MILFORD HAVEN WATERWAY
ENVIRONMENTAL SURVEILLANCE GROUP

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Annual Report 2014

MILFORD HAVEN WATERWAY ENVIRONMENTAL SURVEILLANCE GROUP

ANNUAL REPORT 2014

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COVER IMAGES

Front cover: non-native ascidians (sea-squirts) on Dragon LNG jetty piles:

- Top left: Compass sea-squirt, *Asterocarpa humilis* © David Kipling.
- Top right / bottom left: Unidentified *Didemnum* species, confirmed as not being Carpet sea-squirt, *C. vexillum* © David Kipling (top right) / Blaise Bullimore (bottom left).
- Bottom right: Leathery sea-squirt, *Styela clava* © Sarah Bowen.

Rear cover: Total numbers of waterbirds on the Cleddau Estuary 2014-15 compared with averages for the 2000s and 2010s.

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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

Corresponding & observing members

Wildlife Trust South & West Wales
WG Sustainable Evidence & Assessment

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Field Studies Council:
- Dale Fort Field Centre
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- Haverfordwest
- Milford Haven
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Carmarthen West & South Pembs MP
Preseli Pembrokeshire MP
Carmarthen West & South Pembs AM
Preseli Pembrokeshire AM
Regional AMs

Others

WG Marine & Fisheries
UK Environmental Observation Framework secretariat (e-copy)
UK Marine Monitoring and Assessment Strategy secretariat (Tabitha Dale) (e-copy)
JNCC / UK Marine Monitoring and Assessment: Healthy and Biologically Diverse Seas Evidence Group (Jane Hawkridge - e-copy)
UK Marine Monitoring and Assessment: Clean and Safe Seas Evidence Group (Mike Waldock)
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MILFORD HAVEN WATERWAY ENVIRONMENTAL SURVEILLANCE GROUP

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South Hook LNG Ltd

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Milford Haven Waterway Environmental Surveillance Group
Report 2014

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Chairman's Foreword

It seems that change is ever present. Whether on a global, national or local scale, political or environmental, we see change all around us. Some change is easy to detect, some less so.

One change that is easy to spot is the gap left at the helm of our Group following the well-deserved retirement of our Chairman of 15 years, Captain Mark Andrews. A fitting tribute to Mark is that the Group exists at all. These have, and continue to be difficult times; money is scarce and priorities constantly revisited. Where else would you find a group of organisations, public bodies and industries working collaboratively, self funded and self driven for an objective that lies beyond the immediate and is, by definition, long term?

Change at the top is not the only challenge facing the Group, to understand this you need only refer to the list of signatories to the most recent Memorandum of Agreement, from July 2004. Of the ten members listed only three still remain as they were then named and constituted. That the group has survived is testament not only to Mark (and Blaise Bullimore, our tireless project manager) but to all group members who make time in their busy professional lives to support the functioning of the group. Indeed the Group has said farewell to a number of long serving members this year whose expertise and good counsel will be sorely missed.

The Milford Haven Waterway continues to maintain our interest, scientifically through our well-established work programme and commercially, in that the next new endeavour to make use of our famous deep-water port is never far away. New members open to our ethos of collaboration and a long-term view on environmental surveillance are always welcome, we look forward to finding out who they may be.

Unlike Mark, I will not be able to look back on a catalogue of forewords to our annual reports as we have decided that in the short term the needs of the Group are best served by rotating the role of Chair. To this end Paul Howells of Dragon LNG will take over the reins in due course, for which I wish him well. The sustainability of the Group and maintaining our ability to carry out our work programme remain a key focus.

And for one more change, how we access information. Take a look at the British Library bibliography for the Milford Haven Environmental Surveillance Group: http://bnb.data.bl.uk/doc/organization/MilfordHavenWaterwayEnvironmentalSurveillanceGroup. You won't fail to be impressed.

Roland Long

Pembroke Power Station

Chair

Rhagair y Cadeirydd

Mae'n ymddangos bod newid bob amser yn bresennol. Ar raddfa fyd-eang, neu'n genedlaethol neu'n lleol, ac yn wleidyddol neu'n amgylcheddol, mae newid i'w weld o'n cwmpas ym mhobman. Tra bo rhywfaint o'r newid yn hawdd i'w ganfod, mae'n digwydd weithiau yn llechwraidd.

Un newid amlwg iawn yw'r bwlch a adawyd yn arweinyddiaeth ein Grŵp, yn sgil ymddeoliad haeddiannol ein Cadeirydd ers 15 mlynedd, sef y Capten Mark Andrews. Y dysteb orau i Mark yw fod y Grŵp hwn yn bodoli o gwbl. Mae'r cyfnod diweddar wedi bod yn anodd iawn ac mae'n parhau felly; mae arian yn brin a'n blaenoriaethau'n cael eu had-drefnu'n gyson. Ond ymhle arall y deuech o hyd i gasgliad o sefydliadau, cyrff cyhoeddus a diwydiannau sy'n cydweithio â'i gilydd, yn cyllido ac yn symbylu eu hunain er mwyn cyrraedd nod y tu hwnt i'r presennol, sydd, drwy ddiffiniad, yn nod hirdymor?

Nid y newid ar y brig yw'r unig her sy'n wynebu'r Grŵp; nid oes raid ond edrych ar restr o lofnodwyr y Memorandwm Cytundeb diwethaf yng Ngorffennaf 2004. Allan o'r deng aelod a restrir yno, tri yn unig sy'n parhau fel yr oeddent bryd hynny, gyda'r un enw a'r un cyfansoddiad. Rhaid diolch am y ffaith bod y Grŵp wedi goroesi, nid yn unig i Mark (ac i Blaise Bullimore, ein rheolwr prosiect diflino) ond hefyd i holl aelodau'r grŵp sy'n canfod amser yn eu bywydau proffesiynol prysur i gefnogi gweithgarwch y Grŵp. Yn wir, bu'n rhaid i'r Grŵp ffarwelio eleni â nifer o hen aelodau ffyddlon, y bydd colli eu harbenigedd a'u cyngor da yn ergyd drom.

Dyfrffordd Aberdaugleddau sy'n parhau i gynnal ein diddordeb, yn wyddonol drwy'n rhaglen waith hirsefydlog a hefyd yn fasnachol, gan fod ymgais newydd arall i wneud defnydd o'n porthladd dŵr dwfn enwog yn gyson ar y trothwy. Mae croeso bob amser i aelodau newydd sy'n barod i gofleidio ein hethos o gydweithio a'n persbectif hirdymor ar oruchwylio amgylcheddol, a byddwn yn edrych ymlaen yn eiddgar at ddod i'w hadnabod.

Yn wahanol i Mark, ni fydd modd i mi edrych yn ôl ar gyfres hir o raglithoedd i'n hadroddiadau busnes, gan ein bod wedi penderfynu mai'r ffordd orau o ddiwallu anghenion y Grŵp yn y tymor byr fydd cylchdroi rôl y Cadeirydd. Gyda hynny mewn golwg, Paul Howells o gwmni Dragon LNG fydd yn cymryd yr awenau maes o law, a dymunaf yn dda iddo yn y swydd. Cynaliadwyedd y Grŵp a diogelu ein gallu i gyflawni ein rhaglen waith a fydd yn parhau i hawlio ein prif sylw.

Ac un newid arall yw'r ffordd y byddwn yn cael mynediad at wybodaeth. Edrychwch ar lyfryddiaeth y Llyfrgell Brydeinig ar gyfer Grŵp Goruchwylio Amgylcheddol Dyfrffordd Aberdaugleddau:
http://bnb.data.bl.uk/doc/organization/MilfordHavenWaterwayEnvironmentalSurveillanceGroup. Ni chewch eich siomi.

Roland Long

Gorsaf Bŵer Penfro

Cadeirydd

1. Introduction

This is the fifteenth annual report of the Milford Haven Waterway Environmental Surveillance Group (formerly the Milford Haven Waterway Environmental Monitoring Steering Group). It covers the period January to December 2014.

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.

The Group's major project for 2014 was to initiate routine sediment contaminants surveillance as recommended by Little (2009). This year's work focussed on paired analysis of sediment samples using current and 'historical' (1970s – 80s) analytical techniques to enable integration and comparison of currently incomparable datasets. The report's summary together with extracts from the discussion and the conclusions in full forms section 2.1 of this report.

The established annual wetland bird surveillance projects continued and are summarised in sections 2.2 and 2.3.

The presence and arrival of new invasive, non-native species in the Waterway is becoming an increasingly importance issue. A brief survey of the distribution of marine NNS on vertical artificial structures in Milford Haven undertaken for the Port of Milford Haven by Bangor University's Centre for Applied Marine Sciences is summarized in section 2.5, a brief report on suspect invasive ascidians is included as section 2.6 and a brief exploratory survey of Dragon LNG jetty piles as section 2.7

The Group funded the laboratory costs of analysing 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. His thesis abstract is included as section 2.4.

Finally, continuing the recent series of guest contributions, section 2.8 describes 10 years of survey work carried out in the Haven by volunteer divers contributing to the UK national *Seasearch* project.

2. Group activity 2014

2.1 Milford Haven sediment hydrocarbon and metals contamination: supplemental report on recent contaminant trends

David Little & Yakov Galperin

Executive Summary

The recent sediment chemistry data for the Milford Haven Waterway (MHW) can be reasonably explained by a combination of new contaminant inputs and the disturbance of sediments historically-contaminated by oil and metals. The following peaks occurred:

- LNG-related construction causing sediment resuspension with likely peaks in activity in 2003-2005, 2008, and 2010-2011
- Port of Milford Haven (PoMH) maintenance dredging mainly using trailing suction hopper dredger (TSHD), with possible hopper spillage during activity in 2006 and 2010
- Neyland Yacht Haven (NYH) dredging using cutter suction dredger (CSD) causing mud suspensions with peak disposals at Neyland in 2005, 2007, 2008, 2009 and 2011.

Not in any doubt is the pronounced yet ephemeral peak in polycyclic aromatic hydrocarbons (PAHs) and six heavy metals concentrations at almost every station in MHW in October 2007. The peak was noted in the Sediment and Contaminant Transport Review submitted to MHWESG in 2009, but its causes could not be ascertained at that time. This supplemental report is intended to rectify this issue in light of the geochemical and potential biological significance of the 2007 peak, across numerous receptors.

In the comparisons made, any changes in the mud and organic content of the sediments were considered small, replicate agreement was good, and usually the same laboratory was used. The 2007 peak was 170% more than the previous peak recorded over a decade earlier, which was only eight months after the *Sea Empress* spill in 1996. The increase in mean PAHs concentrations (ΣPAH 17) over the period 1996 to 2007 was statistically significant (*t*-test, $p<0.01$).

Although 1996 to 2007 was a long gap in MHW-wide monitoring for PAHs, other sources of data have been examined such as the dredging control samples analysed periodically for limited areas by the Centre for Environmental, Fisheries and Aquatic Sciences (CEFAS). Annual sampling data were also examined from the Clean Safe Seas Environmental Monitoring Programme (CSEMP) using the National Laboratory Service (NLS), the same laboratory as for almost all the MHW-wide work. It is known from this time series that the contaminant increases started at Cosheston Point in 2003 with a doubling of both Cu and PAHs concentrations. There was another doubling in PAHs and a trebling in Cu concentrations between 2003 and 2007 at this locality. It is also clear that this steady contaminant build-up was further increased in 2011 at Cosheston Point.

In contrast, between the Octobers of 2007 and 2010, ΣPAH 17 concentrations had fallen by 44% across the MHW-wide survey grid. This was also statistically significant (*t*-test, $p<0.05$), and was far more than could be explained by a reduction in inputs from road runoff in the same period of about 8% (estimated using as a proxy the Office of National Statistics' data on annual retail sales of road fuels in Pembrokeshire). The decrease in ΣPAH 29 between 2007 and 2012 was also statistically significant (*t*-test, $p<0.01$).

Finally, atmospheric inputs also may have contributed PAHs and other contaminants *via* both direct deposition and through the tributary catchments. From preliminary analysis of government air quality data it is thought this was particularly true from late 2005 to 2007. If so, MHW indeed suffered a 'perfect storm' during this period.

Extracts from report

Discussion

Morgan *et al.* (1996) showed that MHWESG data had been useful in discussion of a range of potential influences on MHW, including dredging. However, they also identified a gap in knowledge concerning the release and impacts of historical pollutants during dredging and other forms of physical disturbance, not necessarily anthropogenic. Although the work by Hebog (2006) documented the effects at the sites where dredging was conducted, and disposal sites have also been monitored outside MHW, the possible effect of sediment resuspension inside MHW has not been properly studied. Environmental Impact Assessment (EIA) is the formal process by which the possible effects can be assessed and uncertainties managed.

In the context of using EIA to avoid or minimise adverse impacts of LNG developments, the conservation agencies and developers agreed on directional drilling for the power station gas supply pipeline from Blackbridge under the lower MHW, and for the Western Cleddau estuary just south of Haverfordwest for the export line to the east. Such drilling avoids the risk of stirring up fine-grained sediments that could occur by cutting in a cheaper pipeline trench. Construction impacts and especially in-combination impacts from repeated or concurrent dredging are nevertheless sometimes under-estimated in EIAs.

EIAs should first characterise, but seldom do, the baseline levels of potential stressors (e.g. suspended particulate material (SPM) from tidal currents, storm waves, vessel movements, fishing, bait-digging, saltmarsh erosion, etc). The present data has facilitated *post-hoc* recognition in MHW of effects during the recent developments of LNG and power plants, and of licensed disposals from Neyland marina. Dredging effects were identified from the pyrogenic PAH fingerprint and also independently in May 2012 from sediment profile imagery taken in sediments from South Hook LNG to opposite Dragon LNG.

Sediment influx from the MHW drainage basin could also be expected to affect contaminant levels in upper tidal flats and subtidal sediments within the timescales between 2007 and 2012. The effect could be positive in the case of dilution by clean incoming sediments or negative when the influx is contaminated. Partly due to the economic downturn since 2008 that has generally reduced building activity, and reduced refining and usage of road fuels, declining contaminant inputs from the MHW catchment may have caused the observed decrease in sediment and biota concentrations. Some of these decreases could be partly explained by the *ca*. 8% fall in demand for road fuels in the UK between 2007 and 2011 due to the economic crisis (DECC, 2013 Office of National Statistics (ONS) data reported by *The Economist*).

Alternatively, in the negative case, increased pollution may have occurred due to the recent unusually wet summers and cold winters. *The Economist* during 2013 also analysed long-term ONS figures to suggest that pot-hole erosion in asphalt has increased due to road repair budgets being cut across Britain, and that a drop in the use of garages for parking overnight had occurred (due to the increasing size of cars). As a result, the weather, the state of repair of roads and the usage of garages in combination could have increased contaminants in road runoff nationally. Together with the construction in MHW of two new LNG plants and a large power station from 2006-2008, it might have been expected that PAH inputs and concentrations would have increased over the same time frame. Instead, they appear to have generally decreased between 2007 and 2012, and specifically they have increased only in those areas where sediment has been disturbed and sediment transport pathways lead to depositional sinks.

However, in either the above positive or negative case, inputs from a mix of rural and urban tributary catchments of varying discharge rates are unlikely to have simultaneously affected so many of the uppermost tributary reaches, many of which are rural. The only simultaneous source in all the tributaries' drainage basins would be atmospheric deposition, and typically in west Wales and elsewhere this is dominated by petroleum from domestic and vehicular emissions.

Notwithstanding the probable aerial input, the general pattern appears to be derived from activities down-estuary. Such an interpretation is supported by evidence from new MHWESG and Group member studies of sediment structure in the mid-estuarine reaches (*i.e*. drivers or sources of physical disturbance), fine-grained sediment forensics (*i.e.* sources of chemical stress) and bioaccumulation (i.e. status of, and effects on, biological receptors). The connecting pathways were first predicted by published STA. The pathways are now underpinned by data on the likely timescales of allochthonous (inflow) processes using a Chernobyl-produced radionuclide, and of autochthonous (within estuary) transport processes using dredge plume-tracking and sediment fluorescent tracers. These showed net transport rates from two weeks to about one year to traverse distances equivalent to the total axial length of MHW.

Seabed imagery showing independent evidence of cumulative dredging disturbance was taken in May 2012 by Germano & Associates, Inc. for MHWESG. Examples of disturbance on Milford Shelf and off Angle Bay show clasts of dark grey silt/clay near the surface or mottled sediment with a chaotic texture. These can be signs that subsurface material has been disturbed anthropogenically, although some mottling also occurs naturally in reduced, bioturbated silts. About 30 stations showed widespread possible visual impacts of disturbance, all but a few of them in areas subjected to recent construction and dredging in the area of MHW extending between South Hook LNG and Dragon LNG terminals.

The original Sediment Trend Analysis (STA) of the MHW continues to be a very useful paradigm for understanding an important deepwater ria and estuary system. The STA study of sediment transport pathways in MHW was published in Marine Pollution Bulletin over 25 years ago, as one of the first consulting applications of its kind. Environmental monitoring of chronic discharges and acute oil spills has collected an array of additional physical, chemical

and biological data from MHW (*e.g*. Bent, 2002; Little, 2009). The conclusions reached from these varied lines of evidence substantially endorse the STA (Little and Bullimore, in press).

The kinematic approach used by STA in coastal studies has often been greeted with intransigence by those who see it as a disruptive challenge to the incumbent approaches such as dynamic modelling, tracer studies, sediment trapping, etc. Work in MHW by independent researchers in a wide range of disciplines including the use of some of the above-mentioned incumbent methods, clearly shows the fundamental value of STA. The distribution of pollutants was well explained by STA in 1987. Some of the geochemical markers identified between 2007 and 2012 are effective sediment tracers, confirming sediment and contaminant transport patterns that were predicted by STA. The STA combined with the inter-disciplinary work generates practical hypotheses to assess long-range transfer and long-term fate of water and air pollutants arising from chronic inputs and major events.

The pronounced peak in concentrations of PAHs in late 2007 likely contributed to the adverse biological effects that were predicted by sediment quality guidelines and that have been observed simultaneously in many species. The peak contamination resulted from a combination of factors: long, albeit intermittent periods of construction of LNG-related plant, various dredging operations, road runoff, and aerial fallout possibly including from Buncefield. The combination may explain why these impacts were detected near and outside the entrance to MHW, as well as in the innermost reaches where STA points to effects (Little and Bullimore, in press).

Conclusions

Using new data from CCW for PAHs and other contaminants, the changes in absolute concentrations between 2007 and 2012 cannot be explained by changes in laboratory methods or by gross changes in sediment master variables such as % mud and % OC. Instead, the changes suggest that sediment disturbance has re-suspended and transported a pulse of currently and historically PAH-contaminated SPM passing up and down-estuary. Deposition patterns reflect classic clay accumulation models and are consistent with known MHW sediment transport paths determined by STA methods.

The resuspended PAH consist of broadly similar pyrogenic PAH at most stations, deriving as they do partly from the maintenance dredging of channels and berthing boxes. Sediment PAHs at some stations appear to become progressively more pyrogenic from 2007 to 2012, as if still 'recovering' from the more petrogenic signature that was lingering from the *Sea Empress.* The more petrogenic material may have been resuspended prior to 2007 by construction activities outside dredging areas (e.g. pile-driving at South Hook LNG).

Many of the PAHs, in particular those measured in 2007, exceeded sediment quality guidelines and by the nature of such guidelines, this excess is likely to have had biological effects. Recovery to below threshold levels of effect took place at most stations over the period 2007 to 2010, although high levels remained at Angle Harbour and Pembroke River. Additionally, some uppermost stations in the estuary were again high in PAH concentrations in 2012, due to the SPM pulse effect. The recovery is in line with previous MHWESG findings on benthic community recovery periods of from 3 years to more than a decade after dredging.

Bioaccumulation studies conducted for MHWESG have shown no general changes 2008-2010 in PAHs uptake by mussels with the exception of an order of magnitude increase at Angle (Harbour) and Pennar (Pembroke River). In contrast, a downward trend for total PAHs in ragworms was seen overall 2007-2010, again except for higher-molecular weight PAHs at Angle and Pembroke River and some upper estuary stations. There are demonstrable contemporaneous linkages between some biota and nearby sediment contaminant trends for PAHs, and also for PCBs and Hg.

The similar trends across various sample media and differing analytical methods are also further independent checks on the general comparability of data from CCW and ERT laboratories. These linkages and trends support the hypothesis that resuspension of historically-contaminated sediments by construction works and possible SPM spillage from dredging operations and Neyland marina disposal may be root causes: firstly for SPM effects on mussels nearest the construction activities, then secondly for ragworms in sediments further away, in both cases further than the 400m radius quoted in EIA predictions at the time. These areas are located outside of areas predicted in EIAs to be affected by primary (loss of seabed) or secondary (plume sedimentation) impacts. The increased bioaccumulation from SPM by mussels was also outside areas of predicted impact. This represents a tertiary form of effect that could adversely affect animal and human consumers of cockles and winkles in Angle Bay, Pwllcrochan and Pennar Flats, and especially Pembroke River for the native oyster fishery.

In summary, by late 2007, the sediment PAH levels were very high throughout MHW, after historically-contaminated sediments were disturbed by construction and dredging activities and also probably due to aerial inputs. Since then, most of the sediment (and ragworm) contaminant concentrations have generally decreased by dilution (and depuration) within three years (2007-2010). Specifically, they only increased in those areas and for some hydrophobic compounds where a proportion of the surface 1-2 cm sediments were chronically polluted toward the end of LNG-related activities, by NYH marina disposals, and by more general dredging. Most recently, inner reaches of MHW were partially re-contaminated by a pulse of suspended sediment moving mainly on flood transport pathways on timescales of <2 years (2010-2012), and also perhaps by marina-related disposals.

Recommendations

The above findings suggest that the MHWESG members should collectively ensure that forensic-quality analyses of stored reference samples are a formal part of the standard approach to response and monitoring after significant spills or engineering works in MHW. This may not be best left to contractors, unless better guided by strict protocols. Following the *Braer* (1993) and *Sea Empress* (1996) incidents a concerted effort was made to formalise UK spill sampling and analytical methods (Faksness *et al*., 2002; Environment Agency, 2004). Regulators, ITOPF (International Tanker Owners Pollution Federation) and other stakeholders can generally be satisfied with the modified Nordtest method in terms of initially identifying the spilled oil. It is also accepted that the more sophisticated forensic levels of analysis are not needed for each and every sample taken subsequently during a spill.

However, forensics are too often perceived as largely unnecessary, or too expensive, in many UK spill and effluent impact studies except for the short-term or legal application of establishing the identity of the spiller. The present study shows that forensic work is vital to correct identification of sources of chronic, unattributed or historical stressors in estuaries. In most EIAs, these input sources and their baseline conditions are very crudely summarised, and then any new data collected during the EIA can be only judged simplistically to be 'within the normal ranges for the site' or not. This is crude because it allows neither for the effect of a cumulatively increasing baseline nor for accurate prediction of the in-combination and indirect impacts which have clearly occurred during the present MHW studies. Finally, the supporting technical studies and EIAs should be published widely to be compliant with best environmental practices and indeed with UK and European laws.

The studies also confirm that visual survey methods such as benthic sediment profile imagery (SPI), when combined with sediment transport data and advanced forensic analyses have been very powerful in MHW. These tools *inter alia* help not only at the time of an initial spill response or contaminant disturbance but also in longer-term determination of the biota's exposure to the spilled oil, and the correct apportionment of impacts to multiple oil and contaminant sources. In addition, the process rates of physical and chemical impacts from engineering works in commercial waterways may be established. The tools facilitate a fuller and more technically defensible assessment of the ecological impact of the stressors in combination, whether acute oil spill incidents, chronic effluent or non-point source inputs, construction or dredging. Some geochemical markers also act as effective sediment tracers, and in this respect they confirm sediment and contaminant transport patterns that have been described previously in MHW.

The value of forensic analysis of the sediments sampled in 2010 for the MHWESG study has been increased by comparisons to the 2007 and 2012 CCW data using the same field methods, time of year and similar advanced analytical techniques (except no biomarkers were included in the CCW studies). Comparisons with CCW data are largely consistent with the interpretation of the 2010 sources of the PAH and confirmed the return to domination by pyrogenic sources from the earlier petrogenic inputs between 1996 and 2007. The fact that very similar conclusions have been drawn on heavy metals trends between 2007 and 2012 substantially endorses the comparability of the organic analyses. For metals and organics this has successfully extended the forensic work to cover the possible impacts of dredging and construction of the two new LNG and power plants, and of a marina's dredging activities. The value of these findings is increased further by comparison with independent field monitoring and with laboratory bioaccumulation data.

However, some PAH differences between surveys are quite possibly due to the different extraction, calibration and other procedures employed by the laboratories. In order to evaluate the reasons for these differences, detailed data packages with full QA/QC information would be required from them. Closer collaboration between MHWESG members in their various joint and several monitoring activities would help to overcome any changes in personnel, methods and laboratory. Additionally, the suites of PAHs and trace elements that are being monitored have changed through time: for example, in 2007 and 2012 only 6 trace elements were reported, compared with 9 trace and 5 major elements in 1982, 1984 and

1994, albeit using different extraction acids and methods. In coring studies during 1986, 22 trace and 9 major elements were analysed (Little, 2009). This suite included 7 rare earth elements now widely used in fuel cells, batteries, turbines and electronics, and thus likely to enter future waste streams. This selection of elements together with a full suite of alkylated PAHs and biomarkers should be considered as part of the baseline for future MHWESG monitoring, even if not all analytes are to be determined on each occasion.

Finally, knowledge of the interplay between current and historical contaminant inputs would be greatly enhanced by taking carefully-located, radionuclide-dated cores and by hydrocarbon chemical fingerprinting, along the lines proposed by Little (2009). Whereas previous coring efforts in the late 1980s were useful at the time and have also helped in this study to benchmark the process rates of sediment movement and flushing from the MHW catchment using ^{137}Cs fallout from Chernobyl, they did not employ advanced forensic methods for the organic contaminants (including PAHs and biomarkers), some of which were only developed after the 1989 *Exxon Valdez* incident. Future analyses of Hook colliery coal, recovered oil from the interceptor at the former Llanreath oil storage tank site, and groundwater adjacent to Angle Bay should be used as historical source samples, to be examined at the same time as the dated cores.

2.2 Wildfowl and wader counts on the Milford Haven waterway 2014-15

Annie Haycock, Pembrokeshire WeBS Coordinator

Executive Summary

The Wetland Bird Survey was carried out on the Cleddau Estuary system between September 2014 and March 2015 with additional counts for June and July 2014 made by Jane Hodges during the annual survey of summer shelduck populations.

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

A total peak count of 22,806 birds between November and February confirms that the estuary system is still of international importance for its waterfowl populations. This peak count was slightly higher than the previous two seasons, but these three years are still the lowest since 1996-97 when gulls were first included in the counts.

The levels of "National Importance" for many water birds have been revised, and only four species now qualify (based on a five-year mean): wigeon (max. 5720 in November), teal (max 2359 in January), greenshank (max 30 in November), and curlew (1731 in July). Shelduck (422 in February), Dunlin (1555 in February) and Little Egret (25 in October) were well below the qualifying level in 2014-15 but only just short based on the 5-year average.

Following two years of low counts, wigeon numbers seem to have recovered somewhat in 2014-15. However, the numbers are still well below the previous eight seasons. The many birds also arrived later, and some stayed later**.** The reason for these changes is not yet known, however the Milford Haven Waterway is not the only site to have experienced temporary reductions in numbers in recent years.

The total number of birds recorded each month was similar to the average of the past five years, but lower than those recorded during the 2000s. However, there were considerable differences from month to month, and species to species. For example, dunlin numbers were better than in 2013-14, but it was still the 2nd lowest count since 1987-88

Comparison of counts with the national report for 2012-13 (the most recent that is available) show that for most species, the local trends in populations are similar to those experienced nationally.

2.3 Annual summer shelduck survey 2014

Jane Hodges, PCNPA Ecologist

Executive summary

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

The results indicate that in terms of the numbers of broods of ducklings seen on the water, 2014 was an improvement on 2013 which (along with 2012) was the poorest year for breeding shelducks in the estuary since the current sequence of annual surveys began in 1991. As in previous years, predation is thought to have been a major factor affecting the number and size of broods recorded in 2014. Disturbance may also have been a contributory factor, although there is little hard evidence on which an assessment of the importance of this as a factor affecting the population can be based.

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

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

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

2.4 Development of a potential indicator of ecological status in the British Isles, using the seagrass, Zostera marina

Ben Jones, MSc thesis, Swansea University

Abstract

The coastal environment of the British Isles includes a range of ecosystems. Of these, seagrass, specifically *Zostera marina,* are of particular interest. These systems are of ecological and economical importance in terms of the services they provide. However, coastal ecosystems in the British Isles are under direct threat from over enrichment, detrimental to seagrass and ecosystem health. Over-enrichment is difficult to detect in marine environments due to constant mixing of water bodies and problems associated with continuous sampling. Seagrasses are unique and respond physiologically and morphologically to changes in environmental nutrients, which are reflected in their leaf tissue nutrients. Due to this, it is proposed that the use of seagrass as an indicator of ecosystem health and over enrichment is developed. To achieve this goal, seagrass was sampled from a number of sites around the coast of the British Isles, each with varying degrees of associated perceived anthropogenic activity. Leaf tissue samples were analysed for C, N & P, while morphometrics were also taken. Analysis of these variables suggested that sites with lower perceived anthropogenic activity displayed higher C:N, C:P and N:P ratios, which were associated with higher levels of growth (Shoot biomass, Leaf length, Leaf width, Leaf area, Percentage cover). These characteristics were attributed to a healthy ecosystem. Overall, results indicated that the seagrass associated ecosystems of the British Isles are in poor condition in comparison to global averages: however, differences were observed between areas, with some sites being considerably worse. Specifically, the meadow at Porthdinllaen, showed warning symptoms of eutrophication, as did the meadows at Gelliswick Bay and Southend-on-Sea, which are heavily influence by riverine inputs. Although deeper understanding is needed to form a full picture of these ecosystems, these findings can be considered as baseline information for further developments into coastal ecosystem monitoring programs in the British Isles with the approach being readily and easily replicated for future monitoring.

2.5 Distribution of marine non-native species on vertical artificial structures in Milford Haven

Jennie Jones & Jenny Whitmore, Centre for Applied Marine Sciences, Bangor University

Summary

SEACAMS collaborated with Milford Haven Port Authority to provide spatial data on the distribution of non-native species on vertical artificial structures within Milford Haven waterway, Pembrokeshire, Wales, UK that could be used for research and to inform management decisions.

The study focuses on a survey of marine non-native species colonising vertical artificial structures including navigation buoys, pontoons and pier pilings throughout the Milford Haven and covers the area from the mouth of the waterway to the east of Cleddau Bridge. A total of 77 samples were taken across eighteen sites within Milford Haven between the 12th and 14th June 2014. Twelve sites were accessed by boat, the remaining six were accessed by foot at low water. At each site, four 10 x 10 cm quadrat scrape samples were taken within a 0.5m vertical range from each other within +/- 1.5 hours of LW. Specimens were relaxed by adding 0.05 ml of menthol crystals and stored in 80% Industrial Methylated Spirit before being identified in the laboratory and processed within three months of being collected.

Marine non-native species were found at twelve out of eighteen sites sampled. This survey recorded eight invertebrate and one species of algae. Of two species considered to be invasive by NRW only one, *Botrylloides violaceus,* is considered a priority for action. On the Marine Aliens II 'most-wanted' list, we recorded *Grateloupia turuturu, Austrominius (Elminius) modestus, Ficopomatus enigmaticus, Bugula neritina, Corella eumyota, Styela clava*, *Botrylloides violaceus and Botrylloides diegensis.*

Samples containing suspected INNS were sent for verification to the Marine Biological Association. Two samples containing three colonies of suspected *Didemnum vexillum* were identified as other *Didemnum* species but not *D. vexillum* {*see section 2.5*}. Another non-native invasive species, *Botrylloides diegensis* not previously recorded from Milford Haven, was confirmed.

Our recommendation for further research would be to assess the environmental, social and economic impact of NNS in Milford Haven and establish whether any of the species of "potential", "low" or "unknown" risk already recorded could be classified as "invasive". This could be through further analysis of existing datasets, through socio-economic studies involving stakeholders, through monitoring (using established rapid assessment techniques) to record presence of new species and surveillance of NNS including abundance and distribution studies to establish how quickly a species is expanding its range. The results of this survey suggest that targeting "clusters" of fixed vertical artificial structures such as shipping berths and navigation aids could yield useful information on the presence and spread of INNS.

Jones, J & Whitmore, J, 2015. *Distribution of marine non-native species on vertical artificial structures in Milford Haven*. Report to Milford Haven Port Authority from Centre for Applied

Marine Sciences, Bangor University. SEACAMS report -RD-067. Available on request from Port of Milford Haven.

2.6 Laboratory identification of didemnid samples collected from Milford Haven in June 2014.

John Bishop, Marine Biological Association UK, Plymouth

Summary

Two substrates bearing didemnids were received, from which three colonies in good condition were sectioned and stained. All were assigned to the genus *Didemnum*, but none displayed the full combination of characters presented in the literature for *D. vexillum* (Carpet Sea Squirt). It is concluded that the specimens do not provide evidence that *D. vexillum* is present in Milford Haven.

Material and methods

Two substrates were received preserved in 70% industrial denatured alcohol after relaxation with menthol crystals. SEACAMS also provided a photograph (Fig. 1) of the first substrate to be sent ("*Suspected Didemnum vexillum collected 13/6/2014*", no locality details), showing didemnid growth that, upon removal, proved to be two discrete colonies in close contact over a short distance of their respective perimeters (Figs. 1 and 2): Colony 1 (25mm maximum dimension) and Colony 2 (18mm). The second substrate (*Pembroke Dock Ferry Terminal Pontoon Deck 17 13/6/2014*) bore a colony of 19mm maximum dimension comprising narrow lobes rather than a substantial mass (Fig. 3). For comparison, part of a large colony from near Largs, Scotland (colony F 15), already confirmed as *D. vexillum*, was processed in parallel with the Milford Haven specimens.

In the laboratory, each specimen was cut vertically into short slices of ≤1 mm thickness using a razor blade. A small piece from the colony surface was also removed and mounted on a cavity slide for inspection of spicules under the compound microscope. The slices from each colony were placed in a small plastic pot of 35% ethanol to partially rehydrate, and were shaken vigorously, which might have resulted in the displacement of larvae that could subsequently be gathered from the bottom of the pot. While rehydration was taking place, one or more of the sections was examined under a stereomicroscope to determine the distribution of spicules throughout the depth of the colony. The slices were all then rinsed in water and placed in 1% HCl for 1 to 1.3 h to dissolve the spicules, rinsed thoroughly, and then stained in Harris' Haematoxylin (Raymond A. Lamb) diluted x 5 with distilled water, for 5 minutes. They were then examined under water against a dark background with a stereo dissecting microscope (Leica MZ FLIII) and lighting from above, to note tunic and zooidal characteristics. (If present, and if required, additional larvae could also be dissected from the slices at this stage.)

Results

The observations made are summarized in Table 1 overleaf.

Because if their small size, the three Milford Haven colonies were completely divided into slices for staining and microscopical observation, although it is generally desirable to retain intact sections of a colony showing its external appearance for future reference. Larvae were not found in any of the Milford Haven colonies, although all three had fully-formed testes. Colonies 1 and 2 showed a feature not seen in *D. vexillum*, dark staining of the spaces between

groups of zooids (these spaces presumably representing small water channels). All three Milford Haven colonies lacked distinctive inclusions seen in the lower tunic of *D. vexillum*, comprising spheroidal clusters of small spherical bodies with a golden colouration. Instead, denser dark greenish patches of smaller bodies were seen in the tunic. Colony 3, lacking any substantial expanse of zooids (in addition to lacking larvae) could not be scored for a full range of accepted characters and it was not possible to completely rule out *D. vexillum*, although the nature of its tunic inclusions argued against the colony being *D. vexillum*. It is likely that several other *Didemnum* species occur in Milford Haven.

DNA sequence analysis would be an approach more likely to succeed for identification of insubstantial specimens such as colony 3, given suitable preservation.

Table 1. Scoring of characters in preserved didemnid samples from Milford Haven, 2014, with character states for *D. vexillum*.

	Colony single-coloured, pale	Clumping of zoods into small groups	Contracted zooids marked by white spot	Deep cloacal channels	Cloacal channels dark (=semi-transparent spicule-free tunic)	Spicules stellate, most near-surface	Rows of stigmata in branchial basket	Atrial aperture widely open (not tubular)	Coils in sperm duct	Testis lobes	Comments
D. vexillum	✓	✓	✓	✓	✓	✓	**4**	✓	**8-11**	**1**	
Milford Haven Colony 1	✗*	✓	✓	✗	?*	✓**	4	✓	9-10	1	***Didemnum* sp. but not *D. vexillum.*** Larvae not seen. *Channels between zooids generally dark-stained **As defined, but spicules not forming a distinct sub-surface layer between tops of branchial baskets as in *D. vexillum*.
Milford Haven Colony 2	✗*	✓	✓	✗	?*	✓**	4	✓	9	1	***Didemnum* sp. but not *D. vexillum.*** Larvae not seen. *Channels between zooids genrally dark-stained **As defined, but spicules not forming a distinct sub-surface layer between tops of branchial baskets as in *D. vexillum*.
Milford Haven Colony 3	✓	✓	✓	✗*	✓	✓	4	✓	9	1	***D. vexillum* cannot be discounted** but some characters unscorable (larvae not seen). *Absence of deep channels could relate to small colony size.

Taxonomic commentary.

The Didemnidae have miniaturized and simplified zooids, offering relatively few readily scorable characters with distinct and unambiguous alternative states. *Didemnum* is the largest genus within the family and the second largest within the ascidians as a whole, with 230 described species currently regarded as valid (Sanamyan, 2014). For many of these species, the descriptions are old and/or very incomplete. The currently accepted morphological character-set used to recognise *Didemnum vexillum*, detailed by Lambert (2009), is based on direct comparison with only seven or eight other *Didemnum* species, and there are many examples of identical or overlapping characters states even within that subset. For example, the *D. vexillum* larval 'formula' of three adhesive papillae plus six pairs of vascular ampullae is shared by five of the other entities considered by Lambert, and can also be seen in additional European species (e.g. Lafargue & Wahl, 1887). It thus seems probable that the available character-set used here does not uniquely distinguish *D. vexillum* within the entire genus.

References

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Sanamyan, K. (2014). *Didemnum* Savigny, 1816. In: Shenkar, N.; Gittenberger, A.; Lambert, G.; Rius, M.; Moreira Da Rocha, R.; Swalla, B.J.; Turon, X. (2014) Ascidiacea World Database. Accessed through: World Register of Marine Species at http://www.marinespecies.org/aphia.php?p=taxdetails&id=103456 on 2014-11-04

2.7 Invasive Non-Native Species survey dive Dragon LNG jetty

Blaise Bullimore. MHWESG project manager

A team of six divers, diving under the auspices of the MCS *Seasearch* project, carried out a rapid species survey of three of Dragon LNG jetty piles on **26 September 2014.**

Four of the divers are professional marine biologists (three NRW members of staff) and two are joint authors of a new *Seasearch* identification guide for ascidians (sea-squirts) due for publication in 2015-16.

Dragon LNG kindly sponsored the charter of the dive vessel.

The underwater visibility for the survey was extremely poor (<0.5 metre) with useful natural light penetrating to <5 metres depth. These constraints limited the scope for systematic survey, confidence in the comprehensiveness of species recorded and photography. Nevertheless, a *Seasearch* survey form was completed, 50 species were identified, including four non-native species, and a comprehensive range of images obtained.

The piles were dominated by ghost anemones (*Metridium senile*), feather stars (*Antedon bifida*) and a range of solitary and colonial ascidians. Six sponge species, eight molluscs and other anemones and brittlestars were also recorded.

The non-natives recorded are widespread and frequent to abundant throughout Milford Haven: *Crepidula fornicata* (slipper limpet); *Styela clava* (leathery sea squirt); *Asterocarpa humilis* (compass sea squirt) and *Corella eumyota* (orange-tipped sea squirt).

Two, possibly three, other ascidians were observed and photographed as suspect non-natives. The images were examined by INNS specialists at the UK Marine Biological Association, Plymouth, who were able to confirm that the suspects were <u>not</u> the highly invasive *Didemnum vexillum* (carpet sea squirt; not known from SW Wales, nearest known population Holyhead) nor either of the two non-native *Bortylloides* species. However, whilst at least two of these species were known to the MBA specialists, their identity remains unresolved. Provision of carefully preserved samples may enable reliable identification.

2.8 Seasearch in Milford Haven Waterway

Kate Lock, *Seasearch* Coordinator South Wales & Blaise Bullimore, MHWESG Project Manager and *Seasearch* participant

Seasearch

Seasearch is a UK project for volunteer recreational and professional divers who have an interest in what they see under water, want to learn more and want to contribute to helping protect the marine environment around the coasts of Britain and Ireland. The main aim is to map the various types of seabed found in the near-shore zone around the whole of the UK, recording what lives in each area, contribute to establishing the richest sites for marine life, the sites where there are problems and the sites that need protection.

Seasearch provides training in species and habitat identification and recording skills to enable recreational divers to participate in surveys. Surveys target areas around the coast where little data exists or where there is a conservation need. Surveyors record general site descriptions, detailed habitat information and a semi-quantified list of all species observed in each habitat surveyed. As well as photographs being taken, survey forms are completed with the inclusion of a habitat sketch to highlight the overall impression of the surveyed site.

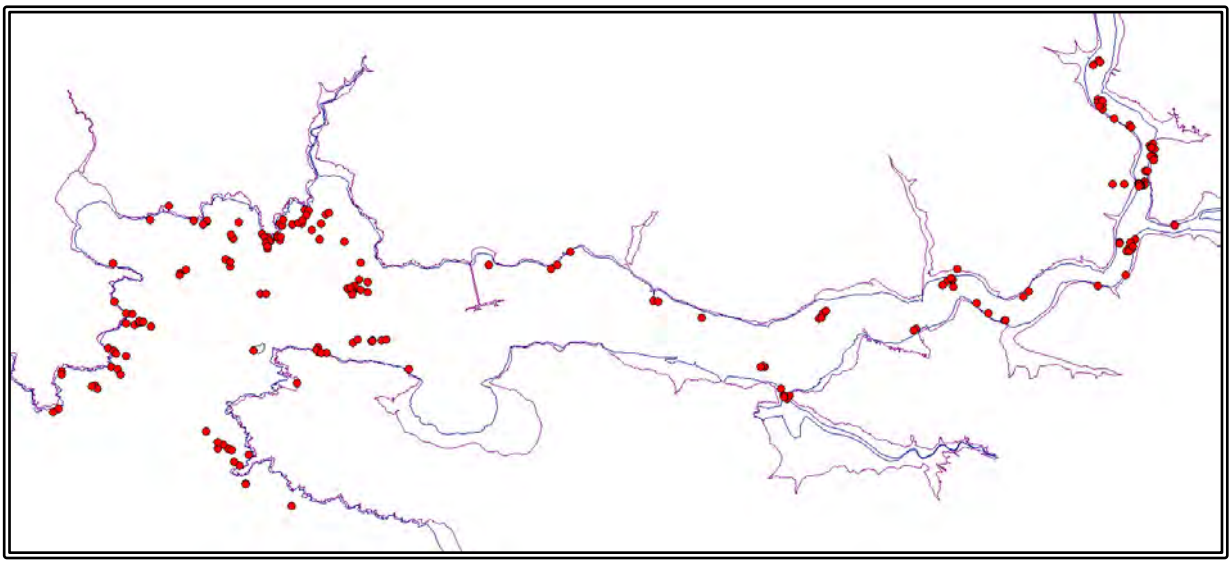
Survey forms are quality checked by experienced marine biologists who enter all data into the national database *Marine Recorder*, managed by Joint Nature Conservation Committee, which contributes to the National Biodiversity Network.

The main aim is to provide quality assured *Seasearch* data to partner organisations and the public. However, the project also aims to raise public awareness of the diversity of marine life and habitats in Britain and Ireland through the dissemination of information gathered and the identification of issues arising from it.

Seasearch in Milford Haven Waterway 1999 to 2014

Although one weekend of *Seasearch* surveys in Milford Haven was completed in 1999, specific effort to survey within the Waterway began in 2004. In total, 280 survey forms have been completed for 46 sites over 39 survey days, extending from Llangwm Ferry in the upper reaches of the Cleddau through the length of the Milford Haven to St Ann's Head and Sheep Island at the entrance of the waterway; 139 forms from 21 sites cover the mid to upper Waterway upstream of Stack Rock with 150 forms from 25 sites from the lower Waterway and entrances (see map).

Site selection and surveys were carried out in liaison with CCW/NRW marine staff, the Pembrokeshire Marine SAC Officer and the MHWESG project manager in order to ensure that data collected will be useful to management needs of the area. As a bonus to the routine *Seasearch* records, many valuable records of UK and Welsh Biodiversity Action Plan and invasive / non-native species have also been collected.



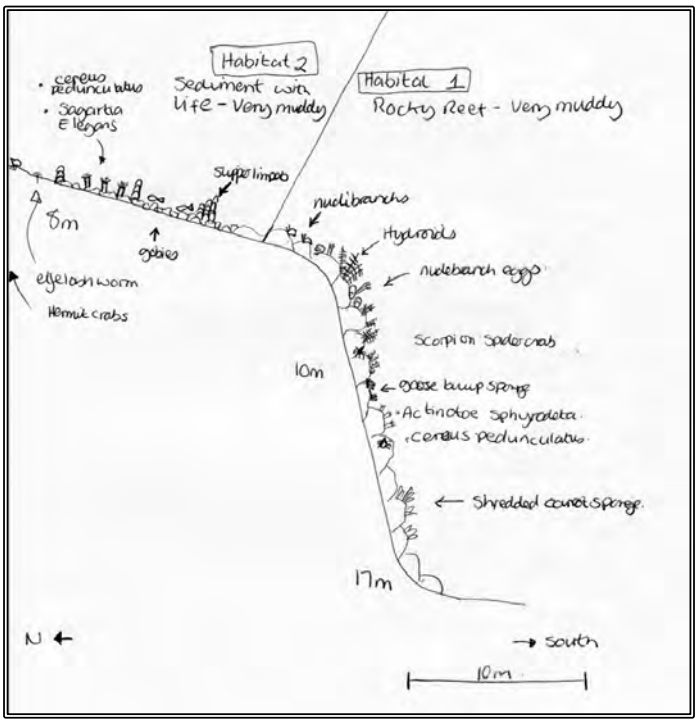
Sites were chosen to target possible reef sites identified using Multibeam sidescan survey outputs with positions being provided by Mike Camplin (NRW Specialist Monitoring Team Leader). These included sites at Llanstadwell where a vertical rock wall was discovered and two reefs at Castle Reach, each site was dramatic with thick covering of sponges, hydroids and ascidians plus a diverse range of associated of nudibranch sea slugs.

Biodiversity Action Plan habitats and species

Milford Haven waterway hosts a range of marine BAP habitats and species, of which *Seasearch* has recorded and surveyed eelgrass (*Zostera marina*), tidal rapid reefs, native oysters (*Ostrea edulis*), fan shell (*Atrina fragalis*) and crawfish (*Palinurus elephas*).

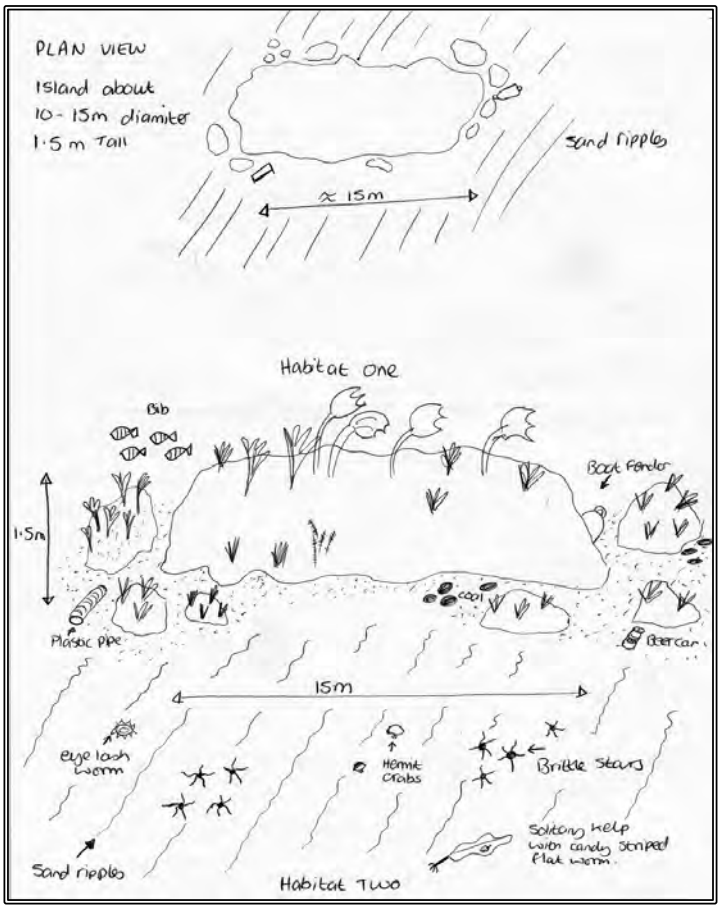
Tidal rapid reefs

The term 'tidal rapids' is used to cover a broad range of high-energy environments including deep tidal streams and tide-swept habitats. Wherever they occur, strong tidal streams result in characteristic marine communities rich in diversity, nourished by a constantly renewed food source brought in on each tide.



Habitat sketch: under Cleddau Bridge

The rocky tide-swept habitats in Milford Haven and the Daugleddau estuary are one of the key features of the reefs present in the Pembrokeshire Marine SAC and are considered of both national and European importance. High-resolution multi-beam bathymetric surveys of the Haven have revealed a number of apparently rocky features that had not been previously identified and *Seasearch* has targeted these features.



Habitat sketch: Sandy Haven Reef

Native oysters, Ostrea edulis

Historically, Milford Haven supported a thriving oyster fishery but overexploitation led to population collapses. Although oyster numbers are much reduced from levels, the Waterway is the only currently known location for live oysters in Pembrokeshire. Following a 2002 survey to assess the distribution and abundance of the native oyster in Milford Haven carried out for CCW by Emu Ltd, *Seasearch* resurveyed six of their sites in 2010 and 2011 to record the current condition.

Habitat sketch: West of Stack Rock

At Jenkins Point the habitats, species and, in particular, the density of native oyster *Ostrea edulis* were surveyed within and outside the area of mooring. Although the Seasearch team did not find high densities of oysters there were a significantly higher number observed within the mooring area than outside which suggests the presence of the moorings may provide protection from the oyster dredging that occurs in the vicinity.

Fan shell, Atrina fragilis

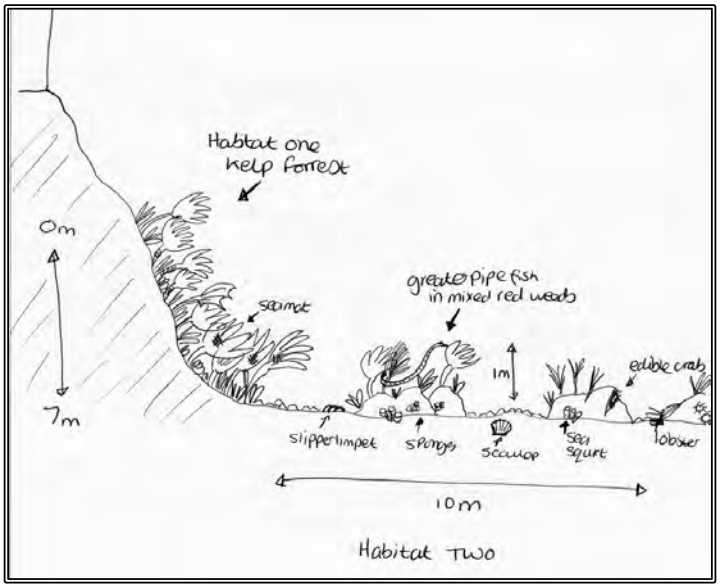
Atrina fragilis is a large, nationally scarce, bivalve mollusc listed for protection in the Wildlife and Countryside Act 1981 and a UK BAP species. Current records of the fan shell show that it is now only found at sites on the west of Scotland and two sites on the south coast of England, Plymouth Sound and Salcombe Bay. However, there are historical records from Wales in Carmarthen Bay and near Stack Rock, Milford Haven.

Seasearch's UK coordinator Chris Wood organised and led a survey targeting these Welsh sites in 2003. Although suitable sediment habitats were found at all sites no living specimens were recorded. The only record for the species was of a single shell found amongst shell debris close to Stack Rock.

Other *Seasearch* surveys have identified sites in the entrances of Milford Haven with suitable habitat for fan shells and in 2007 further survey dives were targeted around Stack Rock and also at areas of reef east of the Dakotian wreck. No fan shells were found despite suitable habitat being present at both sites.

Non-native and invasive species

Seasearch does not specifically target non-native species. However, because Milford Haven is a known marine NNS 'hotspot', surveyors are routinely reminded to maintain a watchful eye for non-natives. Many NNS are difficult to identify or are easily overlooked and photography has proved a useful tool in recording NNS during surveys. In 2014 Dragon LNG funded boat charter for *Seasearch* to specifically record NNS on their jetty piles.



Habitat sketch: Stack Rock Fort

A detailed report summarising the site descriptions and characterising species for the surveys in Milford Haven from 2004 to 2014 is in preparation.

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, and several existing members modestly increased their contributions in 2014. Nevertheless, the Group's real purchasing power has decreased substantially since it was established in 1991 and the scope and cost of the projects undertaken by the Group have increased considerably.

Priority projects were agreed 2012 but because insufficient resources are available within the Group's current annual income to undertake all these priorities at the preferred intervals the medium term work programme is revised on a rolling basis. This potentially includes avoiding expenditure one year to carry it forward to the next to fund particularly expensive projects, at the expense of postponing, or even abandoning, one or more routine projects.

Priorities for the coming year include analysis and reporting of the last three rounds of macrobenthic sampling (2008, 2010, 2013), reviewing recent and current seagrass, Zostera species, data and monitoring to synthesise and summarise recent information and to determine requirement for additional work by the Group and, if resources stretch sufficiently far, the scheduled repeat of rocky shore surveillance.

Following retirement of PCNPA's ecologist, Jane Hodges, the National Park's in-kind contribution of annual summer shelduck breeding surveillance would cease in 2015. As the Group wish to maintain this long data set the work will be continued through a contract with Jane. The wetland bird data collation and reporting will also be continued.

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

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.

[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.

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

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: Memorandum of Agreement

THIS AGREEMENT is made the 1st day of July 2004

BETWEEN:

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

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

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

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

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

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

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

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

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

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

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

Here and after referred to as "the Parties"

RECITAL

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

AGREEMENT

The parties agree as follows:

1. INTERPRETATION

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

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

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

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

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

2. SCOPE OF THE JOINT VENTURE

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

2.2 The Objects of the Group are:

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

2.2.2 to undertake surveillance of the Waterway by:

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

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

2.2.2.3 maintaining a literature and information database.

2.2.3 to share technical output equally under joint ownership and copyright

2.2.4 to function as a technical, science based, group

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

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

3. CONTROL AND MANAGEMENT

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

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

3.1.2 exchanging information

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

3.1.4 preparing an annual business plan

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

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

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

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

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

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

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

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

4. RESOURCING

4.1 Each of the Group Members will provide either a monetary contribution or some other contribution eg services, premises that shall be agreed by all the Group Members for the furtherance of the Objects of the Group in accordance with the annual business plan referred to in clause 3.1.4. The contributions are to be provided promptly within the time frame agreed for contributions

4.2 Milford Haven Port Authority shall receive all financial contributions by Group Members and shall keep such monies in a separate interest bearing bank account in trust for the Group. Milford Haven Port Authority shall make payments on behalf of the Group in respect of

commitments agreed at clause 4.3 below but may not make any other payments or commitments on behalf of the Group without the prior approval of the Committee. Milford Haven Port Authority shall provide quarterly statements to the Committee in respect of such account

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

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

5. INTELLECTUAL PROPERTY RIGHTS

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

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

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

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

6. LIABILITY

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

7. TERM AND TERMINATION

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

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

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

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

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

8. GOVERNING LAW

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

9. THIRD PARTIES

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

10. NO PARTNERSHIP

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

11. SUCCESSORS

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

12. ASSIGNMENT

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

13. ARBITRATION

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

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

Appendix 3: Chronological list of MHWEMSG / MHWESG[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

1996

[2] The Group changed its name in 2000

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. A report to the Milford Haven Waterway Environmental Surveillance Group.

Appendix 4. Invasive / non-natives species in Milford Haven

The table below lists most of the known marine non-natives in Wales, or nearby.

Species	**Distribution**	**Notes**
Undaria pinnatifida (Wakame)	First recorded in Haven 2014 (several records)	Competes for space with native kelp species.
Sargassum muticum – (Wireweed)	First found in Pembrokeshire at West Angle Bay 1996. Now widespread in Haven and open coast.	Overtops and shades native seaweeds. Some debate about whether it is a problem.
Grateloupia turuturu – (Devil's tongue weed)	Found on buoys in the Haven and the marinas in 2014.	Grows very fast - to the size of kelp. Threat to native red algae, can shade other algae http://www.marlin.ac.uk/recording-blog/index.php/2010/09/01/devils-tongue-weed/
Anotrichium furcellatum (Harpoon weed)	Widespread in the Haven	
Codium fragile subspecies *fragile* (Green sea fingers)	Occurs in rock pools at e.g. Freshwater West and St. Bride's. Not considered a problem in the Haven.	Can out compete and displace native *Codium fragile,* ssp *tomentosoides*
Haliplanella lineata (Orange striped anemone)	Only recorded in small crevices and empty barnacle shells at Pembroke Ferry.	A tiny little anemone. Fouls hard substrata in harbours and brackish inshore waters. Associates with mussel and oyster shells, stones and piers. Often found intertidally. May foul hulls of boats as associate of attached bivalve shells. http://www.marlin.ac.uk/speciesinformation.php?speciesID=4686
Ficopomatus enigmaticus (Trumpet tube worm)	In all the saline lagoons in Pembrokeshire; common in Pembroke Mill Pond.	Its preferred habitat within brackish waters, including estuaries, results in this species being ideal for transport on ships hulls (most major ports are sited on estuaries) and commercial mollusc shells. A fouling species which affects

		ships, buoys and harbour structures. Habitat alteration, threat to biodiversity, can block inlet pipes. http://jncc.defra.gov.uk/page-1700
Crepidula fornicata (Slipper limpet)	Widespread and common, locally superabundant, in the Haven.	Habitat alteration, threat to biodiversity and aquaculture. Altering habitats, including the maerl bed.
Urosalpinx cinerea – (American oyster drill)		Threat to aquaculture through feeding on bivalves.
Crassotrea gigas (Pacific oyster)	Widespread and now breeding in the Haven.	Displacement of native oysters; habitat alteration
Austrominius modestus (Australian barnacle – previously named *Elminius modestus)*	Widespread. Present in Haven for decades and considered naturalised.	Competes for space with native barnacles, is faster growing.
Amphibalanus amphitrite (Striped barnacle)	Now occurring on south coast of England. Formerly present in Queens Dock Swansea when heated by power station cooling water.	
Corophium sextonae (amphipod)	Widespread in subtidal sediments in Haven.	Impacts unknown.
Hemigrapsus sanguineus (Asian Shore crab)	First UK reports from Aberthaw power station, Glamorgan, and Kent in 2014. Previously recorded from Jersey and Guernsey since 2009.	Small shore crab distinguished from native green shore crab by three spines on carapace (5 on native crab), striped legs with red spots.
Eriocheir sinensis (Chinese mitten crab)	Established in Dee estuary in Wales.	Occurs in lower estuaries and marine habitats. Young crabs migrate upstream, into freshwater and brackish systems. Adults usually live in burrows in muddy riverbanks causing erosion and destabilisation, and migrate into deep, open, saltwater locations

		to reproduce.
Caprella mutica (Japanese skeleton shrimp)	Widespread. Recorded in Milford marina once in 2009.	Serious threat to native skeleton shrimp populations.
Tricellaria inopinata – (Tufty buff bryozoan)	Widespread in UK, probably under-reported in Wales,	May impact biodiversity. http://www.marlin.ac.uk/galleryimage.php?imageid=3380
Bugula neritina (Ruby bryozoan)	Widespread in Haven and UK.	Potential fouling nuisance on vessels, seawater intake pipes etc. Negative impacts on aquaculture are possible. May impact biodiversity.
Bugula stolonifera (Bryozoan)	Historical records in Haven	
Watersipora subtorquata (Red ripple bryozoan)	Spreading rapidly in England.	Tolerant to copper based antifoulants.
Schizoporella japonica (Orange ripple bryozoan)	First recorded in UK Holyhead marina, north Wales, 2010	Potential fouler of mussel and oyster culture gear.
Didemnum vexillum (Carpet seasquirt)	Present in Holyhead marina, north Wales, North Wales (subject of high cost eradication attempt).	Local threat to biodiversity and aquaculture through smothering. Alert species because of potential impact
Perophora japonica- (Creeping seasquirt)	Single record from near Dale 2002	
Asterocarpa humilis - (Compass seasquirt)	Recently recognised, and spreading rapidly in England. Widespread in Haven.	Potential fouler of aquaculture equipment.
Corella eumyota (Orange tipped seasquirt)	Widespread in Haven and UK. First recorded in the Haven in 2008.	Often forms large clumps of tightly packed aggregations on floating pontoons, piers, ropes, ship hulls, and other submerged structures. Individuals can be so tightly adherent to one another that it is usually not possible to separate them without tearing the external covering

		May overgrow other organisms, including other invasive species
Styela clava (Leathery seasquirt)	Worldwide. Present in the Haven for decades.	Detrimental to aquaculture but may increase biodiversity per unit area of substrate. Common on rocks, floats and pilings in protected waters, and on oyster and mussel shells, and is occasionally found on seaweeds. It mainly occurs in the low intertidal to shallow subtidal zones, rarely to 25 m depth. http://www.exoticsguide.org/styela_clava
Botrylloides violaceus (Orange cloak seasquirt)	Widespread in UK, threat to biodiversity and aquaculture through smothering, can block inlet pipes; entering natural habitats. First recorded in the Haven 2008. Now frequent in the Haven (e.g. by the Cleddau Bridge) and sublittorally.	Found on artificial surfaces in shallow water, especially in harbours and marinas. Also found attached to macroalgae and other unitary sea squirts, for example *Styela clava*. http://www.marlin.ac.uk/speciesinformation.php?speciesID=2791 Grows on a variety of surfaces, include docks, boat hulls, buoys, ropes, pilings, the undersides of rocks, eelgrass (*Zostera marina*) blades and seaweeds. It often overgrows mussels, barnacles, encrusting bryozoans and solitary sea squirts. http://www.exoticsguide.org/botrylloides_violaceus
Botrylloides cf. diegensis (San Diego seasquirt)	Spreading in south and SE England.	Threat to aquaculture through smothering.
Botrylloides sp. X		Recently distinguished.
Ciona intestinalis type A		Recently distinguished; threat to biodiversity – 'cryptic' species, hybridises with native type B; fouler of aquaculture equipment (as is B).