentrations in Milford Haven waterway: data conversion and timeline.

David I. Little

Executive Summary

Introduction: Different methods for analysing hydrocarbons and trace metals give different results. Because methods have changed over the years it has become difficult to compare current levels in a meaningful way with those recorded in the past. This project was designed to establish the long-term trends in the sediment contaminants of Milford Haven Waterway (MHW) by inter-calibrating and comparing the historical and more contemporary analytical methods that have been used. By using data converted so as to be comparable with the more contemporary methods, the aims of the project were to create a reliable baseline for future routine sediment surveillance as well as Environmental Impact Assessments (EIA), to add to the understanding of past oil spills, other oil and trace metals inputs, and engineering interventions in MHW. The objectives were to:

- collect pairs of sediment samples at 15 locations in MHW;
- contract suitably experienced laboratories for the analysis of samples for total hydrocarbons (THC) and selected trace metals (Cefas and University of Plymouth appointed respectively);
- use for both THC and trace metals a historical analytical method on one of each pair of replicates and a more contemporary method on the other of each pair;
- from the above historical and contemporary methods produce a range of conversion charts of THC and trace metals concentration data for critical evaluation;
- use the optimum conversion charts to convert the existing datasets of THC and trace metals from the previous sediment contaminant surveys in MHW; and
- assess and interpret the statistical and environmental significance of the detected changes in the converted data through time.

Hydrocarbons results: Once the results of conversions had been established it was possible to determine reliably the significant changes through time in mean THC concentrations using the t-test. The converted THC timelines and spatial patterns at stations common to many surveys in MHW confirmed that THC concentrations have declined from peaks in World War 2, and from the high levels in the period between the 1960s and peak oil throughput in 1974, as the oil refineries developed but before modern effluent treatment standards were applied. THC peaks also occurred after significant oil spills, but not all oil spills. Very high concentrations of oil from the *Sea Empress* in 1996 were limited to shorelines, in contrast to the muted THC peaks in the subtidal zone. According to recent published chemistry forensics work from MHWESG projects, within MHW this oiling input was of heavy fuel oil (HFO) rather than the cargo of Forties Blend crude oil (FBCO) from the *Sea Empress*.

The hydrocarbons datasets were all converted to the equivalent of FBCO because this oil type had been used widely in MHW to calibrate the post-*Sea Empress* THC analyses by ultraviolet

fluorescence (UVF) spectroscopy. Although all expressed as mean concentrations, the datasets sometimes do not have very wide and comparable coverage, for example as between comparing pre-dredging berthing slot surveys with the periodic wider area surveys of MHW. Nevertheless, it was seen that THC concentrations were:

- Highest in the Pwllcrochan and Kilpaison (Angle Bay) intertidal surveys following the *Sea Empress* (1996);
- High during both World Wars, at peak oil throughput in 1974 before investment in effluent improvements, in 1986 after *Matco Avon* and *Agapi* (both 1984), in 1989 after *El Omar* (1988) and until 1997 after *Sea Empress* (1996) spills;
- Broadly similar near the beginning (19th century) and end of the study period, with generally lower levels from the 1990s (excluding *Sea Empress*) to the early 2000s, in line with oil refinery and municipal effluent reduction programmes; and
- Moderately high again during periods of dredging and construction in the later 2000s including the major developments of liquefied natural gas (LNG).

There were 5 highly-significant increases and 5 highly-significant decreases of mean THC concentrations through time, suggesting a broadly stable anthropogenic background THC concentration in MHW sediments. In addition, an attempt was made to discern spatial trends from among the converted THC data. Unfortunately, even when position-fixing precision was relaxed to include nearby sites, there were relatively few stations in common to most of the surveys (14 stations with 3 - 7 common sampling occasions since 1978). The local variations in THC concentrations through time show that:

- There was a gradient from low to higher THC concentrations from the lower MHW to the inner estuary and central tributaries, superimposed on which were higher THC concentrations at the head of MHW (e.g. from river catchments, trunk road run-off and Haverfordwest);
- The *El Omar* oil spill in December 1988 was the likely cause of increased THC concentrations in Eastern Cleddau, Garron Pill, Cosheston Point, and Carew and Cresswell rivers;
- Sediment off Cosheston Point has shown high but fluctuating contaminant status in a dataset of annual monitoring, and at this site THC concentration was very high in October 1993 which is interpreted as a result of sediment resuspension by dredging disturbance down-estuary;
- The *Sea Empress* oil spill in February 1996 was the likely cause of increased THC concentrations in Angle Bay, two mid-channel subtidal sites (north of Pwllcrochan Flats and near Llanreath), and lower Carew River;
- Sites in Pembroke River, Cresswell River and the mid-channel site off Llanreath showed THC concentration peaks in 2010;
- Although the lower Western and Eastern Cleddau rivers, Llangwm Pill, and lower Garron Pill generally showed decreasing THC concentrations since 1978, they appeared to have deteriorated again by the time of the present survey in 2014.

The above most recent increases in mean THC concentrations might appear anomalous in the absence of significant oil spills, in the light of improving industrial and municipal effluents inputs, and considering the reduced economic activity since the financial crisis from 2008. However, deposition of THC in fine-grained sediment sinks throughout MHW since 2006 may have been caused by redistribution of historically-contaminated sediment previously disturbed during several years of construction and dredging. Each of the above points has been corroborated by the conclusions from detailed forensics and temporal analyses in MHWESG projects, and published in peer-reviewed journals.

The method for the determination of THC in sediments by UVF spectroscopy used at Cefas is fully validated to ISO 17025:2005 and UKAS accredited. However, the gravimetric methodology is not routinely used at Cefas and was implemented solely for the purpose of this project; as such, it was therefore not part of Cefas' Schedule of Accreditation to UKAS. Unfortunately, both of the field replicates were not analysed using both THC methods and this potentially affected the absolute confidence in the otherwise strong data conversions applied for THC. However, the use of the two methods on separate field grabs at least constituted a worst-case comparison, and despite this, produced a significant correlation and a strong regression equation to be used in converting MHW historical datasets.

Trace metals results: Significant changes through time were also determined for selected trace metal concentrations using the t-test, as follows:

- ***Increases*** in mean concentrations of cobalt (Co), chromium (Cr), nickel (Ni) and zinc (Zn) between April 1982 and April 1984 in the MHW down-estuary of the Cleddau Bridge;
- ***Decreases*** in mean concentrations of copper (Cu) and vanadium (V) between April 1982 and April 1984 in both the Jetty area and Pembroke River, and also of Ni in Pembroke River; percentage aluminium (Al) also decreased in the same way;
- ***Increases*** in mean concentrations of Cr and V in the whole of MHW between 1984 and 1993, especially in the Jetty area and Pembroke River, perhaps due to a peak in dredging activity at the Gulf and Petroplus terminal in 1992;
- ***Decreases*** in mean concentrations of Ni and lead (Pb) in the Daucleddau between 1984 and 1993, but many of the stations sampled in 1993 were located nearer channels and thus had coarser sediments than those sampled in 1984;
- ***Decreases*** in mean concentrations of lithium (Li) and lanthanum (La) in the Daucleddau between 1984 and 2014;
- ***Decrease*** in mean Pb concentrations in the whole of MHW between 1993 and 2007;
- ***Increases*** in mean concentrations of Cr, Zn, Pb, and arsenic (As) after dredging at Texaco and Petroplus jetty areas in 2002; increases lasted for up to 2 years, but note that all except Ni had recovered by 2005, and all except Zn had been much higher in nearby stations in 1982 (no data near Texaco and Petroplus in 1984);
- ***Decreases*** in mean concentrations of Cr, Cu, Pb, Zn, mercury (Hg) and cadmium (Cd) in the whole of MHW between 2007 and 2012, probably due to recovering conditions after the largest peak in dredging activity in 2006; and

- ***No changes*** were significant between 2012 and 2014 in spite of ongoing albeit decreasing dredging activity between 2010 and 2012.

The t-test results indicate that there were 22 highly-significant increases and 27 highly-significant decreases of mean trace metals concentrations through time. Unlike the fluctuations in THC which tended to cancel out each other in the long-term, the overall trends in trace metals indicated a noticeable decrease. This was also visible spatially, for example where Pb concentration declined through time at many stations, in particular the innermost reaches of MHW; closure of local sewage outfalls or investment in treatment, reduction in lead domestic plumbing, and the elimination of tetraethyl Pb as a petrol additive are each likely to have contributed.

Some trace metals concentrations were broadly similar almost throughout the period since the late 18th century except after significant dredging and engineering interventions such as those peaking during 2006. This implies that there is also an anthropogenic background of trace metals concentrations through time in MHW sediments, as with the THC concentrations. This finding suggests equilibrium between, on the one hand, new inputs and contaminant resuspension and, on the other, controlling factors such as the clay mineralogy, organic coating, surface charge and surface area of sediment particles.

The trace metals work was outside the scope of the ISO 9001:2008 certification of the laboratory at University of Plymouth, and was implemented for the sole purpose of this project. However, the trace metals data conversions and the above timeline and spatial patterns may be drawn with some confidence, because the laboratory procedures and the results obtained were under good analytical control, as shown by percentage recovery of standard compounds run with the analysis.

In contrast, the variability between the field replicate grabs for trace metals analysis was sometimes high. This is a common factor in all field sampling of sediment systems, due to the necessary compromise between sampling rigour and cost, leading to inevitable concerns about the representativeness of field samples. Therefore, it should be borne in mind during the application of the regression models used for data conversion, in particular where one station (off Llangwm, which has shown anomalous trace metals concentrations in previous surveys) exerted unduly high influence on the slopes of the regression graphs.

Discussion: No chronology of sediment contaminants would have been complete or possible in the present study for the period before 1978 (THC) or 1982 (trace metals) without the radionuclide-dated cores from four locations in MHW analysed in 1985-86. There are always possibilities of diagenetic (post-deposition of sediments) remobilisation of both radionuclides and contaminants, which if not understood may prevent the interpretation of pollution chronologies in cores. However, the 1980s coring locations were selected from areas with positive residuals of multiple regression analyses of contaminants on variables such as particle size and sediment major element composition. This statistical support for the linkage of sediments and contaminants during accretion minimised the problem of contaminant remobilisation after settlement, and means that the data conversion and historical trends produced in the present study were sound. The usefulness of the core-profiling approach to establishing timelines of contaminants is thus reinforced.

These 1980s cores also provided the only previous data on Rare Earth Elements (REE) for MHW, and the comparisons with the recent survey in 2014 were robust. Concentrations of lanthanum (La) and ytterbium (Yb) in sediment have fallen, and dysprosium (Dy) levels increased over thirty years, but there were no major changes in REE concentrations. REE are potentially emerging sources of contaminants from waste streams of the electronics and renewables industries, which to date have not been present within the catchment or MHW.

Dredging is an episodic but recurrent source of fine sediment resuspension, along with the associated contaminants. In low-turbidity systems like MHW, dredging impacts above background conditions are probably greater than in those estuaries with well developed turbidity maximum zones and spring tide movements of cohesive fine sediment taking place on a fortnightly basis. Effects of particle size strongly influence the higher concentrations of both THC and trace metals found in finer-grained sediments. This study has revisited the predictions of THC threshold effects concentrations from percentage mud content of the sediment. In this regard, the literature published after the *Sea Empress* that failed to consider the exact THC methodology before applying the percentage mud/THC model, has now also been corrected.

The effects of percentage mud as a master variable for trace metals concentrations was less distinctive than it was for THC, although positive residuals for both THC and metals clearly indicated contamination peaks once the sediment percentage mud had been taken into account. Previous published studies in MHW have shown that along with particle size, it is likely that major elements such as aluminium (Al), iron (Fe) and manganese (Mn) exert a dominant influence on trace metals concentrations, but this has not yet been fully re-explored in the present study.

One of the more challenging considerations when a long-term timeline is being developed in areas of high background hydrocarbon levels such as MHW is separating specific pollutants from the background. In this regard, for conversion of THC data it might be argued that the UVF data could instead be converted to gravimetric data rather than *vice versa*, as has been done in the present study. The UVF data are not source-specific and are dependent on the choice of calibrant oils, which in the case of MHW has been FBCO since the *Sea Empress*. Ironically, FBCO has not been detected since the immediate spill follow-up in 1997, and so there is no particular analytical justification for continuing with UVF apart from monitoring consistency. When the gravimetric method is supported by more specific methods, such as gas chromatography (GC) and on selected samples by GC-mass spectrometry (GC-MS), the information yield would be far greater, albeit at greater cost than by UVF. There are many important issues in the balance when measuring THC in sediments, and the results are invariably operationally defined by the method used. Hence the need in such work for full descriptions of methods, the reasonable scrutiny of methods and data by the commissioning groups, even after long periods under archive, and the review and publication of results by the researchers involved.

A similar challenge with trace metals work is the sample preparation method and particularly the choice of acids. In the same way as the above trade-off between gravimetric and UVF methods for standardising THC was something of an open question, it might be argued that total metals digestion by strong acids (i.e. mixtures including hydrofluoric acid) is more reliable in monitoring than total metals using *aqua regia*, or partial digestion using weaker

acids. The latter are often used in the belief that they better represent the (unspecified) bioavailability of the metal(s). Hydrofluoric acid is used in the development of sediment quality guidelines and, crucially, also allows normalisation of trace elements to Al, a distinct advantage in sediment monitoring across particle size and mineralogy gradients. The use of *aqua regia* grossly underestimates Al concentrations. And yet, because of the need to maintain consistency in MHW, and the higher hazard of hydrofluoric acid, the present study has converted as much of the data as possible to the equivalent of *aqua regia* extracted from sediments pre-screened at 2 mm.

The screening out of coarse material is sensible in order to reduce the variability of data that is introduced by sub-sampling errors in the laboratory, and because most of the metals reside in the <2 mm fraction. However, there are important reservations concerning pre-screening of sediments when this involves wet sieving prior to trace metals analysis. In MHW this has only been used for the separation of <63 μm sediments in analyses by the National Rivers Authority (NRA) in 1993. It is likely that the more soluble elements which are bound to the sediment particle surfaces (e.g. calcium, potassium, sodium, phosphorus, magnesium, and cobalt), could be lost during the process as the solubility of some of these elements varies between waters of differing salinities. If the total metals concentration actually present in a sample is unknown, then how much would be lost during wet sieving is also unknown. Wet-sieving has the effect of concentrating the finer sediment material so that otherwise sandy stations appear more 'contaminated' compared to results from other methods. Generally, the 1993 NRA survey was satisfactory for the trace metals timeline except in the anomalous cases of Cu and Zn which were extremely high in the wet-sieved samples at all stations. There is a lot to consider when measuring trace metals in sediments and the actual amounts measured are indeed operationally defined by the method used.

The proper design and conduct of field sampling and the employment of modern certificated laboratories and accredited methods are now part of the standard approach in MHW. However, the findings of periodic MHWESG reviews have repeatedly shown the difficulties of data comparability. Laboratory certification alone does not guarantee anything more than that the laboratory follows procedure and is generally fit-for-purpose (e.g. ISO 17025:2005 relates to general laboratory management and competence). In many studies reviewed and from which data were converted for use in this timeline study, the preparatory and digestion methods were not documented properly in several monitoring and important EIA projects. Given the challenges discussed above, this seems to represent a fundamental lapse in the scientific method.

The laboratories employed in the early history of monitoring in MHW and other areas have been bought out and/ or closed down, making changes in personnel inevitable and differences in former laboratory protocols difficult to identify. The market for performing literature searches, analysing samples and writing environmental statements is now dominated by large commercial contract laboratories and consulting companies; as a result, laboratory equipment and management systems have evolved and usually improved. However, the present project has found that the data employed for EIAs is sometimes rather dated, selectively interpreted and difficult to find. Consequently, the environmental assessments themselves in some cases may be of limited or deficient quality. Examples include: the citation by consultants of 1993 NRA data for background

concentrations that in the above cases of Cu and Zn were suspect; and the occasional selective used of unpublished data to best suit a preferred interpretation or a planning application, in spite of the larger datasets from the 1980s being published and available in the peer-reviewed literature.

The intractability of reconstructing historical analytical methods and of interpreting the confusing results sometimes obtained in the development of contaminant timelines was the original unsolved problem that led to this project. New analytical methods for hydrocarbons and trace metals are developed from time-to-time, and laboratory certification and accreditation in part depend on keeping methodologies up-to-date. No-one can or should want to resist the genuine innovation represented by high quality and affordable new methods. However, the dilemma arises that monitoring schemes generally benefit from the maximum possible consistency of methods through time.

An example is that Laser Induced Breakdown Spectroscopy (LIBS) may increasingly replace the established sediment trace element monitoring methods because it has the major advantage for health, safety and environment of not requiring the use of hazardous reagents such as strong or indeed any acids. One of the other advantages of LIBS is that the method only requires very small samples. These could be taken from sectioned cores which are typically sliced thinly and samples are therefore small. LIBS would also help in the case of subsamples from the much larger grabs taken for biota, without the need to take separate grab samples for the trace metals analyses. The traditional dilemma of field sampling is to balance the ideal effort *versus* the cost of achieving it. If this balance is lost, then there is a danger of a sophisticated laboratory analysis failing to represent field conditions adequately. However, the use of LIBS may provide greater insight into field sampling variability because it would reduce ship time and storage space requirements for a given sampling effort and outcome. If it is the expectation that LIBS or another emerging technology will be adopted more widely in future in marine sediment monitoring studies by MHWESG, then more information will be needed on the advantages and disadvantages of any such candidate methods. Most importantly, if a novel method is to be adopted, then a thorough overlap and inter-calibration exercise is essential at the time of changeover.

The MHWESG has clearly played a pivotal role in leading the surveillance effort in MHW. This study has reinforced the view that monitoring and surveillance data collected over long time frames are potentially of great value in understanding estuarine processes and in sustaining environmental quality. However, the potential value is only fully realised when all data are subject to proper curation, and this includes the ancillary information on the context, constraints and methods of each survey. An obvious example applicable to the private, public and voluntary sectors is the need to ensure that sufficient documentation is irrevocably attached to the tables of results whether held in databases or not; otherwise data can circulate long after the original purpose of the project has been served and any specific constraints and methods employed forgotten.

Recommendations: The following recommendations are made in an approximate order of priority (i.e. urgency and importance) and mindful of increasing project size and complexity:

1. Laboratory holding times on the samples from the present study in December 2014 have now expired. If possible, these should be stored by arrangement with Cefas until analysed

with the next sampling event. It would be useful to include them alongside characterisation of the as yet unknown but potentially large historical Polycyclic Aromatic Hydrocarbons (PAHs) inputs from Llanreath tank farm and Hook colliery.

2. There is a need to flag and, if possible, to amend data showing deficiencies for various trace metals before they are used in further EIAs and other projects. In particular, copper and zinc in the 1993 MHWESG survey of metals analysed by the former National Rivers Authority should be given a high alert.
3. The difficulties with data from the 1993 trace metals survey arise from a range of factors, including the well-intentioned use of sieving at 63 μm to overcome sample variability by selecting a narrower range of particle sizes. Future analysis should standardise on <2 mm size followed by *aqua regia* extraction, with a subset using digestion in $HF/HClO_4$.
4. Laboratory methods should be spelled out in project tenders by MHWESG and in reports by contractors using clear documentation including, upon request, laboratory standard operating procedures (SOP). In the present case of MHW historical methods, few of the methods since the work at OPRU in the 1980s were described fully enough, and none were clearly maintained with the datasets themselves.
5. The sampling grid for MHW hydrocarbons and trace metals surveillance should continue from this 2014 study to focus on fine sediment areas on the macrobenthic ('Warwick') grid and on the Natural Resources Wales inlets ('Habitats') grid, avoiding Llangwm Pill and the coarse channel sediments including those in the area of the confluence of the Rivers Carew and Cresswell.
6. Landscape-scale habitat information is important to successful management of MHW, and the corrected and archived sediment contaminant data should be compiled into the facies model developed for MHWESG in 2012 with Germano & Associates. This should be managed within a Geographic Information System, whereby discrete point sediment data can be further analysed and interpreted, for example by developing the contaminants and sediment relationships within each major sediment type (facies).
7. Since the effects of major elements on trace metals and REEs concentrations have not been fully explored in the present study, it is recommended that this be done (including the extensive range of REE analysed in the 2014 survey) in conjunction with procuring existing British Geological Survey catchment geochemistry data to check on natural inputs.
8. Recognising the usefulness of radionuclide-dated sediment coring work both in the past and in this project to extend the timeline back to the late 18^{th} century, it is again recommended that another 2-3 sets of cores are analysed in this way for hydrocarbons and trace metals. If possible, the analytical scope should also include selected contaminants not already characterised in MHW sediments (e.g. pre-1993 PAHs, explosives, fire retardants, persistent pesticides including anti-fouling agents). Dated coring is also valuable because in some cases, contaminants are only of historical interest and thus not worthy of expensive study in ongoing routine sampling surveys.

2.2 Milford Haven Waterway sediment macrobenthos data analysis & review 2008-15

Richard M Warwick, Plymouth Marine laboratory

Executive Summary

The Milford Haven Waterway is arguably the most intensively studied coastal region of the UK with respect to the soft sediment macrobenthos. These studies have largely been motivated by concern for the environmental effects of the oil industry, since the diversity and composition of the macrobenthos have become one of the mainstays of marine biological effects monitoring.

Following a review of historical data, recommendations were made for a future cost-effective and ecologically meaningful macrobenthic surveillance programme for the central Waterway. This has been implemented by three rounds of sampling in 2008, 2010 and 2015 at the so-called "Warwick" stations. During this period, sampling has also been undertaken at various other locations throughout the Waterway, some coinciding with the Group's surveillance stations and others with historical sampling locations not included in its programme.

This report meets the Group's requirement to analyse and examine trends in these datasets and to explore the relationships between macroinvertebrate communities and physicochemical variables throughout the waterway and over time, to make comparisons with earlier data, to assess increase (or decrease) in stress or impacts, change in functional groups, sensitive species etc.

The scope of the work commissioned by the MHWESG comprises analysis and interpretation of data from:

- Eight "Warwick" stations sampled along the axis of the central waterway in 2008, 2010 and 2013.
- Samples collected as part of the Clean Safe Seas Environmental Monitoring Programme (CSEMP) from monitoring site 646 at Cosheston Point, corresponding with "Warwick" station UH6, each year from 1999 to 2010 but excluding 2002.
- Samples collected in connection with the monitoring of Pembroke Power Station at three stations corresponding to "Warwick" stations MH6, MH4 and MH10 in 2012, 2013, 2014 and 2015.
- Samples collected from 18 stations in tributary inlets of the waterway in 2007, 2012 and 2015.

For the MHWESG study along the axis of the Waterway, the original station nomenclature has been replaced by station numbers 1-8 in sequence from west to east, which are now termed "MHWESG stations" rather than "Warwick stations".

Sediments at the MHWESG stations are poorly sorted, with the highest silt/clay content at the middle region.

The outer MHWESG stations are virtually fully saline, and thereafter the maximum tidal variation in salinity increases eastward.

Patterns of diversity change across the sequence of MHWESG stations are not consistent from year to year, but for the recent 2008-2013 data there is a gradual decline in species diversity

measures from the outer to inner stations. Taxonomic distinctness generally falls within the expected range, but for the two inner stations 7 and 8 it is significantly lower than expected in some years. Compared with other CSEMP monitoring stations around the UK, most MHWESG stations have above average taxonomic distinctness in all years, but the two inner stations 7 and 8 are well below the national average in some years.

Abundance / biomass comparison (ABC) plots indicate slight perturbation with *W*-statistic values close to zero at some MHWESG stations in some years, but the *W*-statistics are usually strongly positive and never negative.

There is a sequential change in community composition from the outer station 1 to the inner station 8 resulting from the distributions of coherent groups of species along this transect. This can be accounted for in terms of salinity and sediment granulometry. Species gradually declining or increasing in abundance can be related to the gradient of reducing salinity, while those peaking at the intermediate stations may be favoured by the higher silt/clay content there. None of the species that are indicators of excessive organic pollution are prominent at any MHWESG station.

At the CESMP monitoring station at Cosheston Point, there was a gradual decline in species diversity from 1999 to 2003 and a gradual increase thereafter, with a peak in 2004 interrupting this trend. ABC curves are indicative of moderate perturbation between 2003 and 2007, with a subsequent recovery.

Multivariate analysis of the CSEMP data shows a marked change in community composition from 1999 through to 2001 after which the composition remains relatively stable until a change back towards the 1999 composition from 2008 to 2010.

Changes at the CSEMP station are not inconsistent with the published time sequences of change in PAH and metal concentrations in the sediments, but any such cause and effect relationships remain tentative, since the peaks in contaminants are very ephemeral, which poses difficulties in matching them to macrobenthic data.

Combining MHWESG and Pembroke Power Station data for MHWESG stations 3, 4 and 5 provides a time series from 2008 to 2015 with only 2009 and 2011 missing. At stations 3 and 4 diversity indices suggest an improvement in environmental quality over this period, although at station 5 there is no further improvement from 2010 onwards.

Although the *W*-statistic values are positive at all sites and in all years, ABC plots provide indications of slight perturbation at station 3 in 2012, 2014 and 2015, whereas at stations 4 and 5 there is a lack of disturbance in any year.

Multivariate analysis of the combined MHWESG and Pembroke data highlight the problems of comparing studies conducted by different teams due to the lack of standardisation of taxonomic nomenclature above the species level. Community composition in the Pembroke samples alone varied more between years than between sampling stations, highlighting the temporal instability of the communities in this respect.

The NRW study of 18 stations in inlets and tributaries of the main Waterway extended from Gann Flats in the west to the upper Cleddau in the east. Sediments at Gann Flats and Sandy Haven in the west have a low silt/clay content, while stations further east have higher but variable amounts of silt/clay, with no clear west to east trend. There are progressively

increasing reductions in salinity and increases in the range of salinity variation from west to east.

Although the Gann stations generally have the highest numbers of species they have lower than average taxonomic distinctness. On the other hand, stations at the upper end of the waterway that have lower numbers of species have above average taxonomic distinctness. On average, stations in 2015 have a higher taxonomic distinctness than earlier years.

The numbers of individuals present at each inlet station show marked peaks in Angle Harbour and Cosheston Lower. A group of species that are indicators of organic pollution show a coherent pattern of abundance across the sites and are mainly responsible for this distribution.

All three ABC conditions (unperturbed, moderately perturbed or grossly perturbed) are found at the inlet stations. Only one station on Gann, one in the upper Cresswell and three stations Cleddau have unperturbed ABC configurations and positive *W*-statistics in all three years. Only the station in the lower Carew has the grossly perturbed configuration and negative *W*-statistics in all three years. The remaining stations vary in their status from year to year and there is no obvious relationship with location or any natural environmental variables. There is a greater occurrence of grossly or moderately perturbed conditions in 2012 compared with 2007 or 2015.

Community composition changes in a roughly linear sequence from the Gann stations and Angle Bay to the inner stations of the Cleddau, a pattern that corresponds more closely to salinity than to sediment granulometry. There is only a slightly bigger difference in species composition between stations than between years, but both are highly significant. There is a bigger difference between 2015 and the preceding years.

It is well known that species diversity is reduced in low salinity areas, which is the case in the uppermost stations in the Waterway, but low species diversity is not a good indication of ecological quality. The upper stations in the Cleddau have unperturbed ABC configurations in all three years, with higher values of average taxonomic distinctness and lower values of variation in taxonomic distinctness than the outer high salinity stations in Gann or Angle Bay.

2.3 Status review and surveillance recommendations for seagrass (Zostera spp.) in Milford Haven Waterway.

Unsworth, Richard K, Chiara M Bertelli, Max Robinson & Anouska Mendzil, 2017. Status review and surveillance recommendations for seagrass (Zostera spp.) in Milford Haven Waterway. Report to MHWESG from Aquatic Environmental Research Ltd, Swansea University

Executive Summary

Concern exists as to the status and continued extent of seagrasses in the Milford Haven Waterway. Additional concern has arisen recently from both long-term and rapid surveys of subtidal meadows, specifically those of Littlewick Bay, indicating declining seagrass state. As a result of these suggestions of potentially declining subtidal seagrass in MHW and concern about population changes in bird species that utilise seagrass, the Milford Haven Waterway Environmental Surveillance Group (MHWESG) commissioned Swansea University to assess the long-term change and health of seagrasses in MHW using available historical data and determine the ecosystem value of this key habitat. Swansea University (in collaboration with Project Seagrass) were able to support further detailed assessments of the *Zostera noltii* meadows in the Haven (in 2016) to supplement available information (only available until 2014). Swansea University were also asked to provide recommendations for further research aimed at filling knowledge gaps in our understanding of these systems and for future surveillance.

In Milford Haven there are two scientifically recognised species of seagrass; eelgrass (*Zostera marina*) and dwarf eelgrass (*Zostera noltii*). Seagrass in the MHW is extensive, principally due to the shelter of the waterway from prevailing weather, the large areas of soft-bottom intertidal habitat available for colonisation, and the availability of nutrients necessary for seagrass growth. Evidence of its current and historic presence extends from the mouth of the MHW close to Dale, along the shallow edges of the main waterway, into the bays of Angle, Sandy Haven, the Pembroke River, and at places such as Landshipping.

The data available from MHW finds seagrass to currently cover a total area of 181 ha. The majority of this (158 ha) is intertidal *Zostera noltii*, whilst 23ha is subtidal *Zostera marina*. The largest meadow is the intertidal *Z.noltii* meadow on the Pembroke River, this covers an area of over 97 ha and is possibly the largest seagrass meadow in Wales (if found to be continuous in area). Other large meadows exist in Angle Bay (*Z. noltii*) and Littlewick Bay (*Z. marina*).

All *Z.noltii* meadows in Milford Haven have shown an increase in area (ha) when comparing recent records with earliest available records. *Zostera noltii* extent in the Milford Haven Waterway has more than doubled between 2007 and 2014. Available information indicates this seagrass is probably in a healthy state but condition data is limited. It is unclear why the intertidal meadows have improved in health and extent so markedly since 2007. Historic data on seagrasses in the MHW are limited, however records do exist from three locations (Sandy Haven Pill, Dale and Landshipping) where seagrass is no longer present. Additionally there is good evidence that large areas of intertidal habitat have historically been reclaimed, indicating that potentially there has previously been more extensive seagrass in the MHW.

In contrast to the expanding and largely healthy intertidal *Zostera noltii* meadows, subtidal *Zostera marina* meadows are poorly understood and where data exists this indicates these

habitats are in a poor and declining state and may be close to reaching a threshold at which point the meadows disappear. Urgent action is required to more fully understand the extent and health of these systems.

The ecosystem services of *Zostera spp.* are mostly well studied, *Z.marina* more so than *Z.noltii* (Mtwana Nordlund et al. 2016), however due to the extensive geographic range of these species these services may change with respect to region and locality. Local level data on ecosystem service provision of seagrass in the MHW is extremely limited, with only sporadic species observations data available to ascertain those species utilising seagrass. Some information on ecosystem service provision is available for other sites in Wales, however the majority of this data refers to coastal seagrasses rather than seagrass within estuarine environments.

A series of data gaps were determined based on the findings from the present study, leading to the development of a series of recommendations. The most important of these are:

1. As a priority, initiate an annual programme of assessment and monitoring of subtidal seagrass. This needs to include assessments that provide answers as to the status of the system and its proximity to a fatal threshold, not just its presence or absence.
2. Determine environmental thresholds (light, temp, nutrients) likely to lead to further loss and degradation of seagrass in MHW.
3. Monitoring of *Zostera noltii* by NRW (and others) needs to consider more than just the Water Framework Directive monitoring methodology and needs to be rapidly reported so it is accessible to the general public. This needs to be part of an integrated MHW wide annual seagrass monitoring programme that links to the assessment of subtidal meadows and those in close proximity (e.g. Skomer).
4. Conduct research to begin to understand the ecosystem service value of seagrass meadows in Milford Haven.

2.4 Review of the status of wetland birds in the Milford Haven Waterway and Daugleddau Estuary 2016

Annie Haycock, Pembrokeshire WeBS Coordinator

Executive Summary

The Milford Haven Waterway - Daugleddau Estuary system ("the estuary system") is an important wintering ground for waders and wildfowl because of its sheltered location and open mudflats.

The estuary system is of international importance by virtue of hosting an average of over 20,000 waterbirds or around 60 species each winter. It is of national importance for its populations of wintering wigeon, teal and greenshank, and for migrating curlew. Other species have reached nationally important levels here in past winters, but either numbers have declined, or the threshold for national importance has been raised, and they no longer reach that threshold (eg redshank and little grebe). The estuary system holds some 14.5% of the Welsh waterbirds (on WeBS sites) in mid-winter, and just under 1% of the UK waterbirds counted on WeBS sites.

- Almost all the **shelduck** in Pembrokeshire in winter are found on the estuary system. Numbers of wintering shelduck have fallen, both here and across the UK. Breeding success fell to an all-time low in 2013, but has since recovered slightly.
- **Wigeon** numbers have increased dramatically since 2003, particularly on Pembroke River. They move on, either to other parts of the estuary system or out of the estuary system altogether, as soon as their food supply (*Zostera*) is exhausted in mid-winter.
- **Teal** numbers have fluctuated over the past decade, but are just over the threshold for national importance. The cause is thought to be the recent run of mild winters and an increase in the protected areas on mainland Europe allowing larger numbers of birds to remain further north and east.
- Mid-winter peak counts of **curlew** have decreased both on the estuary system and in Carmarthen Bay to the east, although the UK trend shows an increase. However, data indicate that the estuary system is still an important migratory stop-over for curlew.
- **Greenshank** numbers have increased following a period of low counts in the 1990s. The estuary system is one of the top ten wintering sites for this species in in the UK, and almost half of the birds wintering in Wales are found here.
- **Black-tailed Godwit** numbers have increased on the Cleddau and on other UK sites. This appears to be linked to increases in the breeding population in Iceland.
- **Little egret** numbers increased rapidly between 1995 and 2005, then levelled out. The cold winters of 2010 and 2011 reduced their numbers considerably, although there are now signs of a recovery.
- The **Canada goose** population rose considerably in the 1990s, in line with the trends for the Welsh and the UK populations. Birds are most often found between Llangwm and Boulston, although they also feed away from the estuary. There is no clear evidence yet that they are affecting the numbers or distribution of other bird species, however, they may

have an effect on the flora through trampling and eutrophication.

- **Greylag geese** were rarely recorded on the estuary before 2005, but have since increased to about 60 in 2015-16. There is increasing evidence of them breeding locally, and they may or may not be a future cause for concern.
- **Grey herons** breed at two main sites on the Cleddau system, totalling 10-20 nests each year in the 1990s. However, counts are sporadic and no conclusions can be drawn about the breeding population.
- Although **little grebe** no longer reach numbers of National Importance on the estuary system, 14% of the Welsh wintering population (on WeBS sites) are found here, and it is the second-most important site in Wales for them.

Most of the changes in bird populations on the estuary system are reflected at other sites, either in Wales or in the UK as a whole. For example, some of the observed changes in numbers using the estuary system in winter may reflect the run of mild winters between 1995 and 2009 (which may or may not suggest long-term climate change), so birds do not have to travel so far south and/or west to escape harsh winter weather. Data suggest that large numbers of birds are more likely to visit the estuary system during periods of extreme weather, but during normal weather would prefer the conditions (including a better food supply) on the east coast.

Winter distribution may also be affected by the increase in protected areas on the European mainland, which have resulted in birds, eg teal, that are susceptible to hunting pressure, to remain in those areas.

Counts done at low tide in 1997-98, 2005-06 and 2013-14 show the main feeding areas for most species to be Pembroke River, Angle Bay, Fowborough Point, Carew River and Gann Estuary.

Incidental data collected during annual breeding shelduck surveys in July and early August since 1992 have demonstrated the importance of the estuary system as a migration stop-over for several additional species, notably curlew.

The Cleddau estuary system continues to be of national importance for wintering and migrating wetland birds, and it is vital that the full range of their requirements (eg undisturbed good quality feeding habitat and high tide roosts) continue to be met here.

Why do we need to keep counting?

Annual monitoring will pick up trends in the numbers of birds at local and national levels, and flag up changes that may require further consideration or investigation (eg water quality and recreational use) in the estuary system.

For example, in winter 2012-13 the wigeon arrived in September as usual, but left early, with the peak count some 3000 less than in recent winters. This may have been a one-off event; it may have been caused by events away from the estuary; there may have been some disturbance that kept the birds away, or it may indicate some (temporary) change in the food supply in Pembroke River. The peak count was 1200 lower in 2013-14, but has recovered somewhat in the two subsequent winters.

Redshank numbers dropped by half in the early 1990s, but have been reasonably stable since

then. This is part of a national/international trend affecting other west coast estuaries.

Low tide counts are undertaken only every eight years or so. The 2013-14 counts indicated a considerable drop in dunlin numbers feeding on the mudflats. This was consistent with the regular high tide counts in that season. However, the annual monitoring showed that this was a one-off low season that affected all sites around Britain.

Long-running datasets are very rare, but are extremely valuable in picking up both long-term and short-term changes. It is therefore important to continue with annual surveillance of wetland birds within the estuary system, both as part of the UK dataset and in terms of SSSI monitoring.

2.5 Daugleddau Estuary and Milford Haven Waterway Annual surveillance of summer shelduck populations 2015 & 16

Jane Hodges, Ecologist

Executive summary

The Daugleddau Estuary and Milford Haven Waterway hold regionally important numbers of shelducks during the winter months. In addition there is a small summer population that has been the subject of annual boat surveys carried out between 1991 and 2014. The summer shelduck survey was repeated in 2015 as part of a co-ordinated programme of environmental surveillance work in the estuary system. The aims, objectives and methods used together with the data obtained are described in this report.

In terms of the numbers of broods of ducklings seen on the water, 2015 was a slightly better season than 2014 which in turn was a significant improvement on the two preceding seasons of 2013 and 2012, the poorest years for breeding shelducks in the estuary system since the current sequence of annual surveys began in 1991. The number of broods of ducklings seen on the water in 2016 was one less than in 2015 and the same as that recorded in 2014. Whilst 2016 represented an improvement on the previous six seasons in terms of productivity, the long-term downward trend in the number and size of broods was continued.

As in previous years, predation (by avian and/or mammalian predators) is thought to have been a major factor affecting the number and size of broods recorded in 2015 and 2016. The relatively cold wet weather in May and June in both years and disturbance may also have been contributory factors although there is little evidence on which an assessment of the importance of the latter as a factor affecting breeding success and survival of ducklings to fledging can be based. Other factors such as thick deposits of green algae on mud flats at low tide may have had localised effects on the quality of foraging habitat, hence on fitness and survival of adult and young shelducks

Since the mid-1990s there has been a steady decline in the numbers of shelduck overwintering in the UK. This national decline has been mirrored by a decline in the number of shelducks over-wintering in the estuary system that continued in the 2014/15 winter. The local and national declines are probably linked to an increasing tendency for birds to "short-stop" in mainland Europe in response to the recent trend for mild winters across western Europe. The decline in the over-wintering population has led to fewer birds remaining in 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 although the incomplete coverage achieved through the land-based counts that were carried out in place of the boat survey in July 2015 resulted in many fewer birds, *e.g*. curlew and redshank, being recorded than in previous years.

The reports conclude with recommendations 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.

3. Future work programme

Over 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. Several further members modestly increased their contributions in 2015 and 2016 and Pembrokeshire county Council were able to recommence contributing. However, Natural Resources Wales changed their method of contributing, necessitating bidding for competitive grants and resulting in reduced contributions.

Consequently, after several years of increasing annual income in the early 2010s, income was static during the period of this report. The Group's real purchasing power has again decreased substantially whilst the scope and cost of the projects undertaken by the Group have increased considerably and consultancy costs have continued to rise.

Priorities for 2017 include recommencing field-based surveillance, commencing with a further rounds of macrobenthic sampling and rocky shore sampling. The annual summer shelduck breeding surveillance and the wetland bird data collation and reporting will also be continued.

The Group retains an ambitious aspirational work programme, which seems to increase rather than diminish as recommendations from such reviews as summarised in sections 2.1 to 2.3 are incorporated. However scheduling the frequency of repeating projects within the rolling surveillance programme remains a challenge. 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.

Appendices

Appendix 1: Purpose and terms of reference

Preamble

The Milford Haven Waterway[1] 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.

[1] 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 and Funding

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: Milford Haven Waterway Environmental Surveillance Group Knowledge Collaboration Agreement

Agreement dated 17 January 2017 between:

1) Dragon LNG Limited
2) Milford Haven Port Authority
3) Natural Resources Wales
4) Pembrokeshire Coast National Park Authority
5) Pembrokeshire County Council
6) Puma Energy (UK) Ltd
7) RWE Generation UK Plc
8) Semlogistics Milford Haven Ltd
9) South Hook LNG Terminal Company Ltd
10) Valero Energy Ltd

PREAMBLE

The Milford Haven Waterway 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 as a port handling strategic energy resources and ferry services sustaining many valuable long-term jobs in Pembrokeshire. 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.

RECITALS

(A) The Group Members agree to work collaboratively in a non-binding knowledge collaboration as the **Milford Haven Waterway Environmental Surveillance Group** in order to provide high quality environmental information to the Group Members, so enabling the Group Members to contribute to the maintenance and enhancement of the rich and diverse marine environment of the Waterway whilst sharing this information with the local and scientific communities, and to perform the objects set out in clause 3.2.

(B) This Agreement serves to continue the successful collaborative Milford Haven Waterway Environmental Surveillance Group that began with establishment of the Milford Haven Waterway Environmental Monitoring Steering Group in 1991 and resulted in a Memorandum of Agreement being entered into by the members of the Group on 1 July 2004.

(C) The Memorandum of Agreement has gradually been overtaken by time and is now recognised as being insufficiently flexible for an evolving membership.

(D) Accordingly, on the date of this Agreement the Group Members have agreed to terminate the Memorandum of Agreement on the basis that the Group would be reconstituted as a non-binding knowledge collaboration Group in order to continue fulfilling the Objects of the Group.

(E) Consequently, the Group Members have agreed to enter into this Agreement on the terms and conditions set out below.

The Group Members 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 4.1;

"Group" means the Milford Haven Waterway Environmental Surveillance Group reconstituted under this Agreement and any agreement supplemental to it;

"Group Members" means all of the parties listed on page 2 of this Agreement and Group Member shall have a corresponding meaning;

"Intellectual Property" means all intellectual property rights of whatever nature including without limitation copyright, patents, know-how, trade secrets, trademarks, trade names, design right, get-up, database right, utility models, service rights, moral rights, domain names and all similar rights and, in each case:

a) whether registered or not;

b) including any applications to protect or register such rights and the right to make such applications;

c) including all renewals, continuations and extensions of such rights or applications;

d) whether vested, contingent or future; and

e) wherever existing;

"IP Rights" all rights which may now or in the future subsist in respect of or derived from any Intellectual Property.

"Memorandum of Agreement" means the Memorandum of Agreement dated 1 July 2004 entered into between the parties;

"Objects" means the objects of the Group itemised in clause 3.2;

"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 TERMINATION OF THE MEMORANDUM OF AGREEMENT

2.1 The Group Members agree that as at the date of this Agreement the Memorandum of Agreement shall immediately terminate and be replaced by the terms and conditions contained in this Agreement.

2.2 From the date of this Agreement any monies held pursuant to the Memorandum of Agreement shall be subject to this Agreement and in particular the terms of clause 5.2.

3 SCOPE OF THE COLLABORATION

3.1 The Group Members agree with one another to enter into this Agreement to generate and share high quality environmental information to assist 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 3.2 under the terms of this Agreement.

3.2 The Objects of the Group are to maintain surveillance of the quality of the marine physico-chemical environment, marine biology and ornithology of the foreshore, seabed and waters of the Milford Haven Waterway, by:

a) keeping under review all relevant surveys, surveillance and monitoring;

b) undertaking surveys to improve current knowledge and establish baselines;

c) undertaking surveillance projects;

d) maintaining a literature and information database.

3.3 The Group will:

a) maintain under review a work programme of agreed projects;

b) share technical output equally under joint ownership and copyright;

c) function as a technical, science based, group;

d) make its findings available to the wider community in addition to the Group Members.

3.4 Membership of the Group comprises 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.

3.5 Any Group Member may, at their discretion, share with the other Group Members any information and /or data generated by their own environmental survey, monitoring or surveillance activities. In these instances, any such member shall retain its IP rights to that information or data. However, for the avoidance of doubt, this clause does not constrain the Group's use of information provided by any member to regulatory authorities, for example to meet statutory consenting processes, which has thereby entered the public domain.

3.6 For the avoidance of doubt:

a) any survey, surveillance and monitoring agreed by the Group will be limited to crown foreshore, seabed and/or waters of the Waterway and will specifically exclude the premises, whether freehold or held under the terms of a commercial operating lease or license of any Group Member;

b) nothing in this Agreement shall be deemed to override or in any way restrict the statutory obligations of any of the Group Members;

c) the identification and consideration of political and management issues or the setting of environmental standards are specifically excluded from this Agreement. However, Group members are free, and are expected to use the Group's outputs, to help meet their own requirements.

4 CONTROL AND MANAGEMENT

4.1 A Committee comprising of one or more representatives nominated by each of the Group Members will be maintained for the purposes of:

a) discussing, determining and approving the purpose, terms of reference and work programme of the Group;

b) exchanging information;

c) implementing the agreed work programme;

d) reporting on progress, including publishing an annual report that comprises of a summary of all work undertaken for the year and work planned for the forthcoming year.

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

4.3 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 chair. In the absence of both the chair and the vice chair those nominated representatives present shall appoint one of their members present to act as chair for that particular meeting. The appointment of the chair and the vice Chair will be subject to biennial review, at which time the incumbent vice chair will normally be expected to assume the role of chair and a new vice-chair appointed, subject at all times to principles of good governance and best practice. Notwithstanding the above and subject to the agreement of Committee representatives, the term of the serving chair may be extended or any other representative appointed chair, depending on the circumstances then prevailing.

4.4 The quorum for meetings of the Committee shall be 5 nominated representatives of the Group Members. Notes of all meetings of the Committee shall be taken and copies of such notes circulated to Group Members as soon as practicable after each meeting.

4.5 Every effort will be made to ensure Committee business is conducted by consensus. In the event of issues arising at a meeting of the Committee that cannot be resolved by consensus, they 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.

4.6 The Committee may 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.

4.7 The Committee will meet as often as necessary or desirable for the purposes of achieving the Objects at a convenient time and venue.

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

5 RESOURCING

5.1 Each of the Group Members will provide either a monetary contribution and/or some other contribution, e.g. services, premises, that shall be agreed by all the Group Members for the furtherance of the Objects of the Group in accordance with the work programme referred to in clause 3.3(a). The contributions are to be provided promptly within the time frame agreed for contributions.

5.2 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.

5.3 Other contributions for the furtherance of the Objects of the Group, as identified in clause 5.1, may include (where applicable) the sharing of environmental surveillance or monitoring data, information or reports collected by members for their own purposes or to meet legal obligations, as identified in clause 3.5.

6 CONTRACTS

Under the terms of this Agreement, the members agree that:

6.1 Milford Haven Port Authority shall have the authority to, and be the sole Group member to let contracts with third parties on behalf of the Group in order to achieve the Group's Objects, including the appointment of professionals, advisers and consultants on behalf of the Group, subject to request from and prior approval of the Committee, and clause 6.3. MHPA shall only let contracts with third parties on behalf of the Group upon written instruction from Group compliant with the terms of clause 7.1. Responsibilities and liabilities arising from contracts will be owned by the Group; MHPA is the contract letting agent for administrative purposes.

6.2 Milford Haven Port Authority shall make payments on behalf of the Group in respect of contracts agreed at clause 6.1 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 regular statements to the Committee in respect of such account.

6.3 No such contract shall be entered into unless there are sufficient funds available within the interest bearing bank account referred to in clause 5.2 to meet the obligations of Milford Haven Port Authority acting on behalf of the Group under the relevant contract.

6.4 Consultants and/or contractors will be engaged pursuant to MHPA's contract Terms and Conditions.

7 LIABILITY

7.1 Risk of liability will be minimised by:

a) agreeing to works and requesting contracts be let only when sufficient funds are available as set out in clause 6.3;

b) ensuring prospective contractors have appropriate levels of expertise, experience, competence and responsibility,

c) requiring contractors to carry appropriate liability insurance for damages arising as a result of fieldwork (prior to letting contracts (as stipulated in clause 6.1) and excluding liability arising from force majeure (as defined in clause 7.3);

d) requiring Contractors to submit an appropriate Risk Assessment and Method Statement prior to the commencement of works;

e) review and approval of Contractor's Risk Assessment and Method Statements by appropriate Group members, and / or delegated individual(s), most suited to the task, and maintaining written records of such reviews and approvals;

f) ensuring appropriate oversight of fieldwork and Contractors adherence to Risk Assessment and Method Statements by appropriate Group members, and / or

delegated individual(s), most suited to the task, and maintaining written records of such oversight;

g) including a liability exclusion statement in all Group reports.

7.2 The costs or consequences of any legal action against the Group or against MHPA in connection with the activities of MHSWEG will be shared equally and the MHPA's risk as the party letting contracts will be mitigated through the measures set out in clause 7.1.

7.3 Consequently, as at the date of this Agreement the Group Members shall ensure that the Group has effected public liability insurance with a minimum limit of liability of £5,000,000 (five million pounds) in respect of each and every occurrence to cover the potential liability of the Group Members in relation to this Agreement and shall maintain such insurance until the date of termination of this Agreement.

7.4 The Group shall not be liable for losses, damages, costs and/or expenses incurred as a result of force majeure which shall include without limitation any failure or delay attributable to facts beyond the control of the Group such as wars, hostilities, boycotts, embargoes, public disorders, sabotage, strikes, lockouts, floods, fires or acts of God.

8 INTELLECTUAL PROPERTY RIGHTS

8.1 All IP Rights developed or generated by the Group in pursuance of the Objects shall be owned by the Group Members jointly.

8.2 Any Group member that withdraws from the Agreement will retain joint ownership of Group IP Rights developed or generated during the period of their membership of the Group.

8.3 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 owned by the Group, the Group Members shall jointly agree and grant such a licence to such third party and such third party shall be required to pay a licence fee.

8.4 All costs and expenses and all receipts in respect of any IP Rights owned jointly by the Group Members shall be shared equally by the Group Members.

8.5 Each Group Member shall retain all rights to Intellectual Property in all materials, information etc. contributed by that Group Member as stipulated in clause 3.5.

9 TERM AND TERMINATION

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

9.2 A Group Member may at any time terminate its participation in respect of this Agreement subject to having given notice in writing to the Chairperson with no right of return of financial contributions.

9.3 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, with no right of return of financial contributions.

9.4 Subject to clauses 8.2 and 8.3 this Agreement will terminate on completion of the Objects stated in clause 3.

9.5 Upon termination of this Agreement the Group shall either be:

a) reconstituted as appropriate to fulfil the Objects of the Group; or

b) terminated forthwith and the Group Members shall take such further steps as may be necessary in order to wind up the Group in a fair and reasonable manner.

The financial assets of the Group at winding up should be distributed or shared pro rata to the direct financial contributions by Group Members.

9.6 If a Group Member's participation in the Group is terminated in accordance with clause 8.2 or 8.3 the provisions of clauses 6.1 to 6.3 shall no longer apply in respect of that Group Member.

10 THIRD PARTIES

10.1 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 Group Members to this Agreement. This does not affect any right or remedy of a third party that exists or is available apart from that Act.

11 NO BINDING PARTNERSHIP

11.1 Nothing in this Agreement shall be construed as establishing or implying any legally binding partnership between the Group Members.

12 SUCCESSORS

12.1 References in this Agreement to the Group Members shall include their respective heirs, successors in title, permitted assigns and personal representatives.

13 ASSIGNMENT

13.1 No Group Member should 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 Group Member.

14 GENERAL

14.1 Provisions which by their terms or intent are to survive termination of this Agreement will do so.

14.2 No amendment or variation of this Agreement will be valid unless agreed in writing by an authorised signatory of each party.

14.3 Unless otherwise expressly agreed, no delay, act or omission by either party in exercising any right or remedy will be deemed a waiver of that, or any other, right or remedy.

14.4 Each party will do all further acts and execute all further documents necessary to give effect to this Agreement.

15 INFORMATION SHARING AND DATA PROTECTION

15.1 Several members of the Group (public bodies) are subject to the Freedom of Information (FoI) Act and Environmental Information Regulations (EIR) whilst others (industry bodies) are not. Whilst circumstances under which valid FoI and/or EIR requests may be submitted to the Group are anticipated to be limited since the Group operates transparently, places all outputs in public domain, and commercial tender assessments and contract details are protected by confidentiality exemptions, every effort will be

made to meet any such request, taking into account advice and guidance from the Information Commissioner's Office and the obligations on public bodies.

15.2 The Group will comply with the Data Protection Act and adhere to the data protection principles to ensure personal data is safeguarded.

16 REVIEW

This Agreement will be subject to review and reaffirmation at five yearly intervals from the date of the Agreement.

17 COUNTERPARTS

This Agreement may be executed in any number of counterparts, each of which is an original and which together have the same effect as if each Group Member had signed the same document.

Appendix 3: Chronological list of MHWEMSG / MHWESG[2] 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

[2] 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 2013-14*. A report to the Milford Haven Waterway Environmental Surveillance Group; 24 pp.

Hodges, J E (2014). *Daugleddau Estuary and Milford Haven Waterway surveillance of summer shelduck populations: report for 2014*. Report from Pembrokeshire Coast National Park Authority. 11pp + appendices

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.

Little, D I & Galperin, Y, 2014. *Milford Haven sediment hydrocarbon and metals contamination: supplemental report on recent contaminant trends*. Report to Milford Haven Waterway Environmental Surveillance Group

2015

Haycock, A (2015). *A review of the status of wetland birds in the Milford Haven Waterway and Daugleddau Estuary 2014-15*. Report to the Milford Haven Waterway Environmental Surveillance Group.

Hodges, J E (2015). *Daugleddau Estuary and Milford Haven Waterway surveillance of summer shelduck populations: report for 2015*. Report to MHWESG from Pembrokeshire Coast National Park Authority.

Rumney H S, K Potter, P Mellor & P Bersuder (2015). *Analysis of Sediment Contaminants in Milford Haven Waterway Total Hydrocarbon (THC) concentration in sediments*. Data report to MHWESG from Centre for Environment, Fisheries & Aquaculture Science, Lowestoft.

2016

Clough, R (2016). *Determination of Multiple Analytes in Sediment Samples*. Data report to MHWESG from Analytical Research facility, University of Plymouth.

Haycock, A (2016). *Review of the status of wetland birds in the Milford Haven Waterway and Daugleddau Estuary 2016*. Report to the Milford Haven Waterway Environmental Surveillance Group.

Hodges, J E (2016). *Daugleddau Estuary and Milford Haven Waterway surveillance of summer shelduck populations: report for 2016.* Report to the Milford Haven Waterway Environmental Surveillance Group

Warwick, Richard M (2016). *Milford Haven Waterway sediment macrobenthos data analysis & review 2008-15*. Report to the Milford Haven Waterway Environmental Surveillance Group, Plymouth Marine Laboratory.

2017

Little, D I (2017). *Sediment contaminant concentrations in Milford Haven waterway: data conversion and timeline*. Report to the Milford Haven Waterway Environmental Surveillance Group.

Unsworth, Richard K, Chiara M Bertelli, Max Robinson & Anouska Mendzil, 2017. Status review and surveillance recommendations for seagrass (Zostera spp.) in Milford Haven Waterway. Report to MHWESG from Aquatic Environmental Research Ltd, Swansea University