MILFORD HAVEN WATERWAY
ENVIRONMENTAL SURVEILLANCE GROUP

GRŴP CADW GOLWG AMGYLCHEDDOL
AR DDYFRFFORDD ABERDAUGLEDDAU


# Business Report 2011

# MILFORD HAVEN WATERWAY ENVIRONMENTAL SURVEILLANCE GROUP

# BUSINESS REPORT 2011



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# Milford Haven Waterway Environmental Surveillance Group
# Report 2011
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***Wildlife Trust West Wales (corresponding)***

***Welsh Assembly Government Environment Division (observer)***

**Contact the MHWESG by e-mail at**

**mhwesg@gmail.com**

# Milford Haven Waterway Environmental Surveillance Group

## Report 2011

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# CHAIRMAN'S FOREWORD

As I write, the Earth Summit 2012 in Rio has just finished and the 45,000 participants, including 12,000 delegates, from 188 countries have returned home. As around 700 voluntary agreements were made during the last two weeks leading up to and including the three day event in June, any lasting impact is likely to take some time to emerge.

Whilst there are concerns over what has been achieved, there appears to be optimism that at one of the side events the Global Ocean Forum launched "The Global Partnership for Oceans" wherein over 100 governments, international organizations, civil society groups, and private sector interests agreed to devise strategies to rebuild fish stocks, protect and reduce habitat loss, increase resilience to climate change and reduce pollution from all sources. There was also recognition of the value that increasing efficiency of marine operations would have in delivering sustainable development and reduction of poverty.

For this to be achieved regular monitoring and measurement is essential. The objective of the Milford Haven Waterway Environmental Surveillance Group is to gather data. Data that may be used to assist with research by academic institutions and others that in turn can inform policy makers and politicians charged with delivering these ambitious goals.

2012 is also a landmark for the Group as it celebrates 20 years of continuous working within the Milford Haven Waterway. Indeed, the group has commissioned its most extensive and costly project, sediment profile imaging throughout the Haven, in its history. The results of this work will be included in the next business report.

As well as being distributed across its membership, the reports commissioned by the Group are also circulated to scientific libraries, made available in local libraries in Pembrokeshire, and also from the Group's Project Officer, Blaise Bullimore (via ,hwesg.@gmail.com).

The major reason for the Group's success is the recognition by all members, both private or public sector, of the immense value that such clear objectives and collaborative approach provides to each organisation.

What is even more pleasing is that the membership continues to expand with RWEn Power and South Hook LNG joining over the last two years and Dragon LNG agreeing to join in 2012. This expansion will sustain the Group as it continues to deliver its ambitious but achievable forward programme.

I wish to add my personal thanks to the membership representatives who make available their valuable time contributing to and scrutinising projects to ensure that they deliver maximum benefit.

Finally, my thanks to Blaise Bullimore whose dedication, enthusiasm and support to the Group continues to be immense.

Captain Mark Andrews

Milford Haven Port Authority

*Chairman*

# RHAGAIR Y CADEIRYDD

Rwy'n ysgrifennu hwn pan fo Uwchgynhadledd y Ddaear 2012 newydd ddod i ben yn Rio, a'r 45,000 o gyfranogwyr, gan gynnwys y 12,000 o gynrychiolwyr 188 o wledydd, wedi dychwelyd adref. Gan fod oddeutu 700 o gytundebau gwirfoddol wedi eu gwneud yn ystod y pythefnos olaf, cyn a chan gynnwys y digwyddiad tri diwrnod ym Mehefin, cymer gryn amser cyn daw unrhyw effaith barhaol y cyfan i'r amlwg.

Er bod rhai'n pryderu ynghylch yr hyn a gyflawnwyd, roedd lansio'r "Bartneriaeth Fyd-eang dros Gefnforoedd" gan y Fforwm Cefnforoedd Byd-eang yn ddigwyddiad ymlol sy'n ymddangos yn obeithiol. Cytunodd dros 100 o lywodraethau, sefydliadau rhyngwladol, grwpiau cymdeithas sifil a buddiannau o'r sector preifat i ddyfeisio strategaethau ar gyfer adfer stociau o bysgod, diogelu a lleihau colledion cynefinoedd, gwella'r gallu i wrthsefyll newid yn yr hinsawdd a lleihau llygredd o bob ffynhonnell. Roedd parodrwydd hefyd i gydnabod y byddai gwella effeithlonrwydd gweithrediadau morol yn werthfawr o safbwynt datblygu cynaliadwy a lleihau tlodi.

Er mwyn cyflawni hyn i gyd, bydd monitro a mesur cyson yn hanfodol. Nod Grŵp Goruchwylio Amgylcheddol Dyfrffordd Aberdaugleddau yw casglu data. Data y gellir eu defnyddio gan sefydliadau academaidd ac eraill, mewn ymchwil a fydd, yn ei dro, yn goleuo penderfyniadau'r gwneuthurwyr polisi a'r gwleidyddion a fydd yn gyfrifol am gyflawni'r amcanion beiddgar hyn.

Mae 2012 yn garreg filltir yn hanes y Grŵp, sy'n dathlu 20 mlynedd eleni, o waith parhaus o fewn dyfrffordd Aberdaugleddau. Yn wir, mae'r grŵp wedi comisiynu'r prosiect mwyaf a'r drutaf yn ei hanes, sef delweddu'r proffil gwaddodi drwy'r Hafan cyfan. Bydd yr adroddiad busnes nesaf yn cynnwys canlyniadau'r gwaith hwnnw.

Yn ogystal â dosbarthu'r adroddiadau a gomisiynir gan y Grŵp i'r aelodau, dosberthir hwy hefyd i lyfrgelloedd gwyddonol, ac y maent ar gael mewn llyfrgelloedd lleol yn Sir Benfro, neu gan Swyddog Prosiect y Grŵp, Blaise Bullimore.

Un o'r prif resymau dros lwyddiant y Grŵp yw fod ei aelodau, o'r sector preifat ac o'r sector cyhoeddus, yn sylweddoli mor eithriadol o werthfawr i bob un o'r cyrff yw amcanion eglur a dull cydweithredol y Grŵp.

Yr hyn sy'n fwy calonogol byth yw fod aelodaeth y Grŵp yn dal i gynyddu. Ymunodd RWEn Power a South Hook LNG â'r Grŵp yn ystod y ddwy flynedd diwethaf, ac y mae Dragon LNG wedi cytuno i ymuno yn 2012. Bydd y cynnydd hwn yn cynnal y Grŵp wrth iddo i fynd i'r afael eto yn y dyfodol, â'i raglen uchelgeisiol ond cyraeddadwy.

Hoffwn ddiolch yn bersonol i gynrychiolwyr yr aelodau, sy'n rhoi o'u hamser gwerthfawr, drwy gymryd rhan yn y prosiectau a thrwy graffu arnynt, er mwyn sicrhau eu bod yn cyflenwi'r budd gorau posibl.

Yn olaf, fy niolch hefyd i Blaise Bullimore am ei ffyddlondeb, ei frwdfrydedd a'i gefnogaeth i'r Grŵp, sy'n parhau'n aruthrol.

Y Capten Mark Andrews

Awdurdod Porthladd Aberdaugleddau

*Cadeirydd*

# 1 INTRODUCTION

This is the twelfth business report of the Milford Haven Waterway Environmental Surveillance Group (formerly the Milford Haven Waterway Environmental Monitoring Steering Group). It covers the period January to December 2011.

The Milford Haven Waterway Environmental Monitoring Steering Group was established in 1992 following a highly successful one-day conference to examine the issue of oil pollution in Milford Haven. The Group immediately commissioned and published a review of the then current environmental knowledge of the Milford Haven Waterway, which included a description of the nature and extent of monitoring being undertaken on the Waterway at that time. The review made recommendation as to prioritised work plans for the future, covering obvious gaps and omissions in existing monitoring, and this formed the basis of projects contracted by the Group in the following years.

The Group subsequently let a series of contracts to collect data across the full suite of marine habitats within the Haven and, in collaboration with the Environment Agency, carried out systematic water quality surveillance for several years. Studies are resourced by Group members contributing either directly in monetary terms or in kind, and by undertaking or supporting survey and surveillance projects carried out by Group members directly. The value of the Group's data became very clear during the assessment of the environmental impacts of the 1996 Sea Empress oil spill and subsequently in informing environmental assessments of developments.

During the early 2000s, the need to strengthen and increase the formality of the Group's constitution became increasingly important. The development and agreement of a formal Memorandum of Agreement that met the needs and business concerns of all members of the Group took a considerable time. Following ratification and adoption of the MoA by all the Group's members, financial management of the Group transferred from Pembrokeshire County Council to Milford Haven Port Authority.

During the same period, the surveillance and monitoring obligations on several public bodies arising from, in particular, European directives developed and become clearer; for example the monitoring requirements of the Habitats & Species and the Water Framework Directives. Whilst the Group welcomes the use of data it collects to inform such monitoring, it does not wish to duplicate the efforts of public bodies, or be seen to be undertaking their duties. Rather it wishes to fill the gaps between such work, focus on tasks of the widest common interest to its members, and to synthesise and summarise the information available on the environmental health of the waterway.

Although the outputs are primarily for the benefit of the Group members, reports are lodged with public, academic, government and local school libraries, with the Group's business reports also being circulated to local elected representatives of Welsh, UK and European government.

# 2 GROUP ACTIVITY 2011

## 2.1 INTRODUCTION

The Group's work and outputs during the period are summarised below. After the focus on desk-studies in the mid 2000s, the emphasis on field-based surveillance has resumed.

2011 proved a quiet year for commencing new projects as delays in organising a planned major Sediment Profile Imaging survey resulted in postponing this work to 2012 (see section 3), by which time it was too late in the field season to reschedule another major project.

The second project of what is intended, resources permitting, to become long-term programme of bioaccumulation surveillance was contracted during 2010 to Dr Bill Langston from the Marine Biological Association, Plymouth. A summary of the field sampling reports is included in this report; the final report is anticipated in mid 2012 following completion of all the laboratory analyses.

A peer reviewed paper describing the bioaccumulation work undertaken in 2008 was published in Environmental Monitoring and Assessment. A copy of the abstract is included in Appendix 4; for copies of the paper please contact either the lead author, Dr Bill Langston, or the Group's project officer. An extract from the MBA's Annual Business report describing the work is also included Appendix 4.

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

The programme of survey and monitoring associated with the Pembroke Power Station project being undertaken by RWE Npower that was described in the last business report is brought up to date.

Monitoring work being undertaken in the Haven by the Environment Agency Wales to meet information requirements for the EU Water Framework, Nitrates and Shellfish Waters Directives and the UK government Clean Seas Environment Monitoring Programme is summarised.

The mearl bed adjacent to South Hook point was resurveyed under contract from the Countryside Council for Wales; the abstract from the the report is included.

The investigation into the slipper limpet *Crepidula fornicata* in Mildford Haven summarised in the last report has been completed and published as a peer reviewed paper. A copy of the abstract is included as Appendix 5; for copies of the paper please contact either the lead author, Katrin Bohn, or the Group's project officer.

## 2.2 MACROBENTHIC SURVEILLANCE

### Background

Following recommendations detailed in Dr Richard Warwick's 2006 review of benthic and intertidal sediment macrofauna data (reported and summarised in the 2006 Group business report) eight macrobenthic stations, as recommended by Warwick, were established for long term surveillance. These stations were well spaced between the estuary entrance and the upper reaches of the Daugleddau and had been sampled on at least one previous occasion as part of earlier studies (Figure 1). One of the sites (UH6) had been sampled for at least 20 years as part of the National Marine Monitoring Programme (NMMP), more recently the Clean Seas Environment Monitoring Programme (CSEMP).

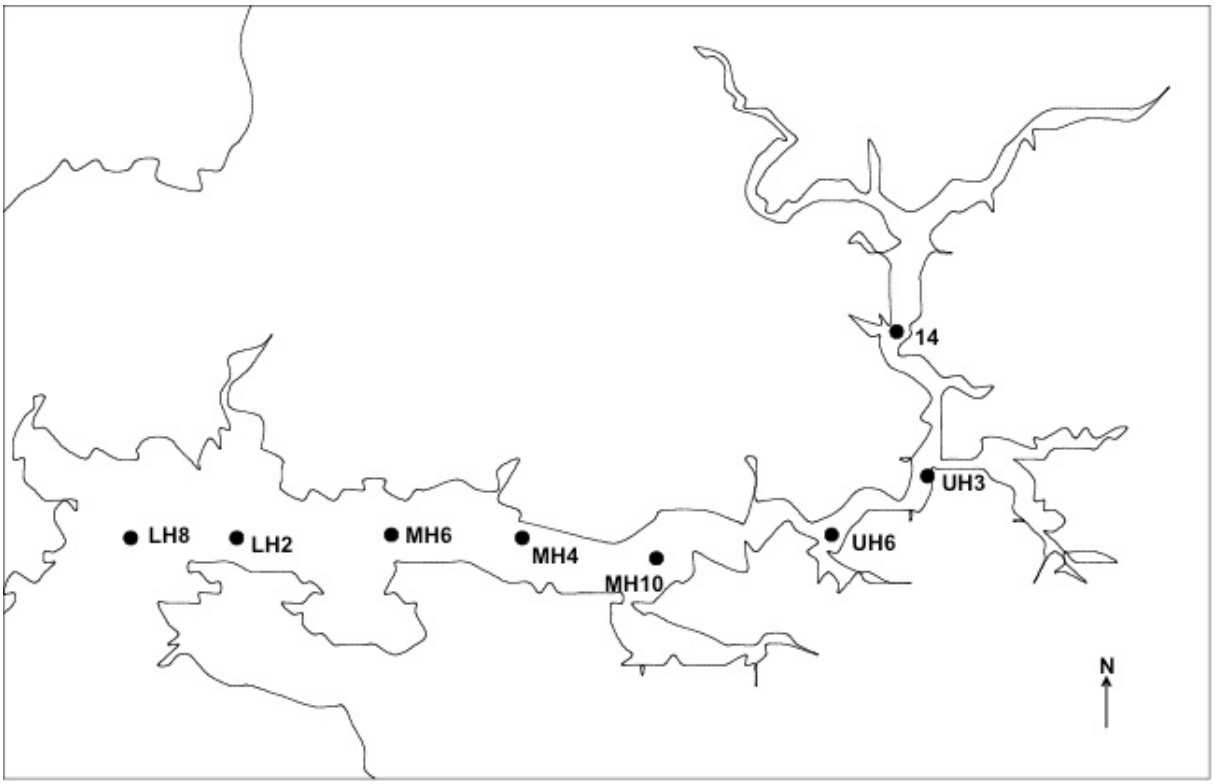


**Figure 1. Location of MHWESG macrobenthic samling stations.**

Sublittoral sediment biology sampling was recommenced in 2008, integrated with the sampling programmes of the Countryside Council for Wales and Environment Agency Wales (under the Habitats Directive and Water Framework Directive respectively). A second sampling round was undertaken in 2010, again carried out from the EAW's research vessel as a contribution in kind to the Group, and the samples were all analysed by the same laboratories to maximise intercomparability. Data from these two sampling rounds have been analysed by CCW and the main findings are reported below.

### Summary of work undertaken

Sampling at each of the eight sites consisted of six replicate Day grabs. Five taken for faunal analyses and one for sediment particle size (PSA). Faunal samples analysed were those retained following washing over a 0.5mm mesh sieve.

Some of the data remains outstanding (PSA data from 2010) and so preliminary analyses have focussed on faunal abundance and biomass.

## Analysis Methods

Multivariate statitical analysis and visualisation of the two year dataset was undertaken using the PRIMER software package. Univariate comparisons were undertaken using Excel.

## Results

Species diversity generally increases down the estuary (Fig 2). MH6 and UH3 showed an increase in taxa between 2008 and 2010 (particularly MH6). Other stations displayed little change.

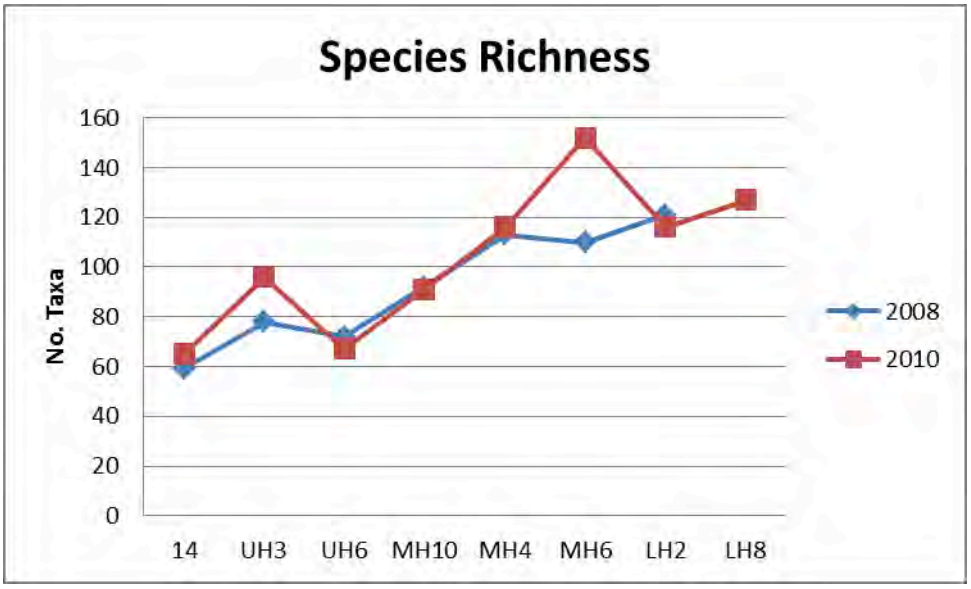


**Figure 2. Number of recorded taxa at each station in 2008 and 2010**. (Note station LH8 was not successfully sampled in 2008).

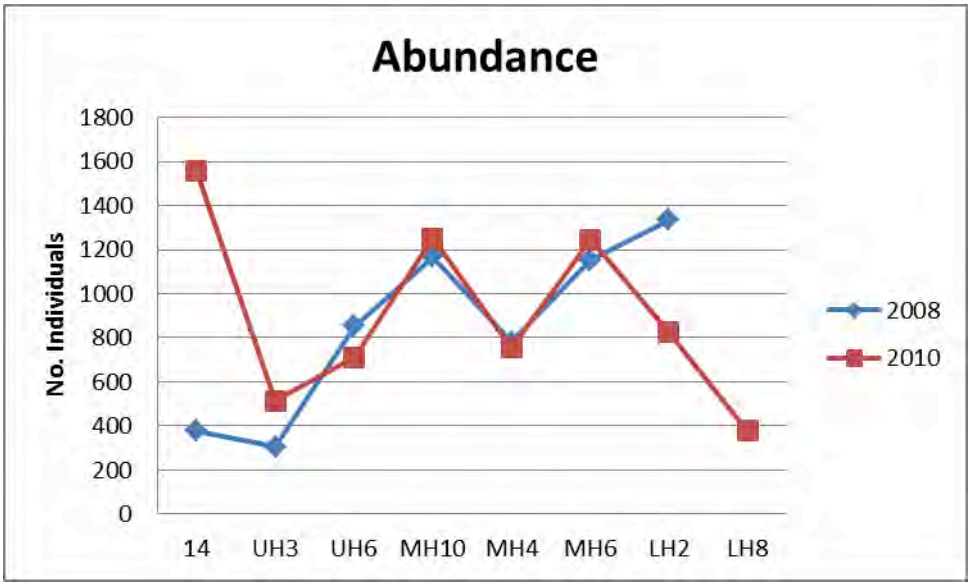


**Figure 3. Total abundance of individuals at each station in 2008 and 2010.**

Overall abundance (numbers of individuals) varied along the estuary (Fig 3). Changes between 2008 and 2010 were greatest in the upper and lower estuary, remaining broadly similar in the middle. The upper estuary tended towards an increase in numbers whilst the

lower estuary showed a decrease; the very large increase at station 14 being due to increased numbers of *Ampharete grubei*, *Aricidea catherinae*, *Tubificoides pseudogaster*, *Tharyx* sp and Nematodes.

Shannon diversity showed a similar pattern across the stations from 2008 to 2010, decreasing slightly at some locations in the upper and middle Haven and increasing slightly in the lower Haven (Fig 4.).

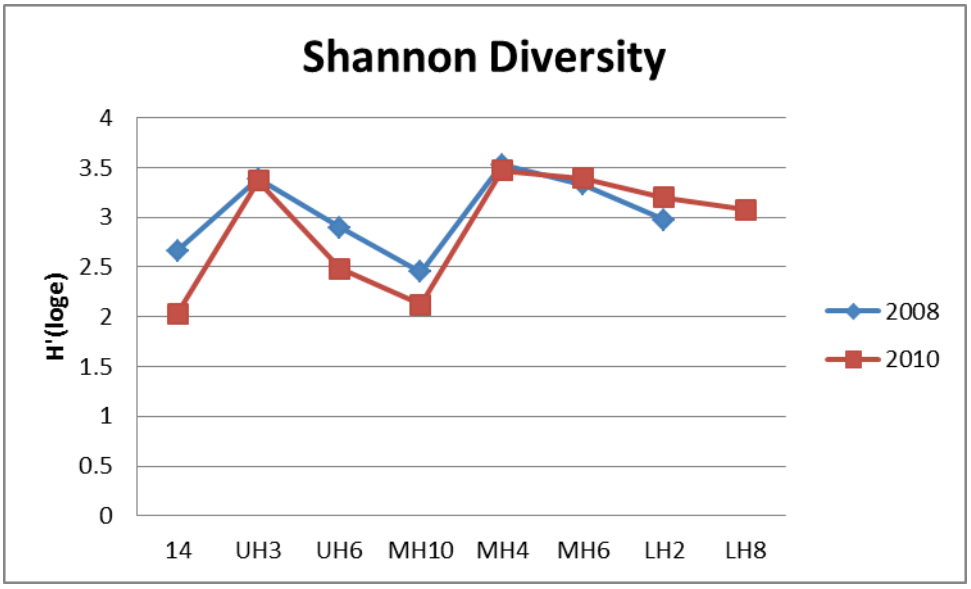


**Figure 4. Shannon Diversity (H'(loge)) at each station in 2008 and 2010.**

***Multivariate analyses***

Visualisations of similarity between each station's community structure were made using non-metric multidimensional scaling plots (MDS). Figure 5 shows good clustering for each station and for each station's year-set of samples, though 2010 samples from station UH6 shows some dispersion – stations are comparatively distinct from each other and there is a degree of separation at most stations between 2008 and 2010 samples.

Averaging the replicates at each station visit provided a clearer summary of change from 2008 to 2010. In Figure 6 the relationships between sampling stations (distance between them) reflects the environmental gradients existing within the Milford Haven Estuary. Stations close geographically have a relatively similar community composition whilst communities from stations at the extreme ends of the estuary are most different.

Community change between 2008 and 2010 displayed a broadly similar trend across all stations. This is shown within Figure 6 by a broadly similar direction of travel across the MDS plot from 2008 to 2010.

An analysis of similarities (ANOSIM) confirmed a significant survey wide change in community structure (abundance) from 2008 to 2010 (R=0.648, p=0.1%) (Table 1a). Pairwise comparisons between years at each station also confirmed significant community change except for all stations except MH10 (Table 1b). 'R' values were highest for station 14 and LH2 indicating a greater level of change at the upper and lower ends of the estuary.

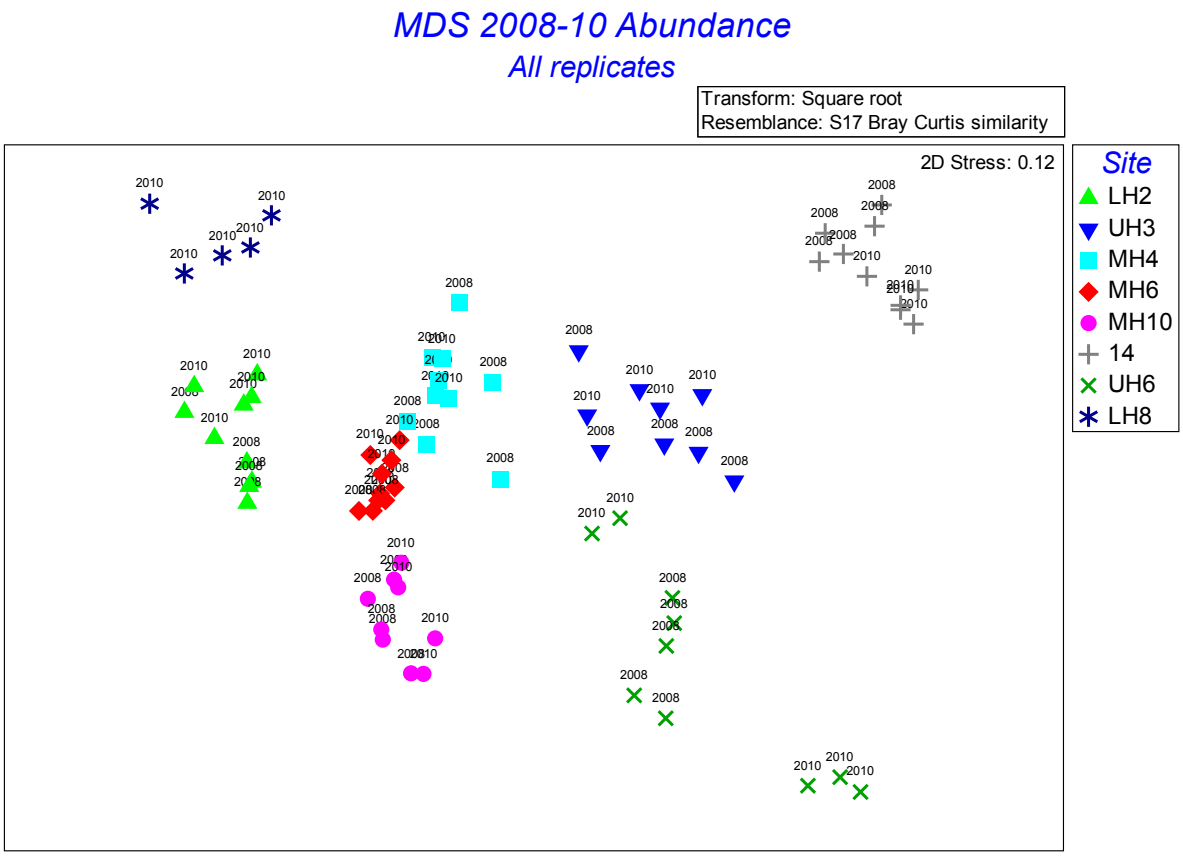


**Figure 5. MDS plot for all 2008 & 2010 samples (abundance).** (Note station LH8 was not successfully sampled in 2008).

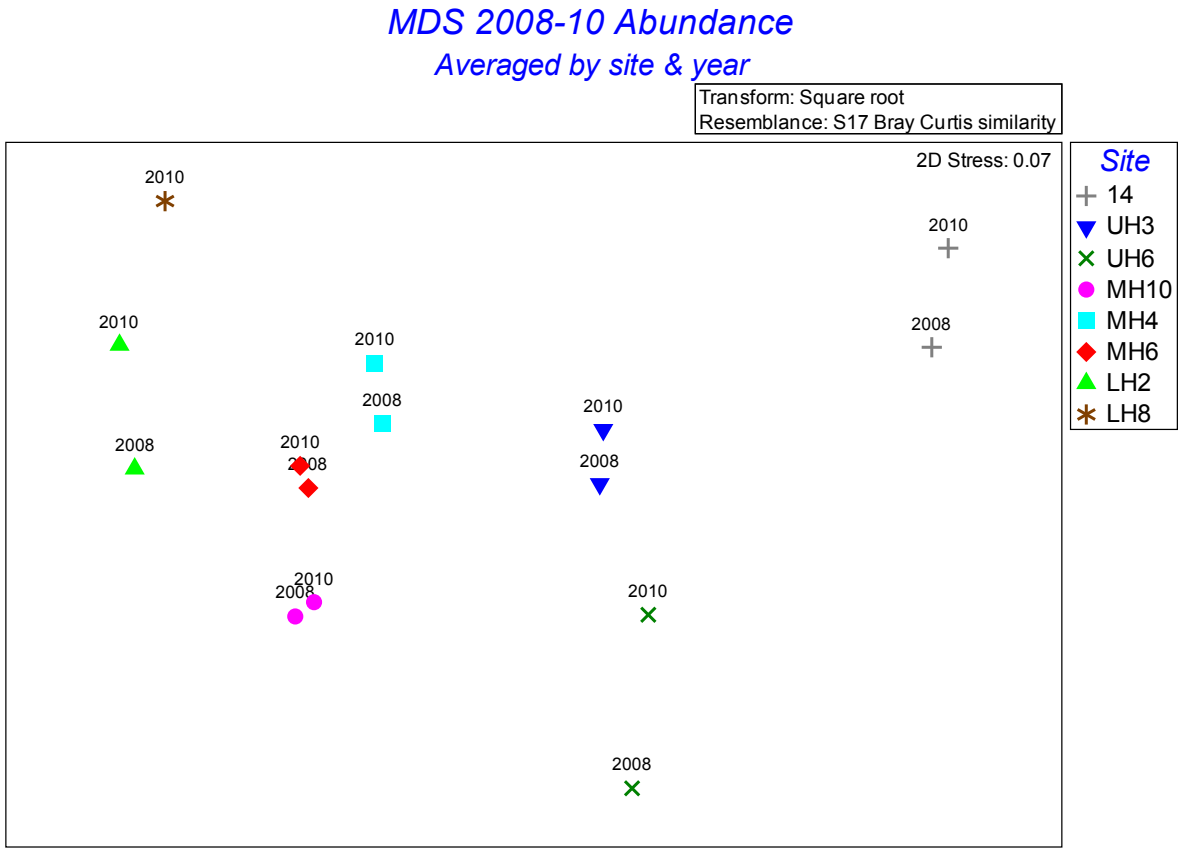


**Figure 6. MDS plot for 2008 & 2010 stations (abundance), replicates averaged.**

***(a)***
*TESTS FOR DIFFERENCES BETWEEN Year GROUPS*
*(across all Site groups)*
*Global Test*
Sample statistic (Global R): 0.648
Significance level of sample statistic: 0.1%
Number of permutations: 999 (Random sample from a large number)
Number of permuted statistics greater than or equal to Global R: 0

| ***(b)*** **Groups** | **R Statistic** | **Significance Level %** | **Possible Permutations** | **Actual Permutations** | **Number >=Observed** |
|---|---|---|---|---|---|
| **UH3** | 0.381 | 1.6 | 126 | 126 | 2 |
| **14** | 0.96 | 0.8 | 126 | 126 | 1 |
| **UH6** | 0.692 | 0.8 | 126 | 126 | 1 |
| **MH10** | 0.288 | 8.7 | 126 | 126 | 11 |
| **MH4** | 0.396 | 0.8 | 126 | 126 | 1 |
| **MH6** | 0.8 | 0.8 | 126 | 126 | 1 |
| **LH2** | 0.888 | 0.8 | 126 | 126 | 1 |

**Tables 1(*a* & *b*). ANOSIM: (a) test for differences between years (across all sites) and (b) Pairwise comparisons (2008 with 2010) for each station.**

Survey wide change from 2008 to 2010 was due to a large number of small abundance changes. The species responsible for the first 20% of dissimilarity between the years are given in Table 2.

Though not presented here, it is more useful to examine the yearly changes at each station as, in the survey wide analysis given here, the wide difference in community composition between the upper and lower estuary tends to mask the species generating the pattern of change from one year to the next.

| **Species** | **Av.Abund 2008** | **Av.Abund 2010** | **Av.Diss** | **Diss/SD** | **Contrib%** | **Cum.%** |
|---|---|---|---|---|---|---|
| ***Melinna palmata*** | 7.80 | 6.66 | 2.93 | 1.02 | 4.29 | 4.29 |
| ***Ostracoda*** | 6.28 | 5.26 | 1.94 | 1.18 | 2.85 | 7.14 |
| ***Ampharete grubei*** | 1.76 | 4.10 | 1.77 | 0.72 | 2.59 | 9.72 |
| ***Aricidea minuta*** | 1.64 | 3.56 | 1.68 | 0.64 | 2.46 | 12.19 |
| ***Abra alba*** | 4.57 | 3.75 | 1.68 | 1.04 | 2.46 | 14.65 |
| ***Tubificoides amplivasatus*** | 4.85 | 4.34 | 1.53 | 1.21 | 2.25 | 16.90 |
| ***Aricidea catherinae*** | 1.77 | 3.40 | 1.39 | 0.76 | 2.04 | 18.94 |
| ***Chaetozone gibber*** | 5.23 | 3.11 | 1.37 | 1.31 | 2.00 | 20.95 |

**Table 2. Species responsible for the first 20% of dissimilarity in community structure between 2008 and 2010.** ('Diss'=Bray Curtis dissimilarity; 'SD'=standard deviation; 'Contrib'=contribution to dissimilarity between years; 'Cum.'=cumulative contribution to dissimilarity).

MDS visualisations of similarity between each station's community (biomass) structure showed clustering for each station and for each station's year-set of samples, but with a couple of outlier replicates (Figure 7.).

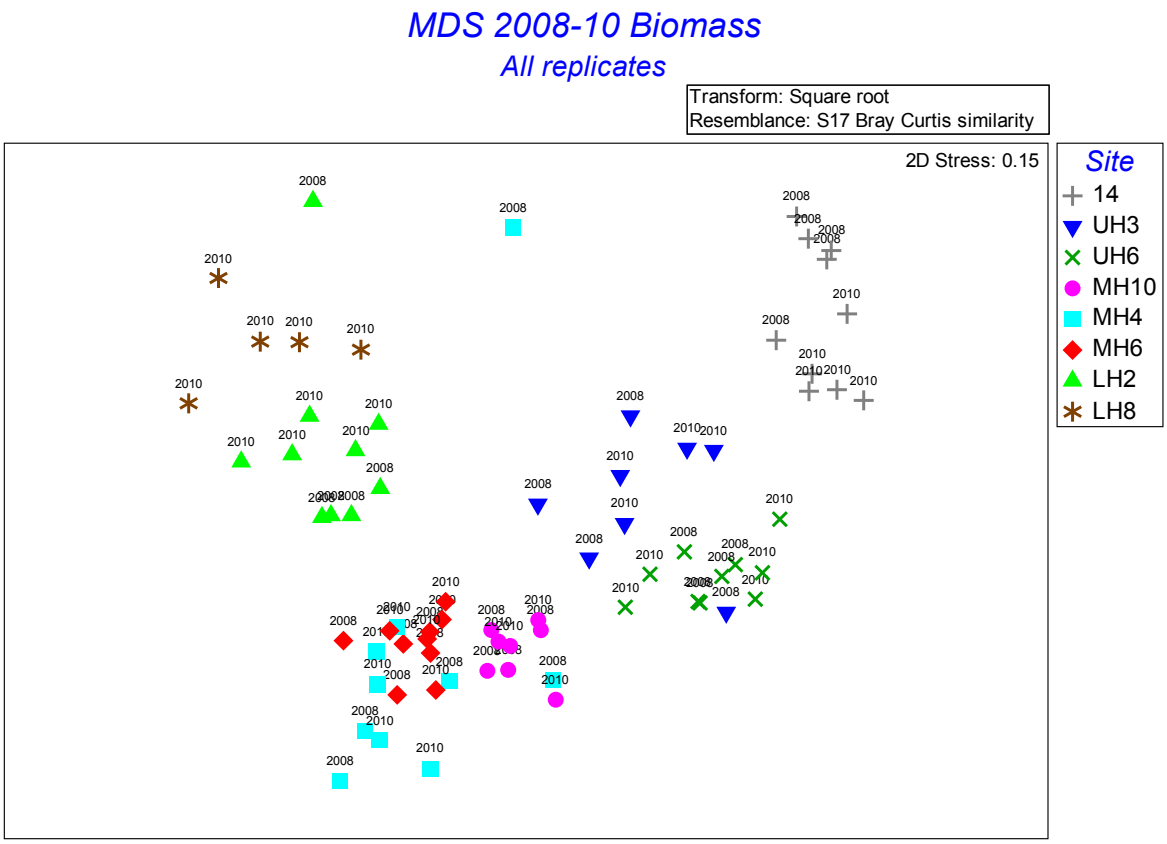


**Figure 7. MDS plot for all 2008 & 2010 samples (biomass).**

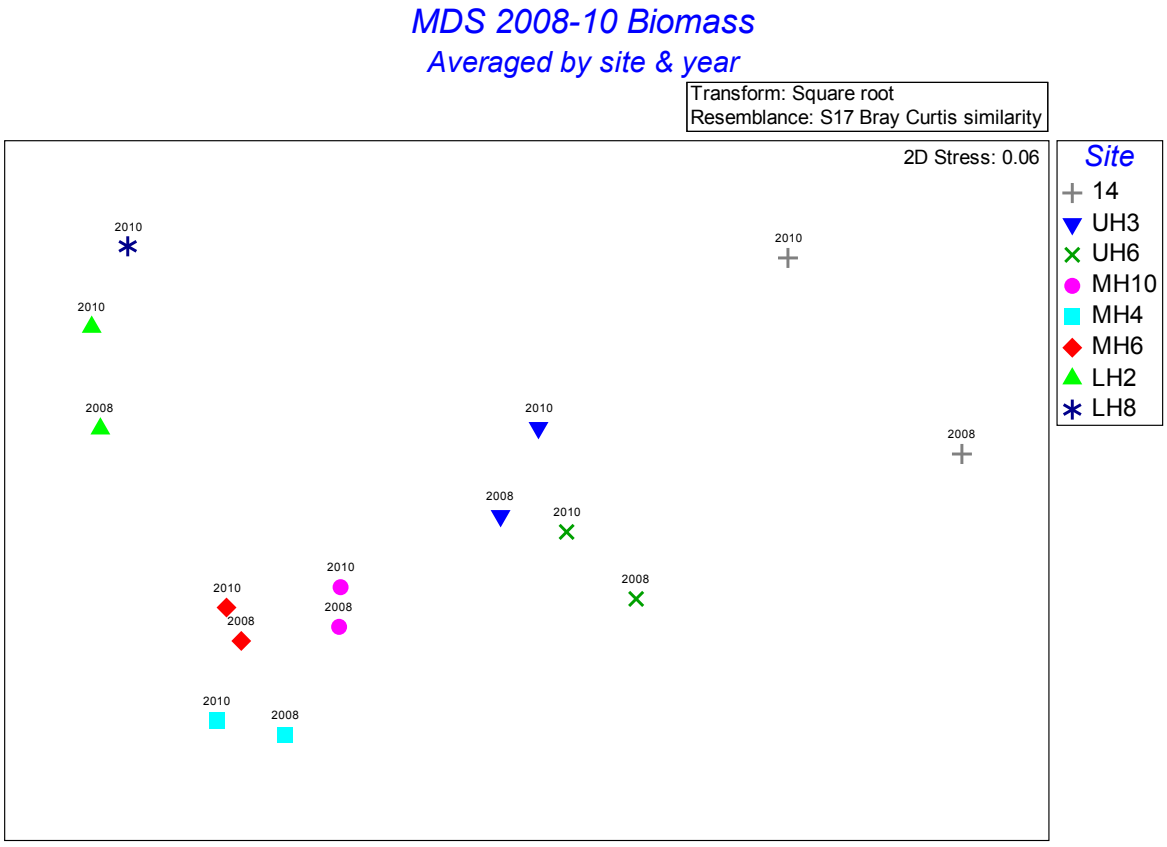


**Figure 8. MDS plot for 2008 & 2010 stations (biomass), replicates averaged.**

Change in community biomass from 2008 to 2010 showed a broadly similar pattern of change (Fig 8.) with some variability in relative 'direction' (e.g. stations MH4 & UH3) and 'scale' (e.g. station 14).

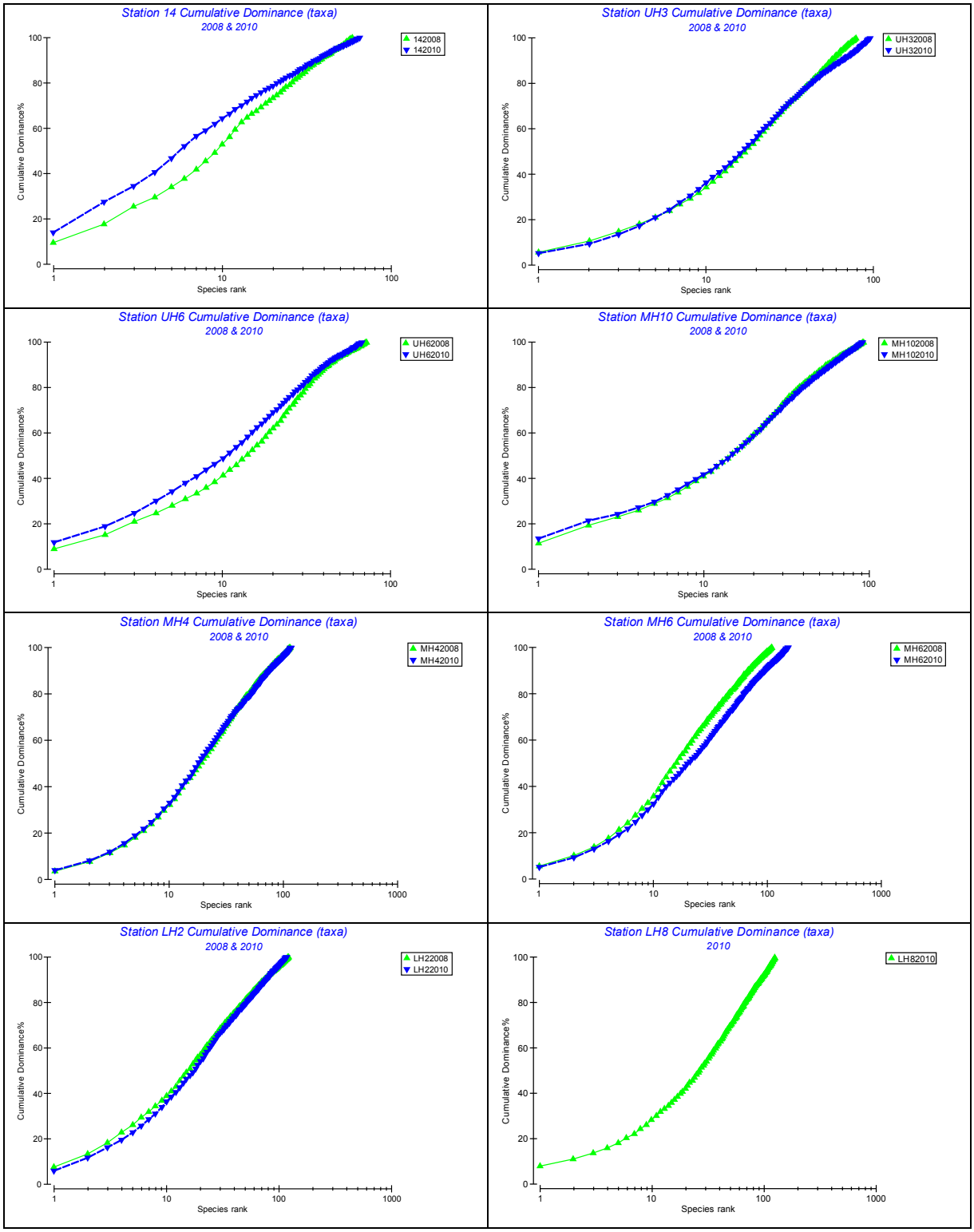


**Figure 9. *k* Dominance plots for all stations, comparing 2008 and 2010 curves.**

An analysis of similarities (ANOSIM) confirmed a significant change in community structure (biomass) from 2008 to 2010 (R=0.864, p=0.1%). Pairwise comparisons (2008-10) at each station showed significant change in biomass was greatest at station 14.

*Changes in species dominance and comparisons with biomass dominance.*

Cumulative species dominance plots can be a useful means of analysing community change for environmental stress. Species are ranked in order of importance along the x axis. Their percentage contribution to the total is plotted along the y axis (Figure 9). Two sets of data defining abundance and biomass can be plotted overlaid (ABC plot) (Figure 11).

Comparisons of cumulative species dominance between 2008 and 2010 revealed little change at most stations (Fig 9.). Greatest change appears to be at stations 14 and UH6 where dominance increases slightly, and at station MH6 where dominance decreased substantially from 2008 to 2010. The change at MH6 appears more substantive (and that at 14 and UH6 less so) when the dissimilarities between the *k* dominance curves are plotted as a MDS (Fig 10).

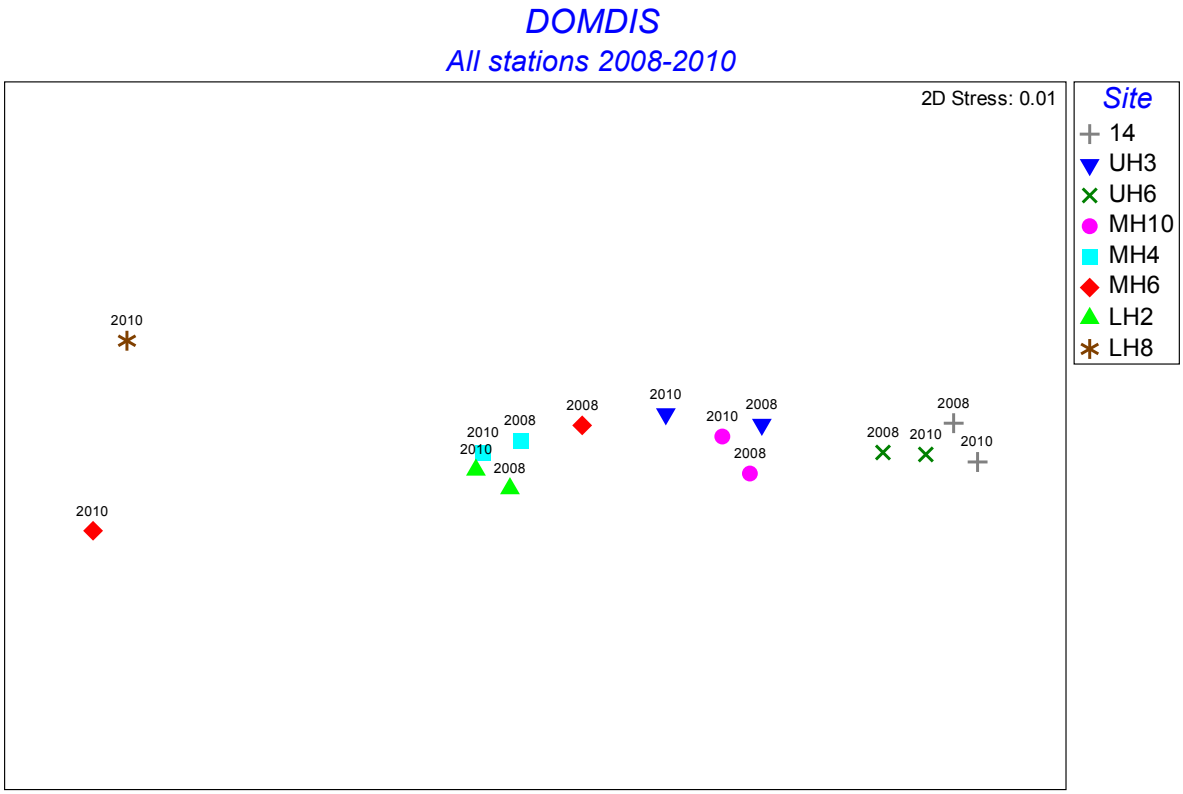


**Figure 10. Difference between all dominance curves represented in an MDS plot.**

The dissimilarity between dominance curves shown in Figure 10 also appears to represent the environmental gradients within the estuary, upper Haven sites to the right, lower Haven sites to the left. The substantial change for station MH6 from 2008 to 2010 appears linked to the increase in recorded taxa at this site.

Where the dominance curve for abundance is higher than that for a sample's biomass, abundance/biomass curve plots (ABC) can indicate environmental stress. ABC plots for 2008 and 2010 did not show any obviously stressed samples. Examples of typical plots are given in Figure 11.

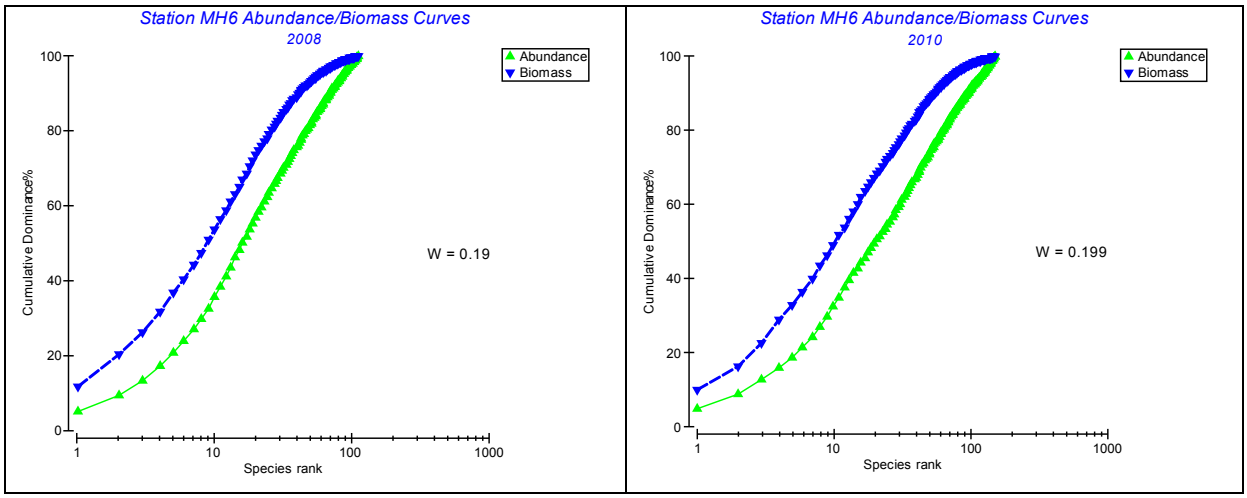


**Figure 11. Representative cumulative abundance/biomass curves (station MH6).**

## Macrobenthic analysis conclusions

These initial analyses after only two sampling events show change occurring between 2008 and 2010 for several infaunal univariate and mutivariate parameters. Changes in abundance and numbers of taxa recorded appear to have been greatest in the upper and lower reaches of the estuary, though generally the pattern of community change appears broadly similar across the stations. Whilst two sampling events provides little opportunity for trend analysis and the lack of a compete set of PSA data limits examination of a key environmental variable, the current data does not suggest any environmental change of concern.

## 2.3 BIOACCUMULATION SURVEILLANCE IN MILFORD HAVEN WATERWAY 2010

W J Langston, S O'Hara, M & Davey, E. Shortridge, N D Pope, H.Harino & C.H.Vane. UK Marine Biological Association

**Executive Summary**

Biomonitoring of contaminants (metals, organotins, PAHs, PCBs) was previously carried out by the MBA ecotoxicology team at a series of sites along the Milford Haven Waterway and at a reference site in the Tywi Estuary during 2007-2008. The species used as bioindicators encompassed a variety of uptake routes; i.e. *Fucus vesiculosus* (dissolved contaminants); *Littorina littorea* (grazer); *Mytilus edulis* and *Cerastoderma edule* (suspension feeders that accumulate from both dissolved phase and suspended particulates); and *Nereis* (*=Hediste) diversicolor* (omnivore which often reflects bioavailable contaminants in sediment).

The purpose of the current project was to resurvey, using consistent protocols, a similar range of species and sites in 2010 and to consider the short term variation in contamination trends in the intervening period. Thus. are trends in bioaccumulation in the waterway stable over periods of ~ 2 years and, if so, would bioaccumulation surveillance at such intervals (or longer) provide an adequate integrated picture of contamination? In the current survey we have also extended sampling upstream in the Daucleddau Estuary (Picton, Hook) and included a further (regional) reference site at Appledore in the mouth of the Taw/Torridge Estuarine system, in order to provide a broader baseline against which the scale of any contamination in MHW can be judged.

There were species differences in bioaccumulation due to feeding strategy and habitat preference, physiological and ecological attributes, and chemical properties of different metals which have subtle implications for monitoring trends. *Mytilus edulis* and *Cerastoderma edule* are considered the best all-round indicators, illustrating trends along the waterway and draw the clearest distinction between MHW and reference sites. Appledore and, in particular, Tywi sites provide suitable baselines for most determinands.

A gradient in metal bioaccumulation (increasing upstream) in MHW was evident and in the mid and upper estuary, Ag, Cd Co, Cr, Fe,Hg, Mn, Ni, and to a lesser extent As, Cu, Pb, Se and Zn exceeded background concentrations in cockles and mussels. *Fucus* showed enrichment for Co, Cr, Cu, Fe, Mn, Ni and Zn; *Littorina littorea* for Co, Cu, Fe and Mn; *Nereis* for Ag, Ni, (and to a small extent Pb, Cu, Hg). Increases in bioavailability at upstream sites reflect the influence of geogenic or other land-based sources, enhanced by lower salinities. However enrichment is seldom more than an order of magnitude and, towards the mouth of MHW, there was a good deal of overlap with reference values and little indication of localised impact. For the majority of samples (94%), concentrations in Milford Haven biota were in the lower-middle part of the UK range. Exceptions were Mn, Ni in mussels, Mn, Ni, Co, Fe, Se in cockles, Co, Mn, Se and As in seaweed, Mn in winkles and Ni in ragworm. Spatial trends for metals in biota were similar overall to those in the earlier survey (2007/8).

One of the principal objectives of the current survey was to begin to establish temporal trends in bioaccumulation. Metals data reveal a number of changes between surveys, both increases and decreases, Significant reductions were observed for As (*Fucus, Mytilus and Cerastoderma*); Hg and Se (*Mytilus* and *Cerastoderma*) ;Cu, Pb (Littorina) . Of these perhaps the most notable trends were for As and Hg where all species exhibited lower values in the current survey. Significant increases were seen for Ag (*Littorina* , *Cerastoderma*) Cr and Fe (*Mytilus*).Both decreases and increases were observed for Co ( *Nereis* and *Fucus, Cerastoderma, Mytilus*, respectively) and for Ni ( *Fucus* and *Mytilus* respectively). There were no significant changes in Cd or Zn.

TBT levels in mussels remain highest in the Haven, reflecting port activites, despite the global ban on organotins in 2008. Lowest TBT values, upstream in the Daucleddau, were similar to local background. As in the previous MHW survey, all TBT concentrations were above Environmental Assessment Criteria (possible sub-lethal effects guidelines) but were below thresholds considered by OSPAR to be acutely toxic. Phenyltins were not accumulated appreciably in *Mytilus* (signifying low use in antifouling) whereas residues in some *Nereis* populations in MH suggest they may have been subjected to localized contamination in sediments, perhaps reflecting past agricultural use of TPT in the catchment.

PCBs concentrations in mussels showed a spatial trend similar to that in the previous survey - unexpected in that highest values occured at the mouth of the Haven: Lower values, upstream were comparable to the reference site in the Tywi Estuary. PCB concentrations in mussels follow a pattern which is similar to the condition index. It may be that body burdens of these lipophilic contaminants are a function of lipid reserves which would be anticipated, from condition data, to be highest in those populations at the seaward end of the waterway (Dale, Angle).

The lower and higher OSPAR environmental assessment criteria (EAC) for ∑ICES7 PCBs in mussel are 5 and 50 μg $kg^{-1}$ dw and all values for Milford Haven and Tywi samples appear to be below the upper threshold at which effects on marine species might be expected, but are above the lower 'no-effects' threshold. The only site above the upper PCB threshold was the regional reference at Appledore (North Devon).

In contrast to mussels, PCB concentrations in sediment dwelling *N. diversicolor* were lowest at Dale and Angle in the mouth of Milford Haven, where they were below the lower EAC threshold for mussels (no EAC available for *Nereis*). Elsewhere, including both reference sites, values were between upper and lower EAC suggesting low levels of contamination, though a contribution to sub-lethal effects cannot be ruled out. At Waterloo (Cosheston Pill) and (opposite) Pennar, values in *Nereis* exceeded the upper EAC (mussels were not found at these two sites). Once again there are caveats regarding the possibility of overprecautionary guidelines and also whether extrapolation to worms is appropriate. The rationale for comparison with EAC set for mussels is principally to provide context, rather than imply rigorous toxicological significance. Nevertheless the results reinforce the need for supplementary biological effects studies.

Further contextual insight into PCB contamination is gained by comparison of values in *N. diversicolor* with samples from the Severn Estuary, taken in 2005. For the lower chlorinated congeners concentrations in both systems are relatively low: for the more highly chlorinated CBs 138, 153 and 180 (hexa- and hepta-chlorobiphenyls), and hence total PCBs, there is considerably more bioaccumulation in the Severn. This is not unexpected since PCBs were previously manufactured at Newport, a known hotspot for contamination on the Severn. PCB Concentrations in MH mussels were again considerably lower than those from hotspots in the Irish Sea such as Liverpool Bay and the Mersey Estuary.

Temporal comparison of PCB concentrations in 2010 with the earlier MH surveys (2007/8) suggests that although CBs 028 and 052 have increased in *Mytilus edulis* across the waterway, CBs 138 and 153 have decreased and, overall there has been no significant net change in ∑PCB concentrations in mussels.

Similarly whilst there has been an increase in PCB levels in *Nereis diversicolor* at Waterloo (near Pembroke Ferry) temporal changes averaged across all sites (figure xxx) were not statistically significant. This suggests that the increase at Waterloo was a confined observation: a landfill site at the industrial estate bordering Cosheston Pill may be responsible for localized enrichment (Smith and Hobbs, 1994).

The pattern of condition indices in bivalves (cockles and mussels) showed significant spatial variation. Condition in these shellfish was highest at the Tywi reference site, and at the mouth of Milford Haven, decreasing upstream in the Waterway and the Daucleddau (observed previously). Comparison with the survey in 2007 indicated no significant temporal change.

There were a number of significant (negative) relationships between CI of bivalves and body burdens of metals. The condition of mussels decreased in line with increasing metal concentrations according to the sequence Cr>Cu>Ni>Zn>Se=Co>As. The corresponding sequence for metals in cockles was As>Hg>Co>Ni. It should be stressed however that these are merely correlations and not proof of cause and effect. It is possible that a combination of contaminants could have an influence on this pattern in the CI (other determinands including organotins, PCBs and PAHs have still to be tested). There may also be a number of (natural) factors which may be influential.

The strategy for biomonitoring undertaken in this project builds on established sampling protocols and is proposed as a basis for a rolling program against which future change could be measured. Complementary, harmonised monitoring in which biological condition and environmental parameters are measured and interpreted alongside body burdens - using multivariate techniques to help assess the status of the site more comprehensively – are also recommended for the future.

Langston, WJ, O'Hara, S, Davey, M, Shortridge, E, Pope, ND, Harino' & Vane, CH. (2012) *Bioaccumulation surveillance in Milford Haven Waterway Phase II (2010)* Report to the MHWESG from the Marine Biological Association UK

## 2.4 ANNUAL WETLAND BIRD SURVEYS 2010 - 11

A Haycock, Pembrokeshire WeBS Coordinator

**Executive summary**

The Wetland Bird Survey was carried out on the Cleddau estuary system between September 2010 and March 2011, with additional counts for June and July 2010 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 26145 birds between November and February confirms that the estuary system is still of international importance for its waterfowl populations. That peak count was similar to the average during the previous decade.

The levels of "National Importance" for many water birds have been revised, and six species now qualify (based on a five-year mean): little egret (61 in October), shelduck (max 765 in January), wigeon (max. 7850 in November), greenshank (max 49 in October), dunlin (max 4709 in February), and curlew (2017 in July). Teal reached the required level (max. 2246 in December), but three of the four previous counts were below this level.

This winter saw the coldest December for 100 years, with temperatures 5C below the long term average. This undoubtedly affected bird distribution and movements across the country.

The total number of birds recorded each month was similar to the average recorded during the past decade, however there were more wildfowl around, particularly in December, wader numbers built up slowly to a February peak, and gulls were relatively scarce.

Comparison of counts with the national report for 2009-10 (the most recent that is available) show that for most species, the local trends in populations are similar to those experienced nationally.

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

## 2.5 ANNUAL SUMMER SHELDUCK SURVEY 2011

J E Hodges, PCNPA Ecologist

**Executive summary**

The Daugleddau Estuary and Milford Haven Waterway hold nationally important numbers of shelducks during the winter months. In addition there is a small summer population which had been the subject of annual summer boat surveys carried out between 1991 and 2010. The summer boat surveys were repeated in 2011 as part of a co-ordinated 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, 2011 was the poorest year for breeding shelducks in the estuary since the current sequence of annual surveys began in 1991. Predation is thought to have been a major factor affecting the number and size of broods recorded in 2011. Disturbance may also have been a contributory factor, although adverse weather conditions are not thought to have been a factor affecting the population. 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.

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. 8 pp + appendices

## 2.6 PEMBROKE POWER STATION BASELINE AQUATIC SURVEYS

*The following summary of survey and monitoring undertaken to date is abstracted from RWE Npower's proposal for monitoring in the Pembrokeshire Marine SAC prepared for: Environment Agency*

Aquatic ecology and marine water quality surveys undertaken by RWE commenced in July 2006 with a view of establishing a baseline understanding of the marine environment in proximity to the Pembroke power station site. These surveys are considered to be extensive and provide a suitable baseline of environmental information.

Baseline surveys of marine water quality, intertidal and subtidal fisheries, intertidal ecology and Ichthyoplankton have been undertaken systematically since 2006 and eels from 2011.

### *Marine Water Quality*

A full programme of marine water quality monitoring has been undertaken at Pembroke since October 2006 to provide data to assist in determining site-specific baseline water quality conditions in terms of both physical and chemical parameters.

Sampling of marine water quality is undertaken on both the ebb and floodtide. Sites positioned upstream of the cooling water outfall are sampled on the flood tide, and sites downstream of the cooling water discharge point on the ebb tide. This means that when sampling is undertaken with the power station operational, any effects of the cooling water discharge will be detected, while ensuring that the sampling methods used pre-and post-power station commissioning will be identical and provide a robust statistical comparison of past and future data.

### *Temperature*

Baseline temperature studies have been undertaken in order to establish the temperature composition of Milford Haven. These have been informed by background studies from the late 1960s through to the mid-1970s, CEFAS data and intermittent EA temperature monitoring, as well as an ongoing long-term monitoring programme implemented by RWE from April 2011.

### *Intertidal and subtidal fisheries (including invertebrates)*

Fish and invertebrate surveys began in October 2006 to provide data to assist in determining baseline biological information. Seasonal surveys of fish and invertebrate communities have comprised otter trawl surveys at 13 locations and seine net surveys at 7 locations. These have continued each year on a quarterly basis. The surveys have monitored fish populations within the Milford Haven waterway and Pennar Gut and have more recently assessed the impacts of power station construction on fish populations. Baseline surveys completed prior to 2009 highlighted seasonal population variation and for that reason quarterly trawl and seine net surveys have been continued.

### *Ichthyoplankton*

The larval and juvenile stages of most fish species are vulnerable to entrainment owing to their small size and poor swimming capability. This survey was designed to gather further baseline information on the identity and abundance of fish eggs and larvae present in the plankton close to the proposed cooling water intake.

The year-round monthly ichthyoplankton surveys undertaken in 2006-7 showed that peak ichthyoplankton densities occurred in May to July, with minimal quantities of ichthyoplankton being present at other times of year.

### *Phytoplankton & zooplankton*

Phytoplankton and zooplankton samples were collected in October 2006 at each ichthyoplankton monitoring site. Samples collected in June and July 2009 at each ichthyoplankton monitoring site have been analysed for zooplankton for inclusion within baseline data.

### *Eels*

In response to increasing concerns about the decline in European eel populations and associated regulatory developments, RWE Npower instructed its consultant to undertake test Fyke netting within Pennar Gut. This took place concurrently with the planned fisheries survey and was to determine the feasibility of netting and subsequently the presence of eel within the Pembroke River.

### *Intertidal Ecology*

The key objective of the intertidal ecology surveys was to inform on the natural variability of the ecological baseline conditions.

Baseline surveys consisted of an annual mapping survey of intertidal biotopes at 11 sites on the mid and upper shore and 5 sites on the lower shore at increasing distances from the cooling water outfall.

Surveys include species assemblage, trochid gastropods, barnacles and sublittoral fringe and shingle.

### *Eelgrass*

Monitoring the condition of eelgrass beds in Pembroke River has been undertaken to confirm the extent or otherwise of any smothering effects from dredging operations. Dredging was undertaken from January 2010 to April 2010.

On completion of the phase 1 dredging in May 2010 and in-line with recommendations from RWE Npower's aquatic ecologist, RWE Npower commissioned a spring 2010 survey to determine any initial impacts on the eelgrass beds on the north and south shores of the Pembroke River. Further surveys were undertaken in September 2010 when a repeat of the September 2009 work was undertaken.

### *Subtidal Benthic Ecology*

A key objective of the subtidal benthic programme was to monitor the recovery of the benthic species community in the areas dredged. Initial work undertaken in July 2006 provided a pre-construction baseline. Subsequent monitoring was undertaken during late summer 2010 and 2011 so coinciding with work previously undertaken.

### *Subtidal Epifauna (Dive) Surveys*

An area of rocky reef is known to exist off the end of the Cooling Water (CW) outfall channel in Milford Haven. The reef is thought to be approximately 700m long consisting mainly of steeply sloping to vertical bedrock walls between approximately 51°41.857N, 5°00.129W and 51°41.782N W4°59.532W. The cooling water outfall channel ends in the centre of the reef.

Both the Environment Agency and CCW requested that consideration be given to undertaking subtidal epifauna dive surveys. Following consideration of these requests RWE npower is currently undertaking surveys of the area of rocky reef that exists off the end of the cooling water outfall channel. Where available, data from other surveys undertaken on this area of reef, such as the CCW survey undertaken during June 2011, will be used to supplement the baseline data.

## 2.7 MAERL BED MONITORING IN THE MILFORD HAVEN WATERWAY

F. StP. D. Bunker, Marine Seen, Pembroke.

Bunker, F.StP. D., 2011. *Monitoring of a Maerl Bed in the Milford Haven Waterway, Pembrokeshire, 2010*. CCW Contract Science Report No. 979. A report to the Countryside Council for Wales by *MarineSeen*, Pembrokeshire 145pp + iii.

**Summary**

Maerl beds are a UK Biodiversity Action Plan (BAP) habitat and are also included in the biodiversity duty of public bodies introduced by the NERC Act 2006. The maerl bed in Milford Haven is the only living maerl bed in Wales and is small being approximately 1.5 square kilometres of which only 0.5 square kilometers contained live maerl (Bunker and Camplin 2005). There are at least two maerl species in the Milford Haven maerl bed, one being *Phymatolithon calcareum* and another whose identity has yet to be confirmed. *P. calcareum* is listed in the EC Habitats Directive Annex Vb. This report presents the results of the 2010 monitoring data.

The fieldwork was a detailed study at six sites by divers who recorded the frequency of occurrence of macrobiota in a series of quadrats (apart from one site where underwater conditions were unfavourable for *in situ* recording). At each site, core samples were collected for infaunal and sediment particle size analysis.

This report outlines the methodology used for the field studies together with the results obtained and some statistical analysis of the data. A brief consideration is given to obvious differences and similarities to the 2005 data set but detailed comparison has not been undertaken.

*In situ* descriptions of each of the study sites are presented together with photographs of quadrats in at each site.

The data shows an apparent decline in the abundance of live maerl in the main maerl bed sampling stations since 2005.

The data shows an apparent decline in the numbers of epibiota species recorded at the sites in the main maerl bed since 2005. This is contrasted by an increase in epibiota species at deeper sites on the edge of the main maerl bed.

Analysis of the epibiota data recorded from quadrats using ANOSIM and MDS plots showed significant differences between study sites. Treatment of the data-using SIMPER shows the key species, which were important contributors to differences between site pairs.

A BVSTEP analysis of the epibiota data showed the species, which characterise the survey area. The rare algal species recorded in 2005 were present in 2010: These included the species endemic to maerl: *Gelidiella calcicola, Cruoria cruoriaeformis* and the recently described *Cladophora rhodolithicola*. Other uncommon species included the algae *Ptilothamnion sphaericum* and *Spermothamnion strictum*.

A marked increase in numbers of non-native slipper limpet *Crepidula fornicata* was recorded in 2010, particularly at the study sites with the most maerl. At one site, it was forming a bed over sediment ridges formerly having the highest percentage cover of maerl.

The scallop, *Pecten maximus* was recorded from three sites but was in low abundance.

In addition to the methods used in 2005, samples of maerl were collected for microscopical analysis of the epiflora. This allowed for the identification of sporelings and species too small to identify reliably in the field. ANOSIM showed the significant differences between all sites except of the two on the east side of the jetty. SIMPER highlighted the main species contribution to the similarities and differences between sites.

The infaunal data from 2010 was presented and a brief comparison made with the data from 2005. In all instances the total taxa recorded is lower in 2010 than 2005. At all sites apart from one, the number of individuals counted in the cores in 2010 was lower than 2005. PRIMER analysis employing ANOSIM, MDS and SIMPER showed that the infauna for the sites sampled were dissimilar. A cumulative dominance plot indicated an impact at one of the study sites and this result was further emphasised in a geometric class plot. A variety of diversity indices were calculated for the infauna at each site.

The results of Particle Size Analysis (PSA) at each site were analysed and significant differences were found between each study site.

RELATE tests were undertaken between the different data sets. The infauna and epibiota and indicated a correlation in community pattern across the sites that were sampled for both. This suggests that either the dominant factors that determined the infaunal community structure, or another correlating factor, played a role in determining the epibiota community structure also. The infauna and PSA data showed a weak but significant correlation. This was also true of epibiota and PSA data.

The methodology used in 2010 appraised and discussed.

The apparent decline of live maerl at the two stations in the main maerl bed is discussed. Comparison is made to another separate study carried out by JNCC divers in Milford Haven in 2011 where estimates of percentage cover of live and dead maerl and *Crepidula fornicata* were made at two sites. Decreases in the abundance of live maerl and increases in *Crepidula fornicata* when compared to 2005 were in line with the observations from 2010.

Reference is made to a study of maerl collected in Milford Haven in July 2011 where rhodoliths were found to be in poor condition and reminiscent of thalli collected from impacted sites in Galicia, Spain.

Trends in the data relating to *Crepidula fornicata*, epibiota and infauna are discussed. Recommendations are made for further work to assist in understanding trends found in this study. In order to understand some of the apparent changes between 2005 and 2010, comparison should be made with other existing data sets.

The infauna from the sediment cores although fairly rich in species was considered to be impoverished for a maerl bed. The amphipod species *Liljeborgia kinahani*, found at one sampling site is typical of maerl beds. The amphipods and molluscs were diverse and this is often the case in maerl samples.

Analysis of the infauna data obtained from cores by ANOSIM and MDS plots appear to show that, for infauna at least, the four sites sampled are quite dissimilar. Treatment of the data using SIMPER showed that there were no key species responsible for inter-site differences. The data suggests a stable and relatively biodiverse habitat where interspecies competition and K dominant species would be expected to be common.

Analysis of sediment samples by particle size analysis (PSA) showed the granulometry of the four sites sampled to be dissimilar.

RELATE tests were carried out on the epibiota, infauna and PSA data sets. Whilst there was some variability in both the degree, and statistical significance, of correlation between the

different data sets there does appear to be a suggestion that there are links in community determining factors for both infauna and epibiota and that substrate composition plays a role in this. As, within the study area, maerl forms a significant component of the substrate, affects granulometry measures, and appears to be a significant player in determining epibiota community composition and infaunal diversity, it is suggested that the key factor to these inter-relationships between datasets is the presence of maerl.

The results of the study are discussed in relation to the author's knowledge of maerl beds elsewhere, however a literature review is beyond the scope of this study.

Conservation concerns relating to the Milford Haven maerl bed are discussed in relation to the results of this survey. Some threats are highlighted and brief recommendations for management are proposed.

## 2.8 ENVIRONMENT AGENCY MARINE MONITORING PROGRAMMES IN MILFORD HAVEN

### *Water Framework Directive*

The Water Framework Directive (WFD) (2000/60/EEC) requires that all countries throughout the European Union manage the water environment to consistent standards. It integrates the ecological and chemical status of surface water, placing a greater emphasis on ecological status. The prominent aims of the directive are to:

- prevent deterioration in the status of aquatic ecosystems, protect them and improve the ecological condition of waters;
- achieve at least good status for all water bodies by 2015. Where this is not possible and subject to the criteria set out in the Directive, aim to achieve good status by 2021 or 2027.

For the purposes of this directive the Haven is divided into two waterbodies: 'Milford Haven Transitional' which includes the inner estuarine waters upriver from Pennar Gut, and 'Milford Haven Coastal' covering the area from Pennar Gut to St Annes Head. All the routine monthly WFD water surveys conducted in the Haven, combined with other biological element surveys throughout the year, provide data on the ecological status of the waters. This data feeds into preparing assessments and classifications of these waterbodies according to their combined chemical and ecological status. From these assessments River Basin Management Plans are produced.

WFD Surveillance Programme water sampling is conducted at 8 sample points spread throughout the Haven. This occurs on a monthly basis using the Environment Agency Coastal Survey Vessel (CSV) Vigilance. Samples for analysis of biological elements such as phytoplankton and chlorophyll are routinely collected alongside supporting elements such as winter nutrients and field determinands including dissolved oxygen, salinity, temperature and turbidity.

Data from yearly fish population studies in Milford Haven transitional waterbody also feeds into informing the ecological component of WFD assessments of the waterbody. Currently, in the autumn two 30-minute otter trawls are conducted at the mouth of Pennar Gut by CSV. Additionally, there are 7 seine net sampling points (covering Carew, Pembroke River, Western and Eastern Cleddau Rivers) which are surveyed bi-annually in May/June and September-November for further fish population analysis.

Benthic data is collected in the Haven on a 3-yearly cycle, with the last full survey being carried out in 2010. The survey consists of 25 sites in the transitional waters of the Haven and 10 from the coastal waters being sampled with a 0.1m² day grab. 7 sites sampled also doubled as MHWESG surveillance sites where chemistry and PSA samples were also taken at each site to support the biological data.

With respect to intertidal sampling for WFD Surveillance Programme monitoring, the ecological components studied are macroalgae, saltmarsh and seagrass, and local area teams are responsible for the completion of these surveys. The location of opportunistic macroalgae is mapped in the Haven as a whole and percentage cover and biomass calculated – this occurs twice every six years. Similarly, transects of salt marshes are also completed twice every six years, whereas seagrass beds such as those at Angle Bay are surveyed annually for extent and percentage cover.

The latest round of WFD classifications of Milford Haven waters occurred in 2009 which resulted in both Milford Haven coastal and transitional waterbodies being classified as having an overall status (when both chemical and ecological components are taken in account) of

'moderate'. The long term goal in the Haven is to work towards both waterbodies developing a 'good' status by 2027. More information can be found in the Western Wales River Basin Management Plan which can be accessed from the Environment Agency website.

(www.environment-agency.gov.uk/research/planning/33106.aspx)

### *Nitrates Directive*

Milford Haven is currently under review as a candidate polluted water under the Nitrates Directive (91/676/EEC). This directive aims to reduce water pollution caused by nitrates from diffuse pollution sources, primarily agriculture. The current monitoring programme in the Haven was set up in 2009 as an ongoing review of the waters when previous rounds of investigation had provided insufficient evidence of water eutrophication to make a case for designation of Milford Haven as a Polluted Water. Sampling for nutrients currently occurs 8 times a year in summer and winter, at 7 sample points. If data from recent years suggests conclusively that nitrogen compounds from agricultural sources are contributing to eutrophication, Milford Haven will become a designated Polluted Water. This would then have implications for surrounding areas as all land draining in the Polluted Water would be designated as a Nitrate Vulnerable Zone and restrictions would be applied to reduce nitrate leaching into the water as a result of agricultural activities.

### *Shellfish Waters Directive*

The purpose of the Shellfish Waters Directive (SWD) (79/923/EEC) it to safeguard shellfish populations from the harmful consequences resulting from the discharge of polluting substances into the sea. The directive is therefore aimed at protecting the shellfish populations themselves rather than the health of the consumers, this is covered by the Shellfish Hygiene Directive.

Currently there are 2 shellfish waters within the Haven, Milford Haven Carew and Milford Haven Cleddau, and sample points within these are sampled quarterly to fulfil requirements for this directive. Bacterial samples are routinely taken and samples for metals analysis are taken twice a year. Mussels are harvested from the banks of the Carew River every quarter for the analysis and reporting of faecal coliform concentrations in shellfish flesh.

### *Dangerous Substances Directive*

Four sites in the Haven are currently sampled on a quarterly basis for Dangerous Substances Directive (DSD) (76/464/EEC), these are the outfalls at Haverfordwest, Chevron, Murco and Petroplus/Dragon LNG. In addition we also undertake sediment sampling at the Petroplus/Dragon LNG site once a year to monitor concentrations of List 1 substances in the sediment. These are substances which are particularly toxic, persistent and which may accumulate in the environment.

### *Clean Sea Environment Monitoring Programme (CSEMP)*

Current CSEMP monitoring in the Haven is focused on the detection of long term temporal trends and the Environment Agency is responsible for delivering benthic invertebrate community data in Milford Haven at the established Cosheston Point CSEMP site. This is sampled yearly in the spring for 5 replicate biology samples and supporting particle size information which form part of a long-term data set.

CSEMP also requires the collection of data for the analysis of metal contaminants in biota in the Haven and this is fulfilled by the annual collection and analysis of mussel flesh from Lawrenny Quay by land-based local area teams.

## 2.9 CEFAS MACROALGAE AND PHYTOPLANKTON MODELLING ASSESSMENT

**Summary**

Environment Agency Wales commissioned Cefas in 2011 to assess the impact of nutrient inputs and the likely effectiveness of nutrient removal scenarios in controlling growth of macroalgae and phytoplankton in the Haven.

A Dynamic Combined Phytoplankton and Macroalgae (CPM) modelling tool was setup and calibrated to simulate an annual cycle of phytoplankton and macroalgal growth for Milford Haven with separate model setups for the inner estuary and for the Haven as a whole.

A final report was produced in September 2011. Key results were:

1. Phytoplankton growth in the estuary appears to be relatively finely balanced between nitrogen, phosphorus and light limitation. Therefore firm conclusions are difficult to make.
2. Phytoplankton growth in the inner estuary was predicted by the model to be mainly phosphorus limited.
3. The outer estuary, and on average the estuary as a whole, was predicted by the model to be nitrogen limited.
4. Macroalgal growth appeared to be constrained primarily by availability of habitat and secondarily, in the inner estuary, by phosphorus limitation.
5. Offshore phosphorus inputs are predicted to be the main source of this nutrient in the estuary as a whole.
6. It is recommended that at this stage predictions of phosphorous limitation be treated with caution. Observed average summer average concentrations of phosphorus in the inner estuary appeared to be reduced only slightly from winter values, which would not be expected if phosphorus limitation was occurring. This may be due to the use of seasonal averages and level of detection issues in data post 2005. However it may be a consequence of phosphorus supply from the bed. This process is not included in the model formulation.
7. Changes of 25% to direct nutrient loadings of N and P were predicted to give rise to changes in summer average chlorophyll concentrations of between 2% - 7% and to changes in summer average macroalgal biomass of between 7% -15%.

The report made recommendations for further data analysis and minor modifications to the model. This extra work will be completed in March 2012.

The report will be used as supporting evidence for our Water Framework Directive investigations and for determining whether the Haven meets the criteria for designation as a Sensitive Area (Eutrophic) under the Urban Waste Water Treatment Directive or a Polluted Water (Eutrophic) under the Nitrate Directive.

# 3 FUTURE WORK PROGRAMME

A medium-term work outline programme identifies tasks for the coming decade, though with the flexibility to bring forward or delay projects depending on the pace of individual projects, unforeseen opportunities to integrate with other projects and the available budget.

The Group's priority for 2012 is the Sediment Profile Imaging survey planned for but postponed from 2011.

A review of sediment contaminants and transport studies and data for Milford Haven completed by Dr David Little in 2009 concluded that, *inter alia*, attempts to reconstruct a broad, landscape-scale picture of sediment distribution from the various available data could only partly be achieved because all the studies had been done at different times with differing aims, and because of the diversity and patchiness of the mosaic of sediments in the waterway. Previous, coarse resolution attempts at describing sediment distributions through the waterway were undertaken in the early 1980s and are still in use today in the absence of anything more precise. Nevertheless, landscape-scale habitat information remains vital to support informed management of the waterway.

Dr Little recommended that a broad-scale survey be undertaken of the entire waterway using sediment profile imaging, a non-invasive, rapid method of assessing the condition of benthic biotopes, involving minimal laboratory work-up. Although Dr Little advised that the value of a synoptic view of the sediment mosaic of the entire estuary in the context of informing future MHWESG surveillance could not be over-stated, the same is also true for its value in the assessment of development and maintenance projects, for helping understand sediment transport, the sediment biology and ecology of the Haven and for determination of sinks and remobilisation risks for contaminants.

Sediment profile imaging (SPI) technology was developed more than twenty years ago as a rapid reconnaissance tool for characterizing physical, chemical, and biological seafloor processes unlimited by water turbidity. It has been extensively used in numerous sediment quality surveys throughout the United States, and from Azerbaijan to New Zealand, via Canada China, Ireland and Italy, to characterize sediment quality, monitor the environmental impacts of dredged material disposal, oil spill environmental assessment (most recently in the Gulf of Mexico following the BP Deepwater Horizon spill) and look for pollution "hot spots".

The optical coring device works like an inverted periscope and takes cross-sectional images of the upper 20 cm of the seafloor that can be analysed rapidly. It incorporates an innovative design where water turbidity is never a limiting factor.

More than 20 different physical and biological parameters can be measured using computer image analysis. Because the sediment column is a superb time-integrator of short- and long-term perturbations in the water column or the seafloor, the technology allows investigators to deduce sediment dynamics from imaged structures. However, one of the technology's greatest assets is the production of a visual image from environments that normally can never be viewed making it a powerful communication tool to inform non-scientific audiences about environmental conditions through visual images that are easily understood.

In addition to producing results that are easily understandable by a non-scientific audience, a sufficient density of samples enables the accurate delineation of sediment gradients and facilitiates the design of the most efficient and parsimonious sampling strategies for future surveys

In addition to this major survey, annual summer shelduck breeding surveillance and wetland bird data collation and reporting will continue.

The Group's budget remains healthy but the 2012 SPI survey will be the most expensive project underaken by the Group by a wide margin and will substantially deplete the budget.

Whilst the Group looks forward to welcoming further new members from the new industries around the Haven and, naturally, their contributions, at the same time it is conscious of the resource cuts facing some of the public body members of the Group and anticipates commensurate reductions in their contributions may be likely in the short-term.

Consequentially a thorough review of the Group's aspirations and work programme needs to undertaken on completion of the SPI survey when the Group's exact remaining balance is confirmed.

# APPENDICES

# APPENDIX 1: PURPOSE AND TERMS OF REFERENCE

**Preamble**

The Milford Haven Waterway[1] is an extensive natural inlet of the sea with a long and distinguished maritime history. Its deep waters provide a natural harbour of significant economic importance. It is one of the best examples of a ria system in Britain and supports a particularly diverse range of high quality marine and estuarine habitats and biological communities.

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

**Purpose**

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

**Terms of Reference**

The Milford Haven Waterway Environmental Monitoring Steering Group will:

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

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

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

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

2.3 undertaking surveillance projects;

2.4 maintaining a literature and information database.

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

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

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

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

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

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

**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'.

[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.

# 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

[2] The Group changed its name in 2000

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**

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. 8 pp + appendices

Langston, WJ, O'Hara, S, Davey, M, Shortridge, E, Pope, ND, Harino, & Vane, CH. (2012) *Bioaccumulation surveillance in Milford Haven Waterway Phase II (2010)* Report to the MHWESG from the Marine Biological Association UK

## APPENDIX 4: BIOACCUMULATION PAPER ABSTRACT

Abstract from

Langston, W.J.; O'Hara, S.; Pope, N.D.; Davey, M.; Shortridge, E.; Imamura, M.; Harino, H.; Kim, A.; Vane, C.. 2012 Bioaccumulation surveillance in Milford Haven Waterway. *Environmental Monitoring and Assessment*, 184 (1). 289-311

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DOI 10.1007/s10661-011-1968-z

# Bioaccumulation surveillance in Milford Haven Waterway

**W. J. Langston · S. O'Hara · N. D. Pope · M. Davey · E. Shortridge · M. Imamura · H. Harino · A. Kim · C. H. Vane**

Received: 1 November 2010 / Accepted: 23 February 2011


**Abstract** Biomonitoring of contaminants (metals, organotins, polyaromatic hydrocarbons (PAHs), PCBs) was undertaken in Milford Haven Waterway (MHW) and a reference site in the Tywi Estuary (St Ishmael/Ferryside) during 2007–2008. Bioindicator species encompassed various uptake routes—*Fucus vesiculosus* (dissolved contaminants); *Littorina littorea* (grazer); *Mytilus edulis* and *Cerastoderma edule* (suspension feeders); and *Hediste* (=*Nereis*) *diversicolor* (sediments). Differences in feeding and habitat preference have subtle implications for bioaccumulation trends though, with few exceptions, contaminant burdens in MHW were higher than the Tywi reference site, reflecting inputs. Elevated metal concentrations were observed at some MHW sites, whilst As and Se (molluscs and seaweed) were consistently at the higher end of the UK range. However, for most metals, distributions in MH biota were not exceptional. Several metal-species combinations indicated increases in bioavailability upstream, which may reflect the influence of geogenic/land-based sources—perhaps enhanced by lower salinity. TBT levels in MH mussels were below OSPAR toxicity thresholds and in the Tywi were close to zero. Phenyltins were not accumulated appreciably in *M. edulis*, whereas some *H. diversicolor* populations appear subjected to localized (historical) sources. PAHs in *H. diversicolor* were distributed evenly across most of MHW, although acenaphthene, fluoranthene, pyrene, benzo(*a*)anthracene and chrysene were highest at one site near the mouth; naphthalenes in *H. diversicolor* were enriched in the mid-upper Haven (a pattern seen in *M. edulis* for most PAHs). Whilst PAH (and PCB) concentrations in MH mussels were mostly above reference and OSPAR backgrounds, they are unlikely to exceed ecotoxicological thresholds. Bivalve Condition indices (CI) were highest at the Tywi reference

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W. J. Langston (✉) · S. O'Hara · N. D. Pope · M. Davey · E. Shortridge
Marine Biological Association, Citadel Hill, Plymouth PL1 2PB, UK
e-mail: wjl@mba.ac.uk

M. Imamura
Central Research Institute of Electric Power Industry Environmental Science Laboratory, 1646, Abiko City, Chiba, 270-1194, Japan

H. Harino
School of Human Sciences, Kobe College, 4-1 Okadayama, Nishinomiya, Hyogo, 662-8505, Japan

A. Kim · C. H. Vane
British Geological Survey, Kingsley Dunham Centre, Keyworth NG12 5GG, UK

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site and at the seaward end of MH, decreasing upstream—giving rise to several significant (negative) relationships between CI and body burdens. Despite the possible influence of salinity gradient as a complicating factor, multivariate analysis indicated that a combination of contaminants could influence the pattern in condition (and the biomarkers metallothionein and TOSC). Integrating bioaccumulation data with biological and biochemical endpoints is seen as a useful way to discriminate environmental quality of moderately contaminated areas such as MHW and to prioritise cause and effect investigations.

**Keywords** Milford Haven · Bioaccumulation · Metals · PAHs · PCBs · Organotins · TOSC · Metallothionein

## Introduction

Milford Haven Waterway is a ria-type estuary, part of the Pembrokeshire Marine Special Area of Conservation (Burton 2006). The Haven is fully marine for 12 km, to the confluence of the Pennar River (Fig. 1), with a shoreline of >100 km. The Daucleddau—the common Estuary of the Eastern and Western Cleddau Rivers—also has a marine influence for much of its length because of the small freshwater ingress relative to the tidal incursion (Nelson-Smith 1965).

Despite its important conservation status, MHW is subjected to contaminants from various sources including Eastern and Western Cleddau Rivers, industry, waste-water discharge, diffuse inputs associated with landfill leachate, urban development, agricultural run-off and atmospheric deposition. Maritime operations and pollution incidents (hydrocarbons and antifouling), dredging and spoil disposal add to this inventory (Atkins 2005). Milford Haven handled >50 M tonnes shipping in 2009, supplying, among other cargoes, 25–30% of the UK's petrol, diesel and liquefied natural gas. Contamination by biologically deleterious substances has implications for the 'favourable condition status' of the site and other conservation objectives. Potential sensitivity and impact on fauna, at its most extreme, was highlighted by the 'Sea Empress' oil spill, in the mouth of MHW, in February 1996 (Nikitik and Robinson 2003).

Milford Haven has been a major oil terminal since the 1960s and has received chronic releases of hydrocarbons (<250 tonnes pa) from various routes including refineries, power stations, shipping, road run-off and small-scale domestic sources. These inputs are mostly dispersed along the waterway in association with suspended particulates (Little et al. 1987; Nikitik and Robinson 2003). The loss of 72,000 tonnes of light crude oil and 480 tonnes of heavy fuel oil from the *Sea Empress* represented a significant departure from

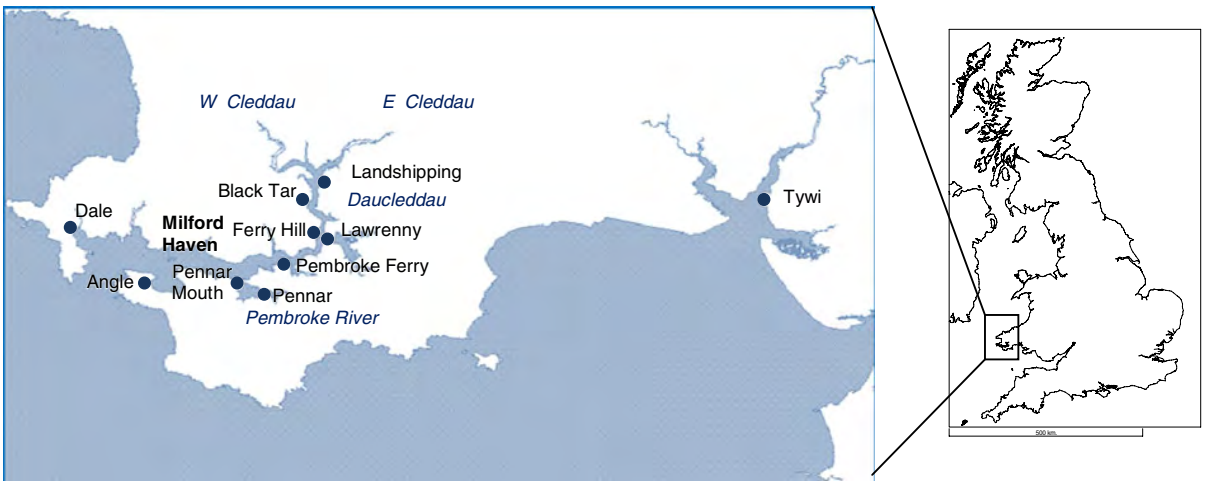
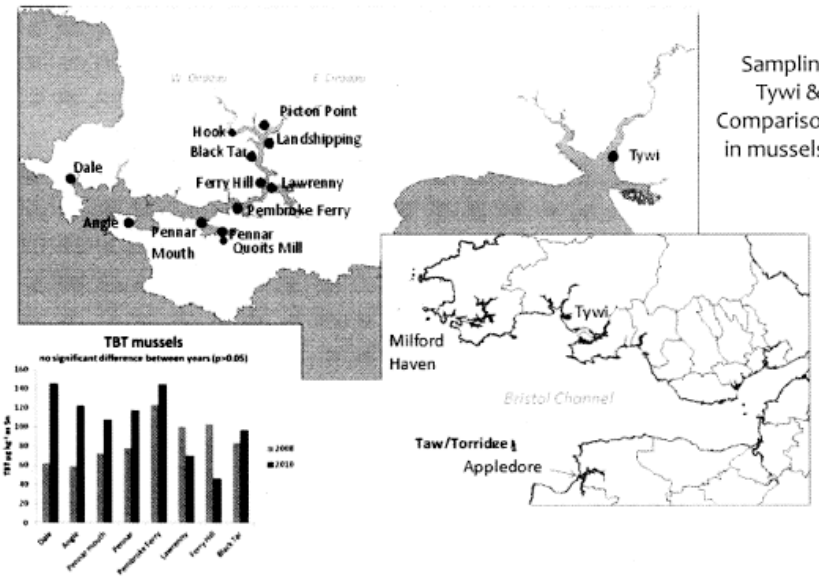



**Fig. 1** Location of sampling sites for biota, Milford Haven and Tywi Estuary

Extract from MBA Annual Report 2011

## Milford Haven Bioaccumulation Surveillance




Sampling sites in Milford Haven, Tywi & Taw/Torridge Estuaries. Comparison of TBT concentrations in mussels *Mytilus edulis* 2008 and 2010.

The emphasis of current work is to establish reliable and consistent indicators of different pollutant classes (metals, organotins, PAHs and PCBs) and to describe recent changes in body burdens and their distribution in Milford Haven Waterway (MHW) and the Daucleddau Estuary. The latest surveys have confirmed the most useful sites and species for long-term surveillance. Bioindicators encompass various uptake routes – *Fucus vesiculosus* (dissolved contaminants); *Littorina littorea* (grazer); *Mytilus edulis* and *Cerastoderma edule* (suspension feeders); and *Hediste (=Nereis) diversicolor* (sediments). Local and regional 'reference' sites, in the Tywi and Taw/Torridge Estuaries (Appledore), respectively, have also been characterized.

Trends in bioaccumulation – TBT. Lowest concentrations in MHW were upstream in the Daucleddau, and at 40 µg $kg^{-1}$ TBT levels in mussels were, similar to the regional background. Highest concentrations (~150 µg $kg^{-1}$ TBT) were in the Haven signifying inputs due to port activities. These concentrations exceed Environmental Assessment Criteria (OSPAR) indicating the possibility of sub-lethal effects. Theoretically, the global ban on TBT in 2008 should produce a decline in TBT contamination; however, the current data for MHW suggests little change over the past two–three years.

The study is supported by the Milford Haven Waterway Environmental Surveillance Group, a consortium consisting of EA, CCW Milford Haven Port Authority and petrochemical industries. It is intended that the survey results will form a reliable platform against which future trends in contaminant inputs (from a wide variety of sources) can be assessed. They will also be used to recommend an optimal strategy for future monitoring and to indicate priorities for biological effects investigations.

MBA Annual Report 2011

## APPENDIX 5: *CREPIDULA FORNICATA* PAPER ABSTRACT

Abstract from

The invasive gastropod *Crepidula fornicata*: reproduction and recruitment in the intertidal at its northernmost range in Wales, UK, and implications for its secondary spread Katrin Bohn, Christopher Richardson, Stuart Jenkins *Marine Biology* (13 July 2012), pp. 1-13

Mar Biol
DOI 10.1007/s00227-012-1997-3

ORIGINAL PAPER

# The invasive gastropod *Crepidula fornicata*: reproduction and recruitment in the intertidal at its northernmost range in Wales, UK, and implications for its secondary spread

**Katrin Bohn · Christopher Richardson · Stuart Jenkins**

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**Abstract** The establishment and spread of a non-native species in an introduced range depends to a large extent on the performance of the species under the prevailing environmental conditions. The spawning, larval and spatfall periods of the invasive gastropod *Crepidula fornicata* were monitored in the intertidal zone at its northernmost range in Wales, UK, between February 2010 and January 2011. The duration of the reproductive season was similar to that recorded from more southerly European populations. Spawning and larval release occurred throughout most of the year even at low seawater temperatures of <7 °C, but benthic recruitment was observed over a much shorter period at seawater temperatures >16 °C. Recruitment was low and likely controlled by post-settlement mortality. These observations suggest that *C. fornicata*'s northwards spread in Welsh waters will not be limited by seawater temperature negatively affecting reproduction, but by processes acting after larval release. These data show the importance of incorporating settlement and post-settlement processes into studies on recruitment success when aiming to predict the potential spread of a potentially harmful invader such as *C. fornicata*.

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K. Bohn (✉) · C. Richardson · S. Jenkins
School of Ocean Sciences, College of Natural Sciences, Bangor University, Anglesey, Wales LL595AB, UK
e-mail: Katrin.Bohn@gmail.com

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## Introduction

The spread of non-native species (NNS) poses a serious environmental threat worldwide due to their negative impacts on native species biodiversity and ecosystem processes in the recipient habitats (Grosholz 2002; Stachowicz et al. 2002). Understanding the processes that determine the success of NNS is critical if their ecological and economic impacts are to be mitigated. After initial introduction and successful establishment, the secondary spread of NNS may be controlled by a variety of factors including their dispersal potential, the availability of suitable habitats and their ability to cope with biotic and abiotic conditions in the novel environment (Colautti and MacIsaac 2004). Amongst the latter, prevailing seawater temperatures may be one of the most important factors in determining the range a marine NNS may occupy in the novel area. Exposure to temperatures close to the thermal tolerance limits of the species may restrict its local abundance and geographical spread in the new environment (Chapman 2000; Colautti and MacIsaac 2004).

Once established, the expansion of NNS may be limited by similar processes acting on native ones. Warming seawater temperatures in North West Europe are thought to have resulted in increases in abundance and northward expansion of a number of southern Lusitanean species (see Hiscock et al. 2004; Mieszkowska et al. 2005, 2006; Hawkins et al. 2008; Masuda 2008). Temperature-induced phenological changes such as an extended reproductive season (Moore et al. 2011; Valdizan et al. 2011) may be one important mechanism by which breeding populations can establish beyond their normal northern range limit (Hawkins et al. 2008). The expected rising seawater temperatures as a consequence of global climate change are therefore expected to facilitate the spread of NNS, by