Intertidal Monitoring of rocky reefs, Pembrokeshire Marine SAC. Population trends for selected species 2005 to 2014

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Aquatic Survey and Monitoring Ltd.

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- Mae’r adroddiad hwn yn ategu’r adroddiadau ynghylch tueddiadau mewn cymunedau a geir yn Bunker & Brazier (2013) rhwng 2007 a 2010, lle nodir llinell sylfaen y gellir ei defnyddio i bwyso a mesur newidiadau yn y dyfodol.
- Mae’r adroddiad hwn yn ystyried data a gasglwyd rhwng 2005 a 2014 oddi mewn i gwadratau monitro parhaol ar wyth o safleoedd creigiog yn ACA Pembrokeshire Marine/Sir Benfro Forol. Cyfrifwyd amlder cyfartalog y rhywogaethau a’r grwpiau rhywogaethau hollbwysig a chymharwyd yr wybodaeth dros amser er mwyn canfod tueddiadau o safbwynt amlder ar y safleoedd gwahanol.
- Dengys y canlyniadau amrywiadau yn nifer y rhywogaethau (neu’r grwpiau o rywogaethau) ar y safleoedd monitro dros amser, a phwysleisir rhai o’r gwahaniaethau mawr rhwng y glannau.
- Caiff y tueddiadau a ddangosir gan y gwahanol rywogaethau eu trafod, gan gyfeirio at lenyddiaeth gyhoeddedig, a chyflwynir argymhellion ar gyfer gwaith yn y dyfodol a fyddai’n ddefnyddiol i wella ein dealltwriaeth o’r rhywogaethau a’r cymunedau.

Executive Summary

- The work described in this report was undertaken to provide information necessary to report to Europe on the condition of Pembrokeshire Marine European Marine Site and inform on management of the site and to facilitate with advice of plans and projects.
- This report compliments the reporting of trends in communities in Bunker & Brazier (2013) from 2007 to 2010, which identified a baseline against which future changes can be considered.
- This report considers data collected between 2005 and 2014 from permanent monitoring quadrats on the eight rocky sites in Pembrokeshire Marine SAC. Average frequencies of key species and species groups were calculated and compared over time to view trends in abundance at the different sites.
- The results show fluctuations of species (or species group) abundances at the monitoring sites over time and emphasise some of the major differences between the shores.
- The trends shown by the different species are discussed with reference to published literature and recommendations are given for future work that would be useful to further our understanding of the species and communities.

1. Introduction

Aquatic Survey & Monitoring Ltd. (ASML) were contracted by the Countryside Council for Wales (CCW), now National Recourses Wales (NRW) to work as a team with HQ and Regional staff to develop and manage the intertidal monitoring program for each marine SAC in Wales. The monitoring program was first implemented in 2005 by CCW and the Institute of Estuarine and Coastal Studies (IECS, University of Hull). From 2007 on, the monitoring program has been managed by ASML, except for 2010 where the project was managed solely by CCW.

The Pembrokeshire Marine SAC feature and attribute prioritised by CCW for the survey work is intertidal rocky reef (see Table 1).

Table 1 Features, study sites and purpose of surveys described

Feature / attribute	**Site(s)**	**Purpose**
Reefs (rocky shores)	Lawrenny Quay, Pembroke Ferry, Hazelbeach, Pembroke Power Station, South Hook Point, Monk Haven, West Angle Bay, Nolton Haven	To provide data to support a condition assessment of the feature by undertaking quantitative monitoring of the biota colonising sloping emersed bedrock at six rocky shore sites within the Milford Haven waterway and one open coast site at Nolton Haven.

Six permanent monitoring sites were established in 2005 (Hull *et al*, 2006) within the Milford Haven Waterway. These comprised of Lawrenny Quay, Pembroke Ferry, Hazelbeach, South Hook Point, Monk Haven and West Angle Bay. A further study site, Nolton Haven was established in 2007 on the open coast of St Bride’s Bay, north of Milford Haven (Mercer, 2008) and a monitoring site adjacent to Pembroke Power Station outfall was added in 2011. Pen-Y-Holt in South Pembrokeshire was established as a study site for rock pools, limpets and barnacles in 2008. A map showing the locations of the Pembrokeshire Marine rocky reef shore study sites is given in Figure 1.

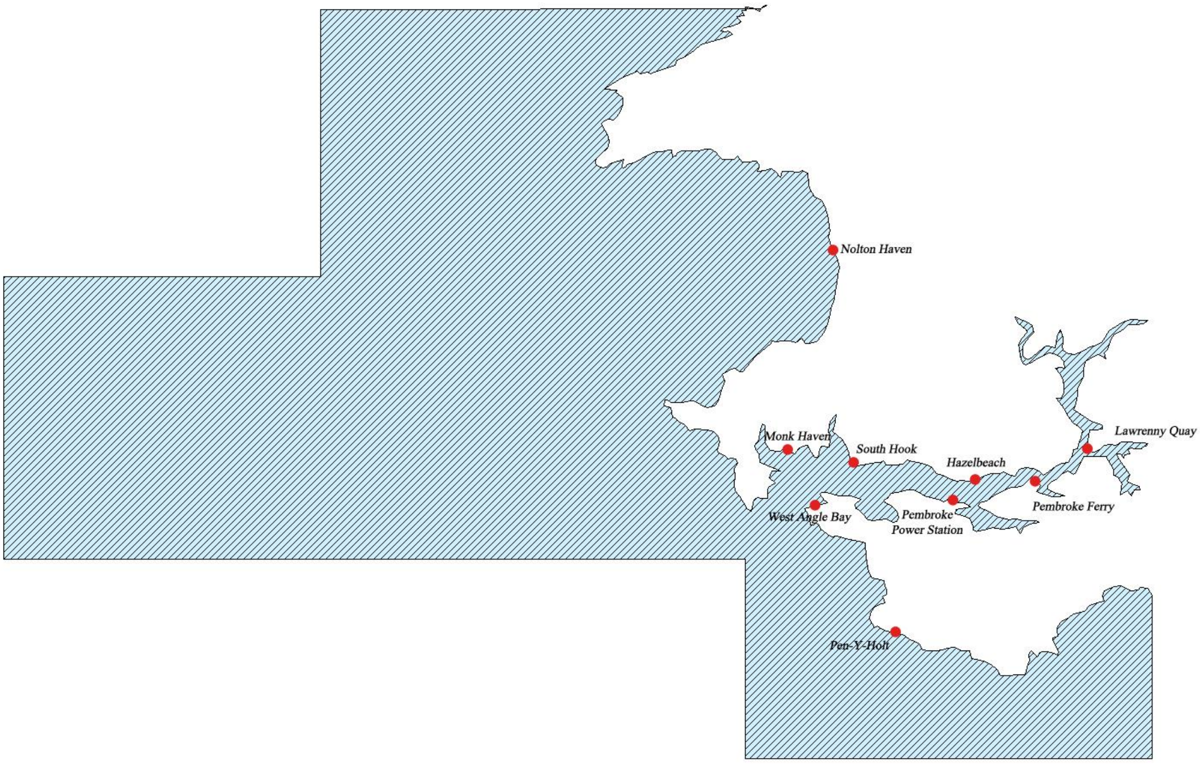

Figure 1 Location of Pembrokeshire Marine SAC intertidal rocky shore monitoring sites (showing the SAC boundary)

This report considers data collected between 2005 and 2014 from permanent monitoring quadrats on the eight rocky sites listed in Table 1. Although the study aims to collect data annually from all sites, this has not been possible. No contract was in place in 2006 so data was not collected. Also, Monk Haven was omitted from the 2011 survey due to time and manpower constraints. It should be noted that Nolton Haven was first set up as a survey site in 2007 and Pembroke Power Station in 2012.

The main methodology employed in the rocky shore studies was to collect frequency data from 4 fixed 1 m^2 quadrats in each of the upper shore (US), middle shore (MS) and lower shore (LS) zones at each site, together with limpet counts and measurements, percentage cover of barnacle species and for Lawrenny Quay only, *Ascophyllum nodosum* measurements.

The initial findings of the rocky shore studies are presented in Hull, Tobin *et al*. (2006), Mercer and Brazier (2008) and Bunker and Brazier (2013). In Bunker and Brazier (2013) the data sets from 2005 to 2010 were analysed using multivariate statistical techniques and the following statements were made about the data:

1. A general trend was noted with the number of species increasing down the shore and decreasing with exposure.

2. The data grouped together into 9 main cluster groups:

i. MS Lawrenny Quay (all years), LS Lawrenny Quay (all years)
ii. US Hazelbeach, Lawrenny Quay, Pembroke Ferry (all years)
iii. LS Hazelbeach (all years)
iv. US South Hook (all years), West Angle (all years), Monk Haven (all years), Nolton

Haven (all years), MS Hazelbeach (2005), MS Monk Haven (2005).

v. MS Nolton Haven (all years) and LS Nolton Haven (all years)

vi. LS Pembroke Ferry (all years), LS Monk Haven (all years), LS West Angle Bay (2005), MS West Angle Bay 2005, LS South Hook (all years).

vii. MS Nolton Haven (2010), MS West Angle (2007 to 2010) MS South Hook (2009), MS Hazelbeach (2008 and 2010), LS West Angle (2007 to 2010), LS Monk Haven (2009 and 2010),

viii. MS Hazelbeach (2007 and 2009), MS Pembroke Ferry (all years)

ix. MS Monk Haven (except 2005), MS South Hook (all years except 2009)

Long term rocky shore study data sets have been collected from the Skomer Marine Nature Reserve (now Skomer Marine Conservation Zone (SMCZ)) in Pembrokeshire, since 2002. A conclusion reached by the Skomer MCZ team is that at least 6 years of annual sampling is required in order to start seeing patterns in the data set, which can be separated from natural variability (Lock, Burton *et al*., 2015).

Pembrokeshire Marine SAC rocky intertidal monitoring was designed to be analysed by multivariate statistical techniques, but such analyses will not readily highlight changes in abundance of particular species.

Rather than repeat the multivariate analyses employed by Bunker and Brazier (2013), it was decided in this report to examine how the abundance of some of the more common species and species groups from a variety of phyla vary over time. Although the abundance data for individual species and species groups at individual sites is not suitable for statistical analysis, probable trends in changes of abundance can be noticed by examining changes in frequency over time.

2. Method

2.1. Field methods

All field methods have remained consistent and are described in Mercer and Brazier (2008).

2.2. Data preparation and analysis

Prior to analysis, the data for each species at each zone at each site were averaged for each year. For the years 2005 to 2011 the data preparation was carried out by Mark Burton (CCW, Skomer MCZ).

Some rationalisation of the data was undertaken by Mark Burton who aimed to combine the data from the shores described in this report combined with the data from shores surveyed around the Skomer MCZ. Some further rationalisation was then carried out by Francis Bunker and applied to the data set as a whole. Rationalising the data mostly involved combining species data where there was inconsistent naming of the same entity.

The following question was asked of the data:

'Have particular species or species groups changed over the years?'

To investigate possible changes over time, the averaged data was plotted graphically in Excel in order to give a visual interpretation of trends.

2.3. Photography

A variety of digital cameras were used to take pictures on site. Pictures of each quadrat were taken as well as general location shots and other subjects thought to be relevant at the time of survey.

Jpeg photographs from individual cameras were re-named using the following convention:

'Date (year month day)' underscore 'Survey location' underscore 'Photographers Initials' (up to 5 letters, extra underscore at end if only 2 letters) underscore 'photograph number'

e.g. 20080902_WestAngle_BAB_0165.jpg

The photographs were organised using Apple Aperture software where captions and keywords were added. A catalogue of photographs was exported to Microsoft Excel and has been archived by NRW.

2.4. Species identification and nomenclature

Species have been named according to WoRMS (December 2014). The species lists were uploaded to WoRMS and spell checked and matched to authorities using the 'Match Taxa' feature on the web site.

3. Results

The abundances over time for a selection of seaweed and animal species found in the monitoring quadrats are presented in this section and noticeable trends are outlined.

A key to the graphs and tables presented in this section is given in Table 2.

Table 2 Abbreviations used in the graphs and figures of this results and discussion sections.

Abbreviation	Name in Full
LQ	Lawrenny Quay
PF	Pembroke Ferry
HB	Hazelbeach
PS	Pembroke Power Station
SH	South Hook
MH	Monk Haven
WB	West Angle Bay
NH	Nolton Haven
MHWN	Mean High Water Neaps

3.1. Brown Seaweeds

3.1.1. *Pelvetia canaliculata*

The upper shore brown seaweed *Pelvetia canaliculata* is most abundant at sheltered sites, with the exception of South Hook where dense growths are noticeable. At Lawrenny Quay and Hazelbeach there is little variation in the abundance of this species over time. At Pembroke Ferry there appears to be a fairly steady decline and at most sites there appears to be a decline in 2014 (see Figure 2 and Table 3)

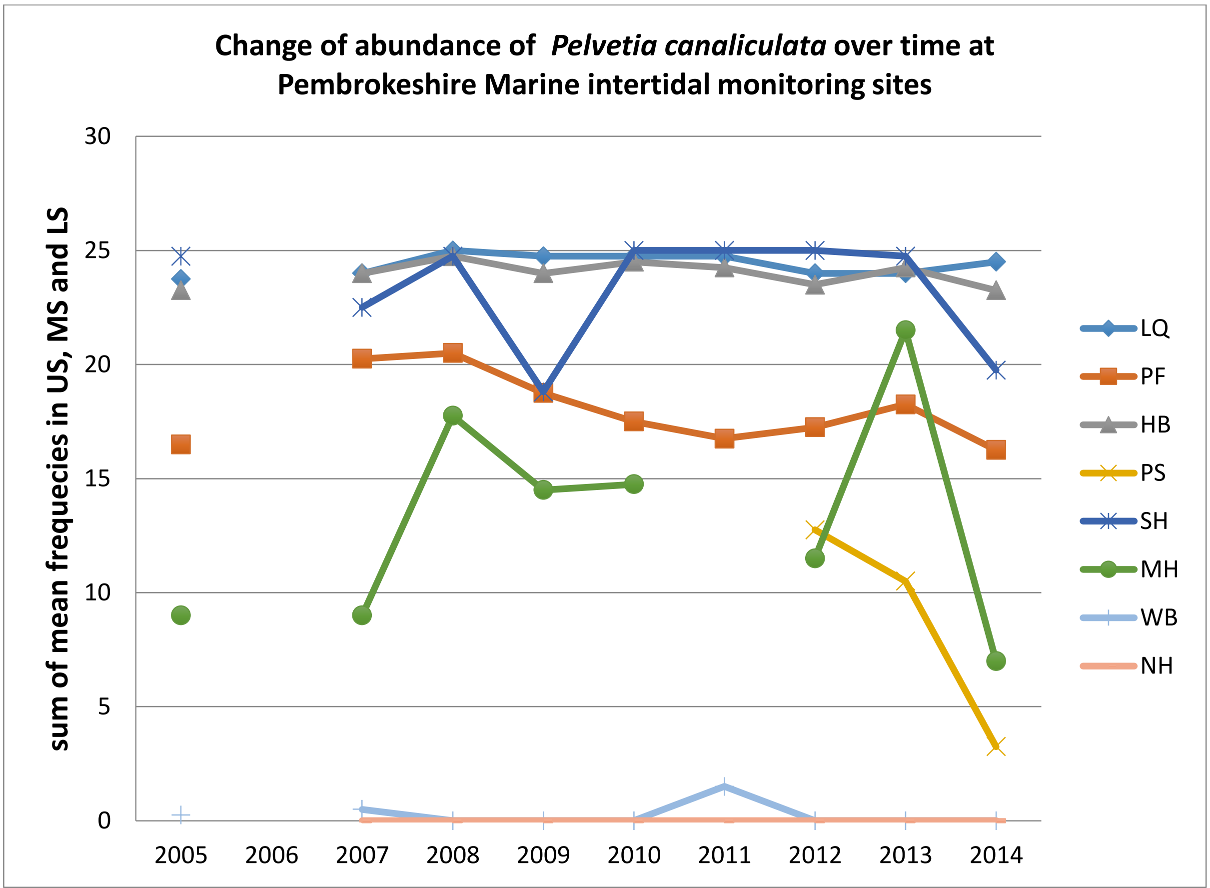

Figure 2 *Pelvetia canaliculata* abundance graph 2005 to 2014

Table 3 *Pelvetia canaliculata* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	23.75		24	25	24.75	24.75	24.75	24	24	24.5
PF	16.5		20.25	20.5	18.75	17.5	16.75	17.25	18.25	16.25
HB	23.25		24	24.75	24	24.5	24.25	23.5	24.25	23.25
PS								12.75	10.5	3.25
SH	24.75		22.5	24.75	18.8	25	25	25	24.75	19.75
MH	9		9	17.75	14.5	14.75		11.5	21.5	7
WB	0.25		0.5	0	0	0	1.5	0	0	0
NH			0	0	0	0	0	0	0	0

3.1.2. *Fucus spiralis*

The brown seaweed *Fucus spiralis* is most abundant at Pembroke Ferry but the abundance appears to vary a lot between years. At both Lawrenny Quay and Hazelbeach, a steady increase in abundance has been recorded over the years. There has also been an apparent increase in abundance at South Hook. See Figure 3 and Table 4.

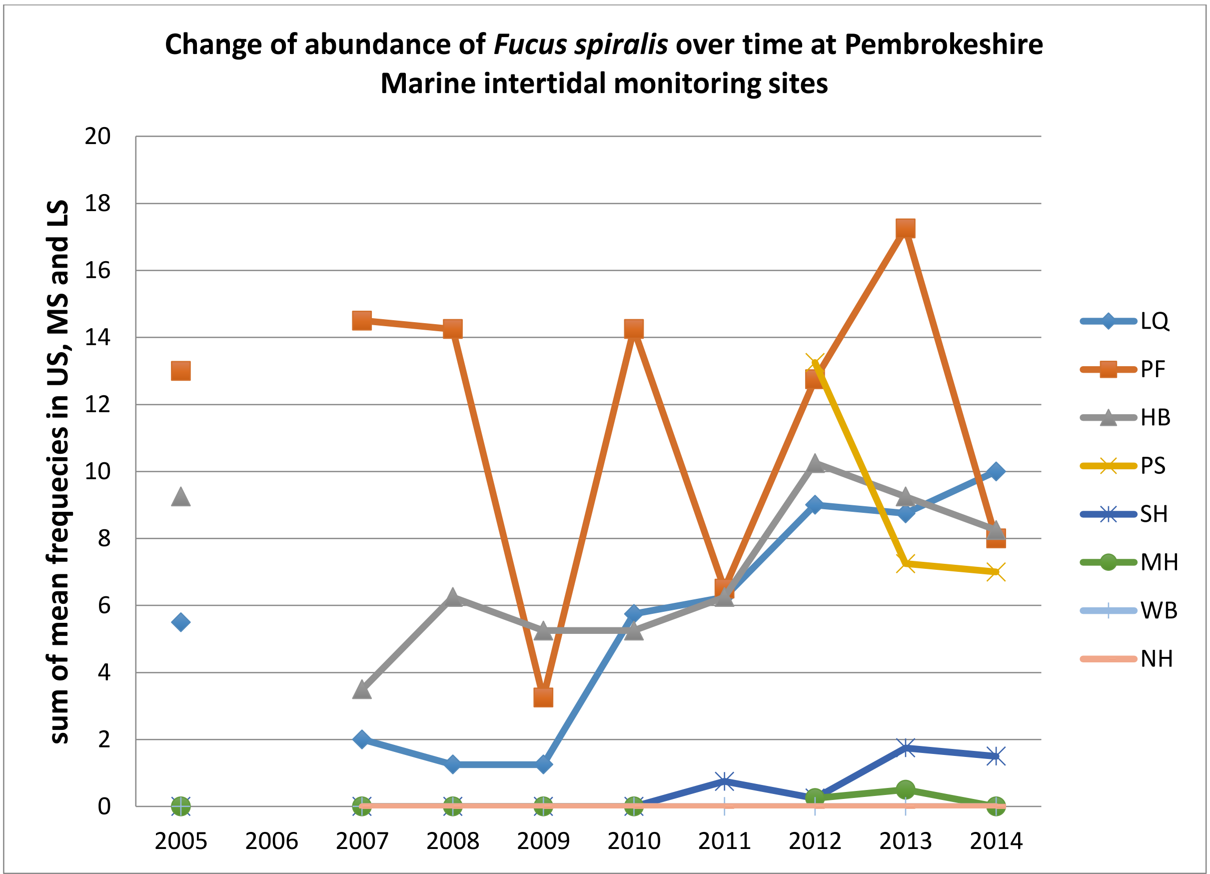

Figure 3 *Fucus spiralis* abundance graph 2005 to 2014

Table 4 *Fucus spiralis* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	5.5		2	1.25	1.25	5.75	6.25	9	8.75	10
PF	13		14.5	14.25	3.25	14.25	6.5	12.75	17.25	8
HB	9.25		3.5	6.25	5.25	5.25	6.25	10.25	9.25	8.25
PS								13.25	7.25	7
SH	0		0	0	0	0	0.75	0.25	1.75	1.5
MH	0		0	0	0	0		0.25	0.5	0
WB	0		0	0	0	0	0	0	0	0
NH			0	0	0	0	0	0	0	0

3.1.3. *Fucus vesiculosus*

The brown seaweed is found sporadically over the sites but is only present in significant quantity at Pembroke Ferry and Nolton Haven. At Nolton Haven it exists as the robust bladderless form known as *Fucus vesiculosus* var. *evesiculosus*. A decline in population followed by recovery can be seen at both sites. See Figure 1 and Table 5.

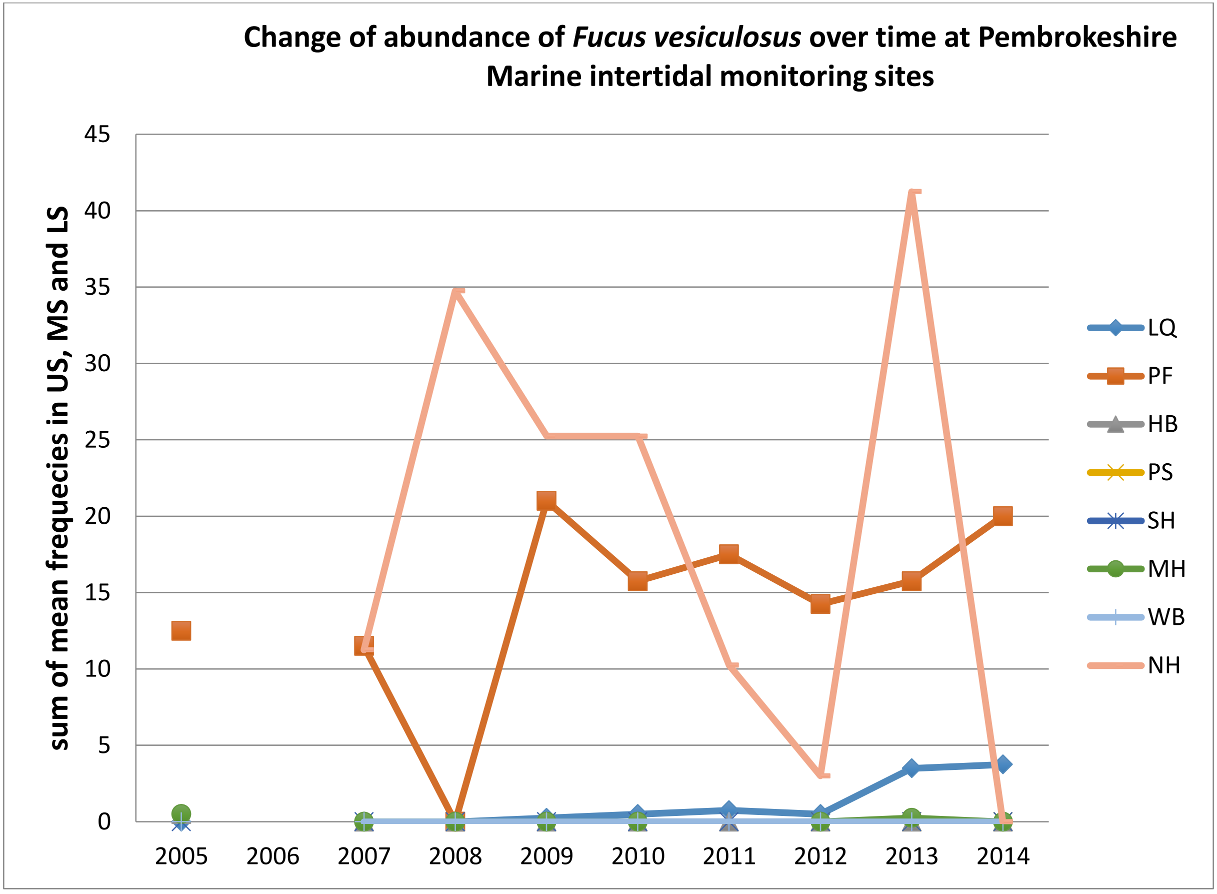

Figure 4 *Fucus vesiculosus* abundance graph 2005 to 2014

Table 5 *Fucus vesiculosus* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	0		0	0	0.25	0.5	0.75	0.5	3.5	3.75
PF	12.5		11.5	0	21	15.75	17.5	14.25	15.75	20
HB	0.5		0	0	0	0	0	0	0	0
PS								0	0	0
SH	0		0	0	0	0	0	0	0	0
MH	0.5		0	0	0	0		0	0.25	0
WB	0		0	0	0	0	0	0	0	0
NH			11.25	34.75	25.25	25.25	10.25	3	41.25	0

3.1.4. *Ascophyllum nodosum*

The brown seaweed *Ascophyllum nodosum* is only found in any significant quantity at Lawrenny Quay, where it dominates the middle shore. The graph in Figure 1Figure 5 indicates a decline since 2005. Other than Lawrenny Quay, the only other shores where *A. nodosum* occurs are Pembroke Ferry and Pembroke Power Station and it is at a fairly low frequency at both. See Figure 5 and Table 6.

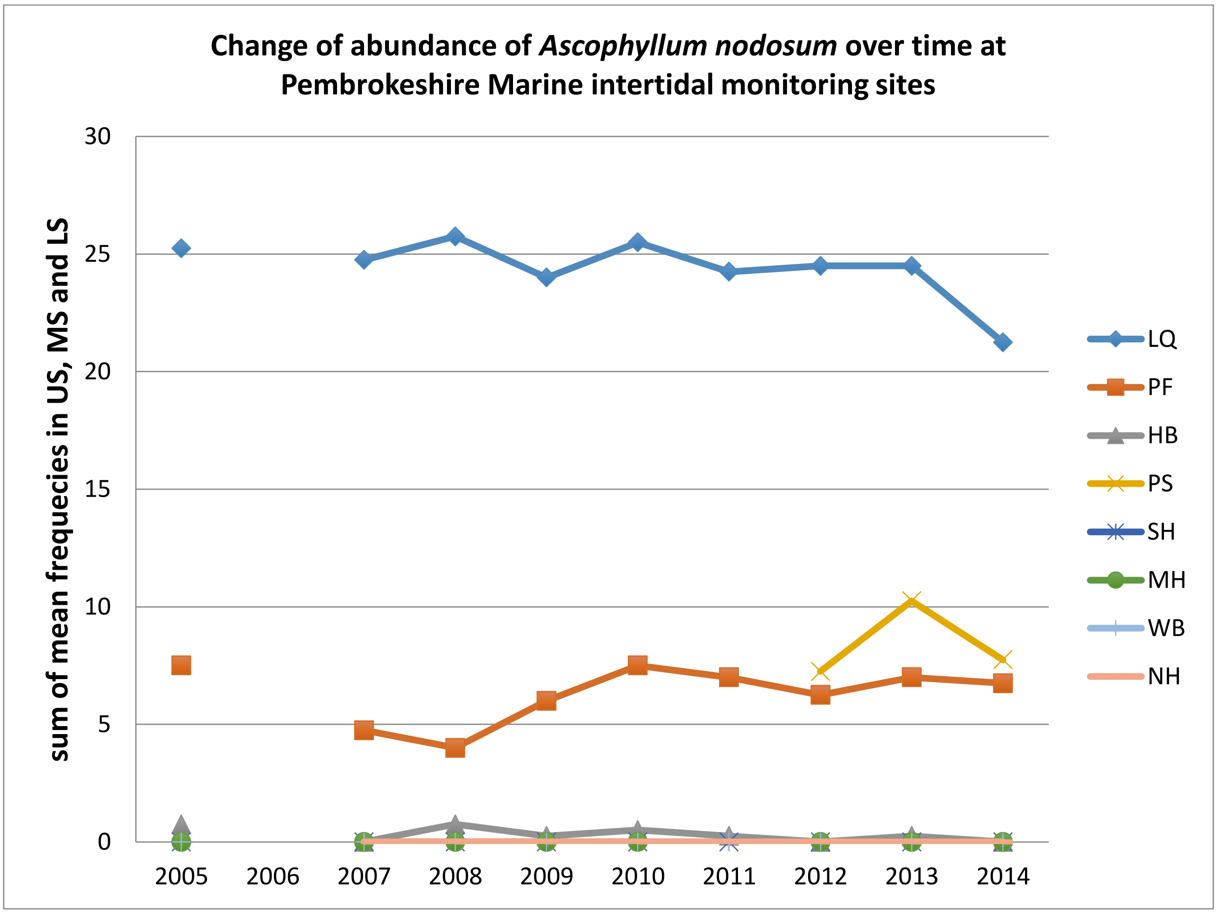

Figure 5 *Ascophyllum nodosum* abundance graph 2005 to 2014

Table 6 Ascophyllum nodosum average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	25.25		24.75	25.75	24	25.5	24.25	24.5	24.5	21.25
PF	7.5		4.75	4	6	7.5	7	6.25	7	6.75
HB	0.75		0	0.75	0.25	0.5	0.25	0	0.25	0
PS								7.25	10.25	7.75
SH	0		0	0	0	0	0	0	0	0
MH	0		0	0	0	0		0	0	0
WB	0		0	0	0	0	0	0	0	0
NH			0	0	0	0	0	0	0	0

3.1.5. *Fucus serratus*

The brown seaweed *Fucus serratus* exists mainly on the lower shore. It is fairly abundant at Lawrenny Quay and to a lesser extent at Pembroke Ferry but generally rare elsewhere. The results indicate a fluctuating population possibly showing a general increase in abundance at Lawrenny Quay, whereas the population at Pembroke Ferry shows a general decline. See Figure 6 and Table 7.

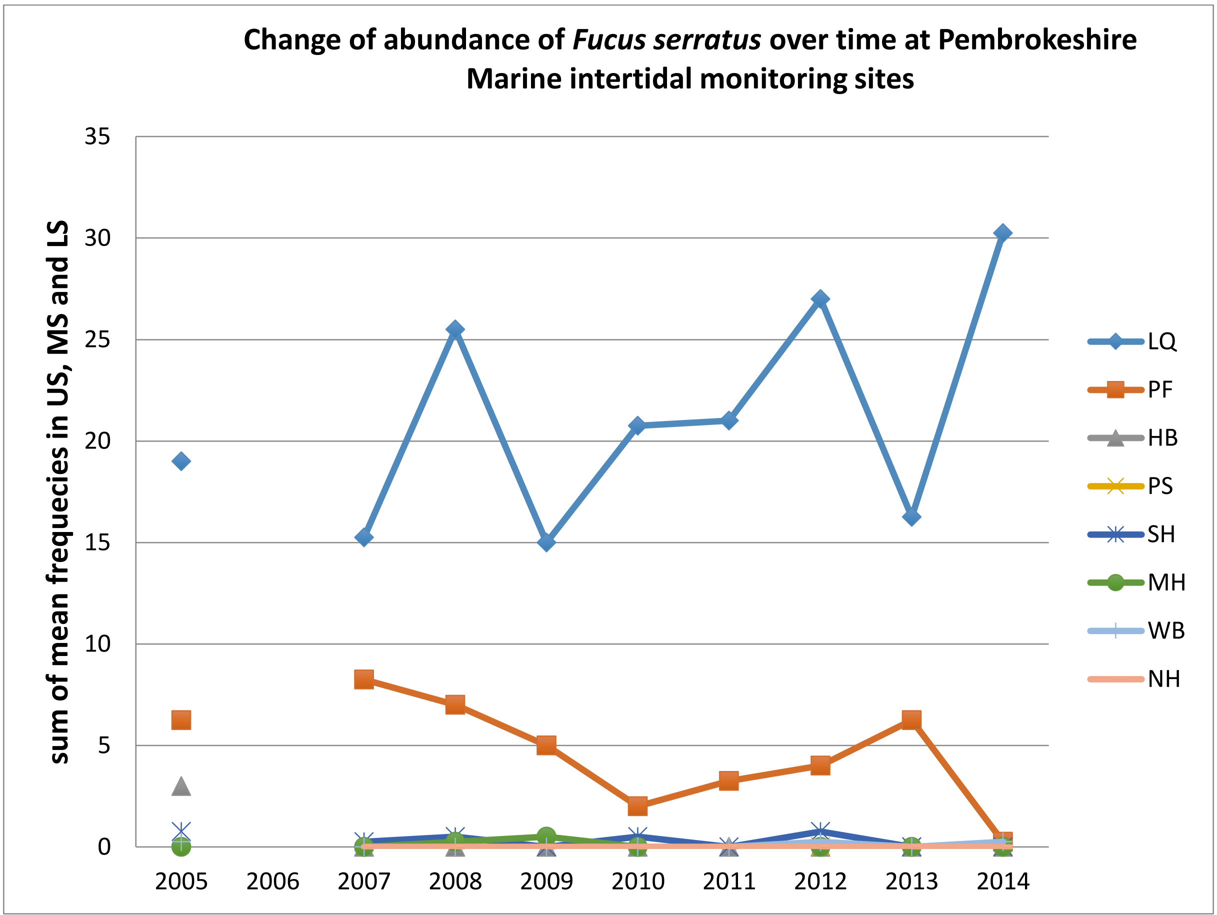

Figure 6 *Fucus serratus* abundance graph 2005 to 2014

Table 7 *Fucus serratus* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	19		15.25	25.5	15	20.75	21	27	16.25	30.25
PF	6.25		8.25	7	5	2	3.25	4	6.25	0.25
HB	3		0	0	0	0	0	0	0	0
PS								0	0	0
SH	0.75		0.25	0.5	0	0.5	0	0.75	0	0
MH	0		0	0.25	0.5	0		0	0	0
WB	0.25		0	0	0	0	0	0.25	0	0.25
NH			0	0	0	0	0	0	0	0

3.1.6. *Laminaria digitata*

The kelp *Laminaria digitata* is most abundant around the low spring tide mark and is therefore not abundant in the monitoring quadrats (which are generally positioned at the top of the lower shore). The only site where this species is relatively common is Lawrenny Quay that is until 2014, when no plants were found. See Figure 7 and Table 8.

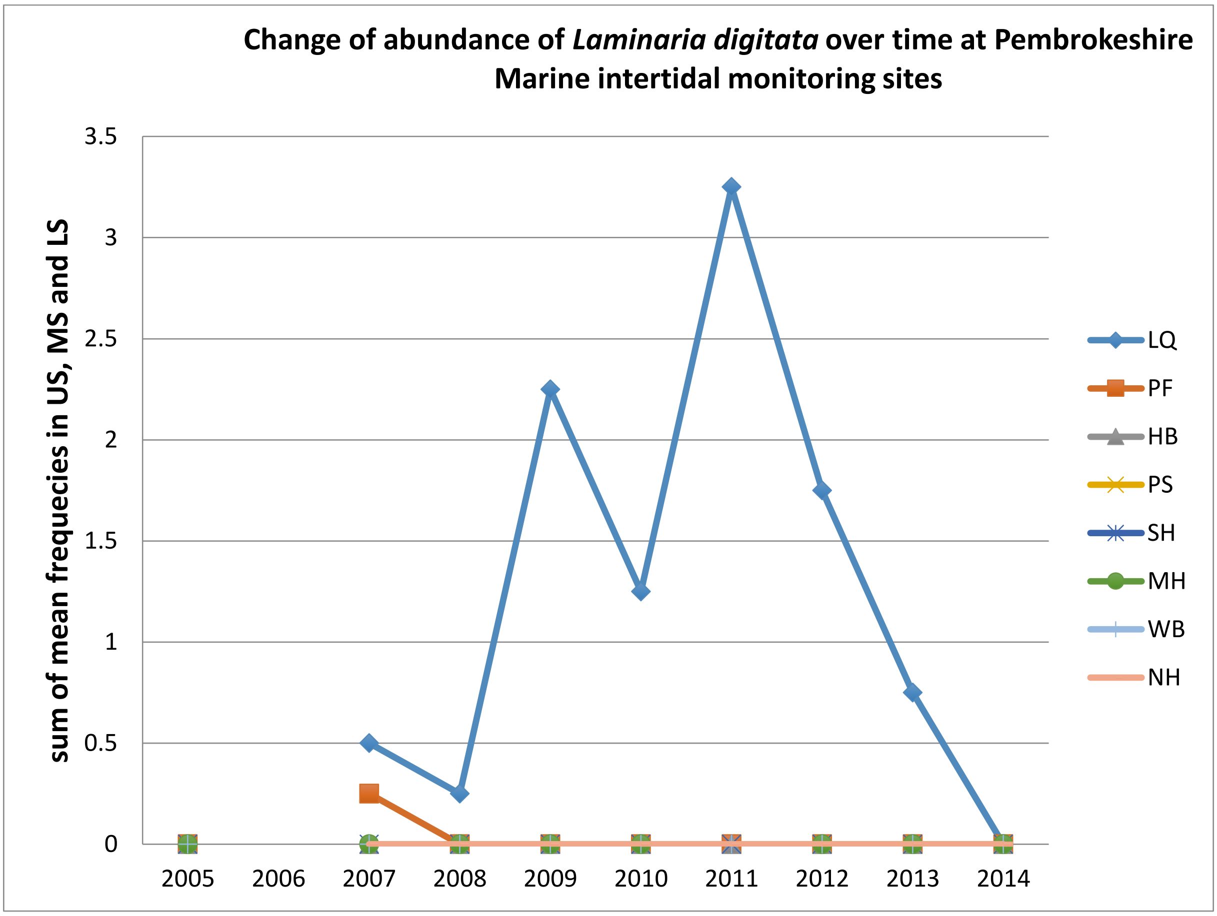

Figure 7 *Laminaria digitata* abundance graph 2005 to 2014

Table 8 *Laminaria digitata* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	0		0.5	0.25	2.25	1.25	3.25	1.75	0.75	0
PF	0		0.25	0	0	0	0	0	0	0
HB	0		0	0	0	0	0	0	0	0
PS								0	0	0
SH	0		0	0	0	0	0	0	0	0
MH	0		0	0	0	0		0	0	0
WB	0		0	0	0	0	0	0	0	0
NH			0	0	0	0	0	0	0	0

3.2. Red Seaweeds

3.2.1. *Bostrychia scorpioides*

The red seaweed *Bostrychia scorpioides* is found in the upper shore at sheltered sites in Milford Haven and occurs both at Lawrenny Quay and Pembroke Ferry. The populations appear to fluctuate at both sites. See Figure 8 and Table 9.

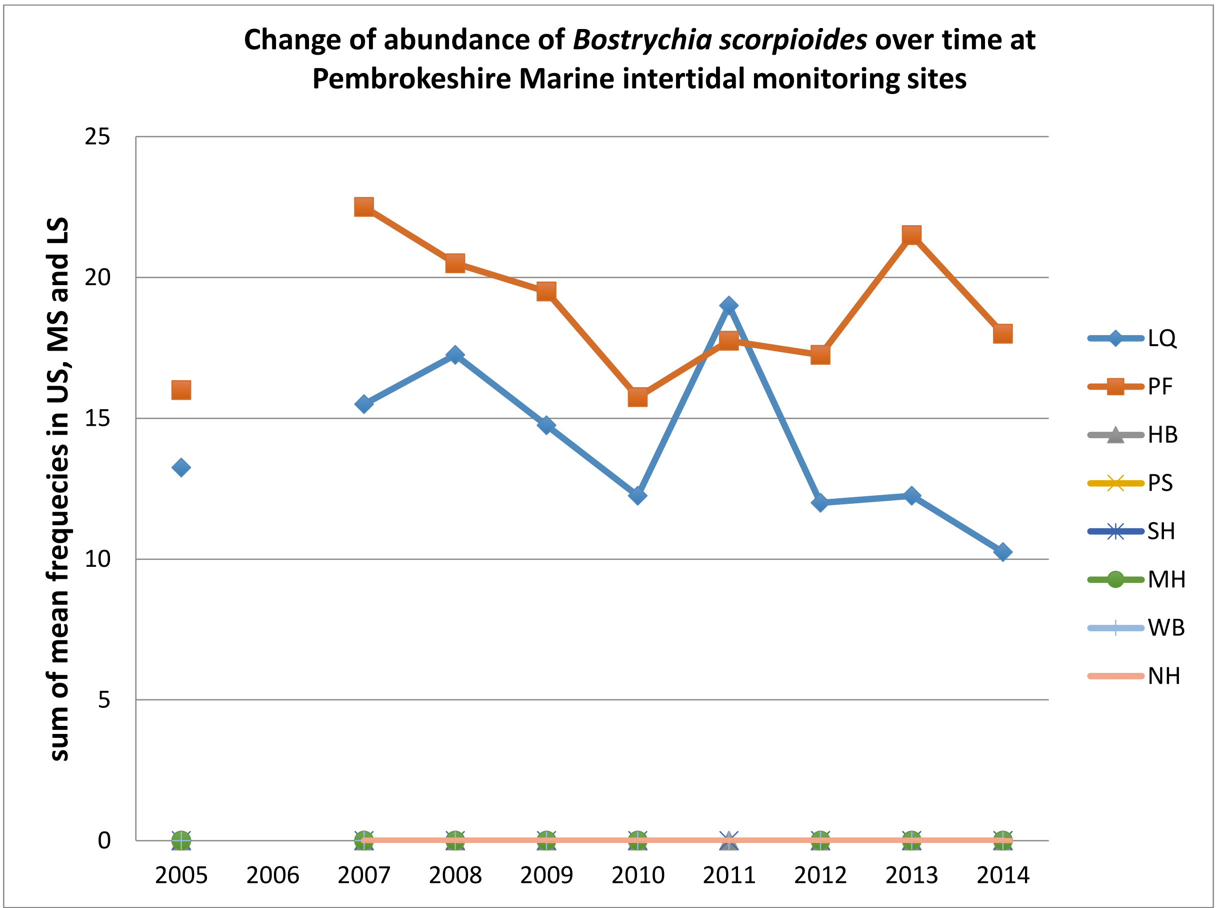

Figure 8 *Bostrychia scorpioides* abundance graph 2005 to 2014

Table 9 *Bostrychia scorpioides* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	13.25		15.5	17.25	14.75	12.25	19	12	12.25	10.25
PF	16		22.5	20.5	19.5	15.75	17.75	17.25	21.5	18
HB	0		0	0	0	0	0	0	0	0
PS								0	0	0
SH	0		0	0	0	0	0	0	0	0
MH	0		0	0	0	0		0	0	0
WB	0		0	0	0	0	0	0	0	0
NH			0	0	0	0	0	0	0	0

3.2.2. *Catenella caespitosa*

The red alga *Catenella caespitosa* favours sheltered, shaded situations and occurs mainly at Pembroke Ferry, Pembroke Power Station, Lawrenny Quay and Hazelbeach. Populations at Pembroke Ferry have remained fairly constant whereas at Lawrenny Quay and Hazelbeach the population appears to have declined around 2008 / 2009 and grown in size again since then. See Figure 9 and Table 10.

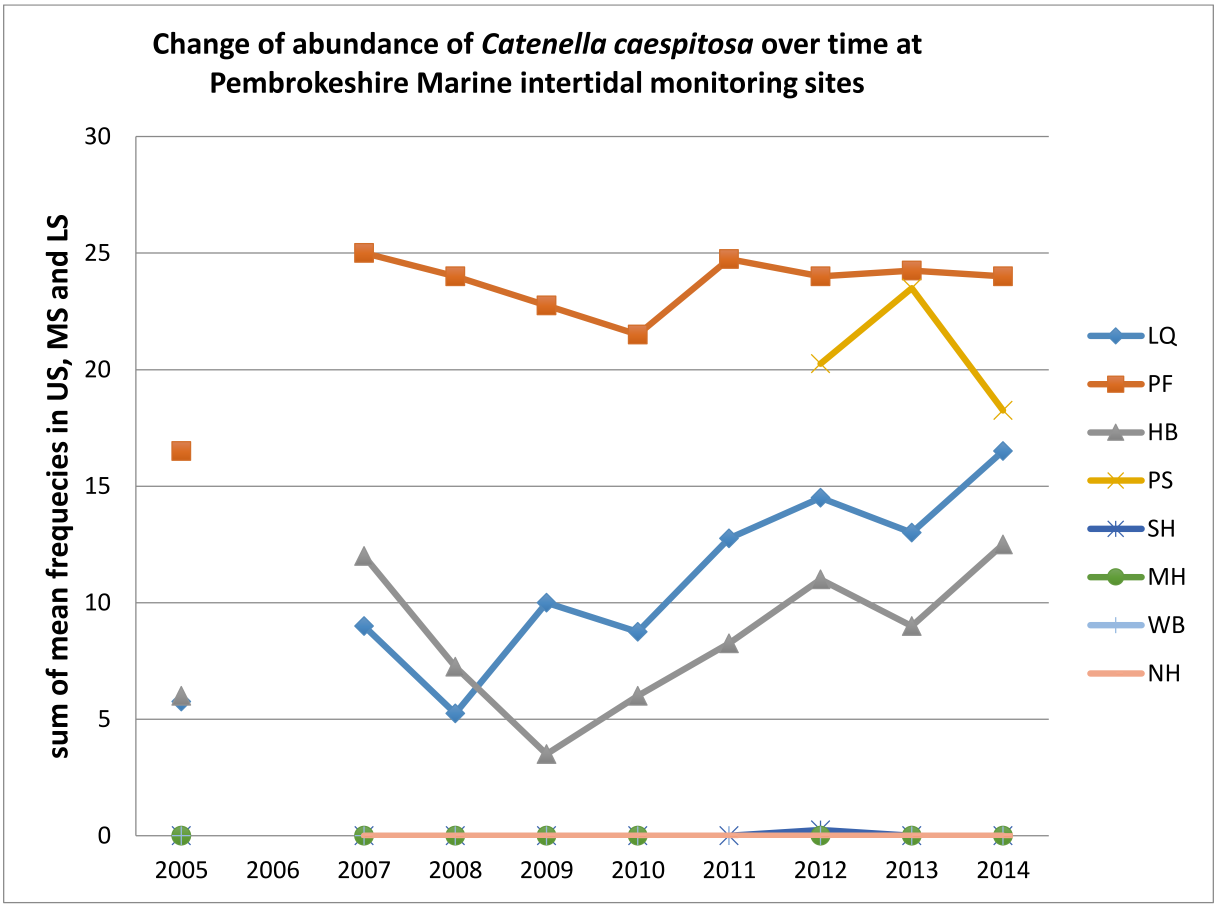

Figure 9 *Catenella caespitosa* abundance graph 2005 to 2014

Table 10 *Catenella caespitosa* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	5.75		9	5.25	10	8.75	12.75	14.5	13	16.5
PF	16.5		25	24	22.75	21.5	24.75	24	24.25	24
HB	6		12	7.25	3.5	6	8.25	11	9	12.5
PS								20.25	23.5	18.25
SH	0		0	0	0	0	0	0.25	0	0
MH	0		0	0	0	0		0	0	0
WB	0		0	0	0	0	0	0	0	0
NH			0	0	0	0	0	0	0	0

3.2.3. *Corallinaceae crusts*

Corallinaceae crusts include several species, but mainly comprise of common thin crustose species such as *Phymatolithon laevigatum, Phymatolithon lenormandii* and *Phymatolithon purpureum* and *Lithophyllum incrustans* (Irvine and Chamberlain, 1994). The species / genera cannot be reliably separated in the field and hence they are recorded under the family name Corallinaceae.

Encrusting coralline algae are recorded from all of the monitoring sites, with populations varying from year to year. See Figure 10 and Table 11.

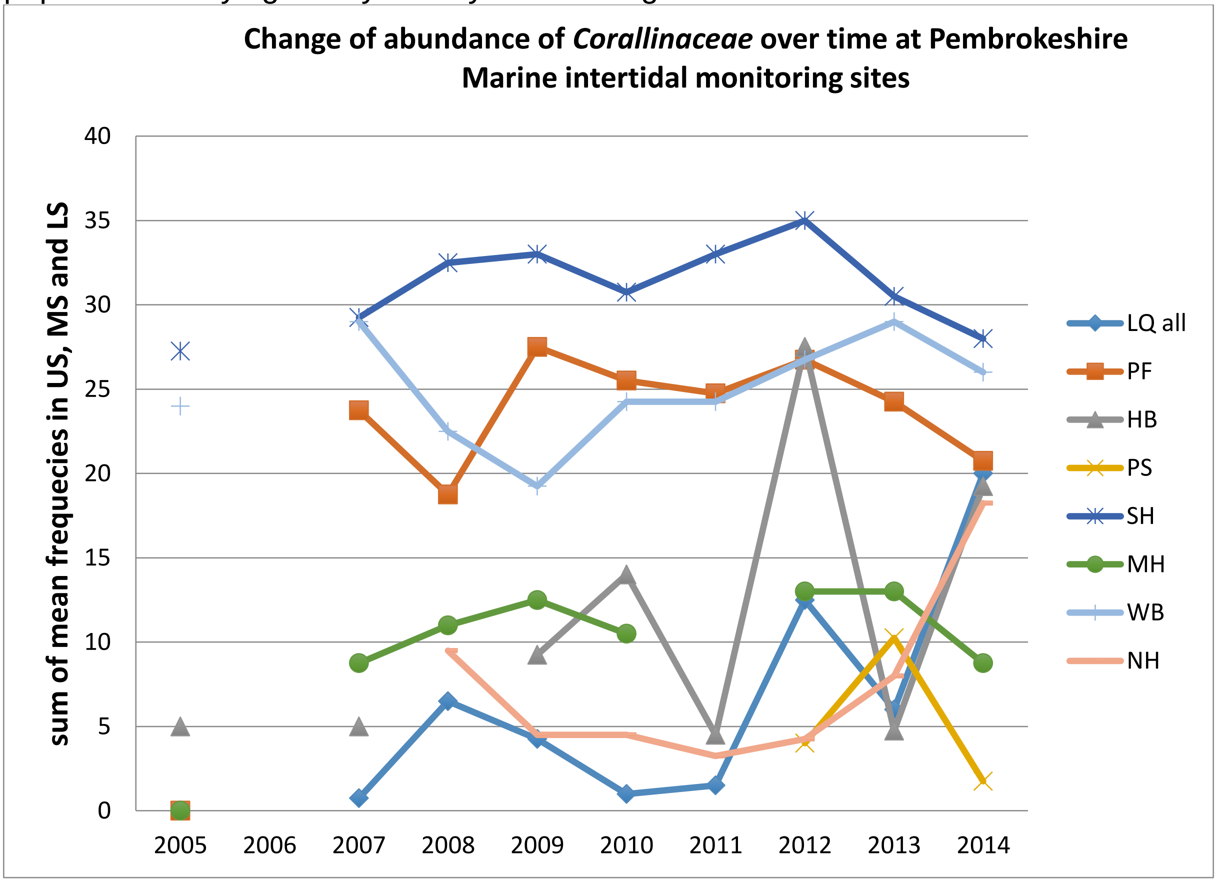

Figure 10 Corallinaceae crust abundance graph 2005 to 2014

Table 11 Corallinaceae crust average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ all	0		0.75	6.5	4.25	1	1.5	12.5	6	20
PF	0		23.75	18.75	27.5	25.5	24.75	26.75	24.25	20.75
HB	5		5		9.25	14	4.5	27.5	4.75	19.25
PS								4	10.25	1.75
SH	27.25		29.25	32.5	33	30.75	33	35	30.5	28
MH	0		8.75	11	12.5	10.5		13	13	8.75
WB	24		29	22.5	19.25	24.25	24.25	26.75	29	26
NH				9.5	4.5	4.5	3.25	4.25	8	18.25

3.2.4. *'Corallina' spp.*

There are three species found at the monitoring sites included under *'Corallina'* spp. and these include *Corallina officinalis*, *Corallina caespitosa* and *Elisolander elongata*. The species can be difficult to separate reliably in the field, especially when individual specimens are incompletely formed and hence they are recorded in a collective grouping. *Corallina officinalis* and *Corallina caespitosa* are the commonest species with *Elisolander elongata* being rarely recorded. '*Corallina*' spp are found at all monitoring sites, most commonly at West Angle Bay and at the more exposed sites. There have been no dramatic increases or decreases in the '*Corallina'* spp populations at the sites studied. See Figure 11 and Table 12.

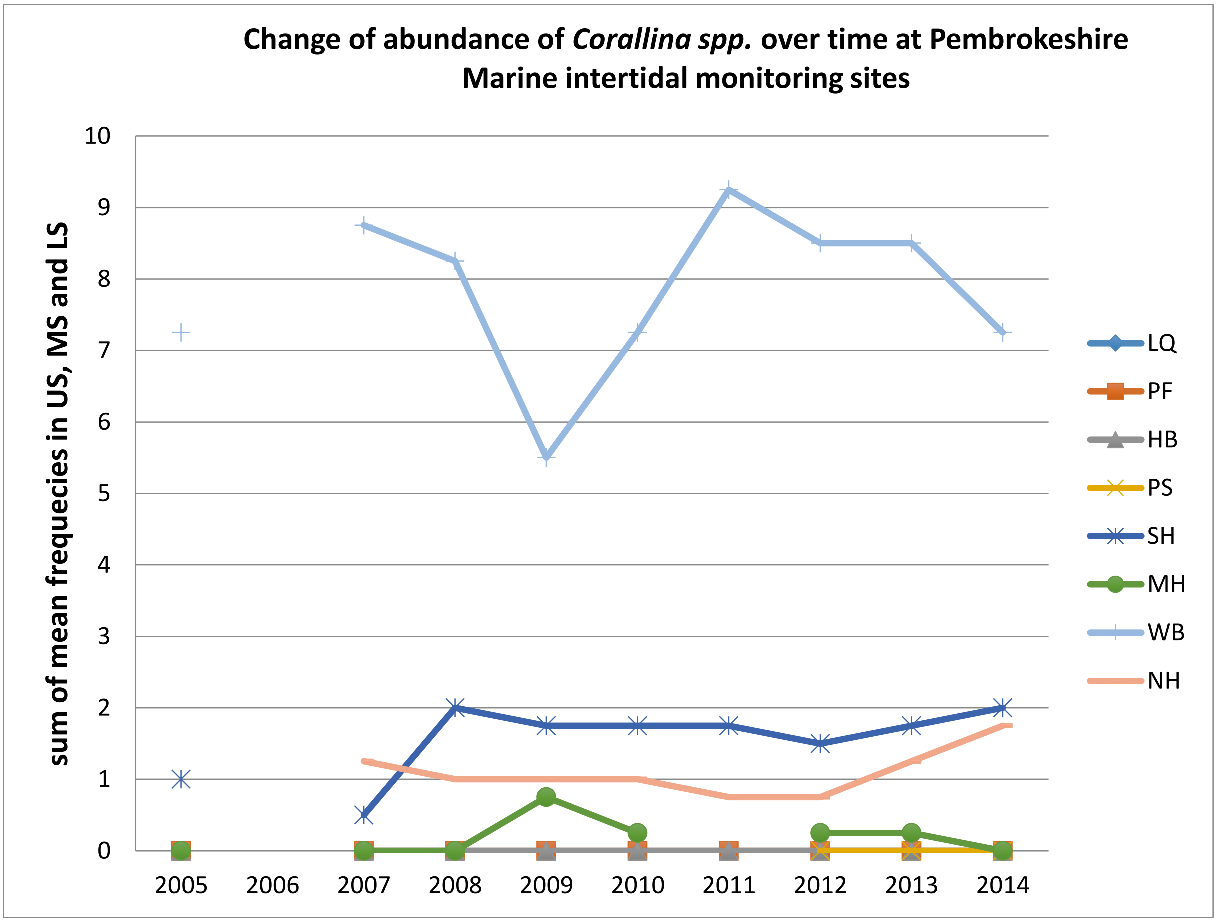

Figure 11 '*Corallina*' species abundance graph 2005 to 2014

Table 12 *'Corallina'* spp. average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	0		0	0	0	0	0	0	0	0
PF	0		0	0	0	0	0	0	0	0
HB	0		0	0	0	0	0	0	0	0
PS								0	0	0
SH	1		0.5	2	1.75	1.75	1.75	1.5	1.75	2
MH	0		0	0	0.75	0.25		0.25	0.25	0
WB	7.25		8.75	8.25	5.5	7.25	9.25	8.5	8.5	7.25
NH			1.25	1	1	1	0.75	0.75	1.25	1.75

3.2.5. *Chondrus crispus*

The red seaweed *Chondrus crispus* is most abundant in the monitoring quadrats on the lower shore at sheltered sites of Lawrenny Quay and Pembroke Ferry. There has been little variation in the population of this seaweed over the years. See Figure 12 and Table 13.

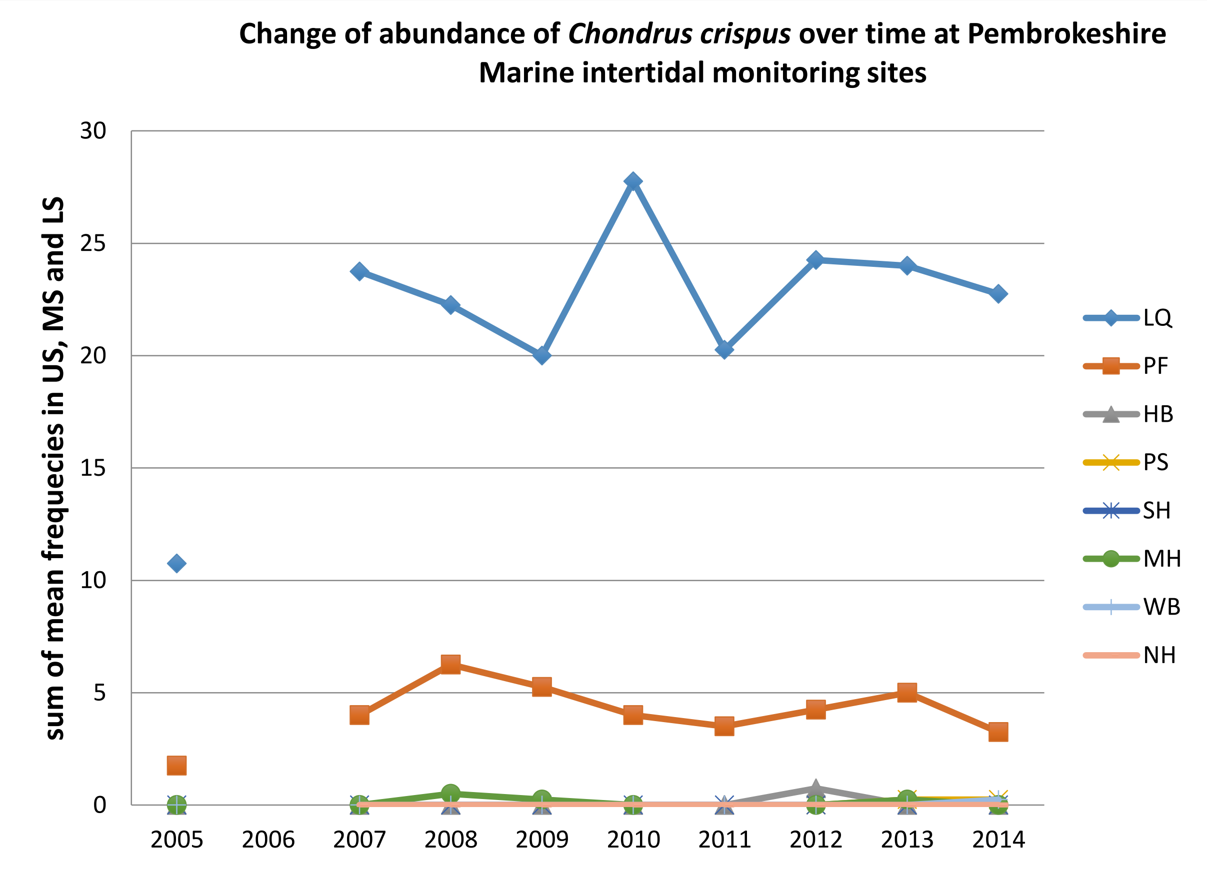

Figure 12 *Chondrus crispus* abundance graph 2005 to 2014

Table 13 *Chondrus crispus* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	10.75		23.75	22.25	20	27.75	20.25	24.25	24	22.75
PF	1.75		4	6.25	5.25	4	3.5	4.25	5	3.25
HB	0		0	0	0	0	0	0.75	0	0
PS								0	0.25	0.25
SH	0		0	0	0	0	0	0	0	0
MH	0		0	0.5	0.25	0		0	0.25	0
WB	0		0	0	0	0	0	0	0	0.25
NH			0	0	0	0	0	0	0	0

3.2.6. Mastocarpus stellatus

The abundance of the red seaweed *Mastocarpus stellatus* is greatest at the sheltered sites of Hazelbeach followed by Pembroke Ferry and Lawrenny Quay. The abundance is quite variable from year to year at Hazelbeach but less variable at the other sites. See Figure 1 and Table 14.

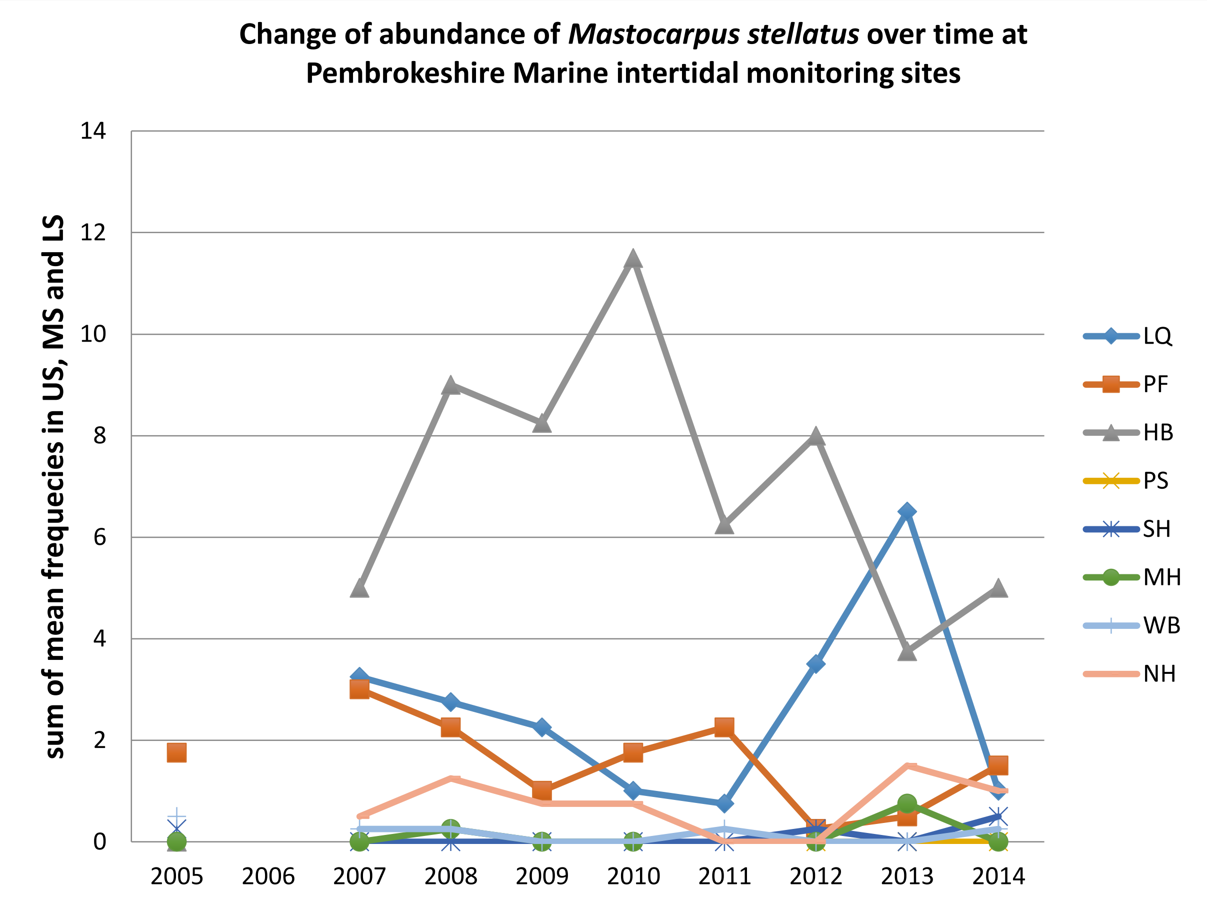

Figure 13 *Mastocarpus stellatus* abundance graph 2005 to 2014

Table 14 *Mastocarpus stellatus* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	0		3.25	2.75	2.25	1	0.75	3.5	6.5	1
PF	1.75		3	2.25	1	1.75	2.25	0.25	0.5	1.5
HB	0		5	9	8.25	11.5	6.25	8	3.75	5
PS								0	0	0
SH	0.25		0	0	0	0	0	0.25	0	0.5
MH	0		0	0.25	0	0		0	0.75	0
WB	0.5		0.25	0.25	0	0	0.25	0	0	0.25
NH			0.5	1.25	0.75	0.75	0	0	1.5	1

3.3. Porifera

There are several species of sponge present on the study shores but the most commonly encountered in the monitoring quadrats are *Hymeniacidon perlevis* and *Halichondria panacea.* Sponges are most commonly found at South Hook, Pembroke Ferry and Lawrenny Quay. At these sites the general trend is of a population rise over the years, falling slightly in 2014. See Figure 14 and Table 15.

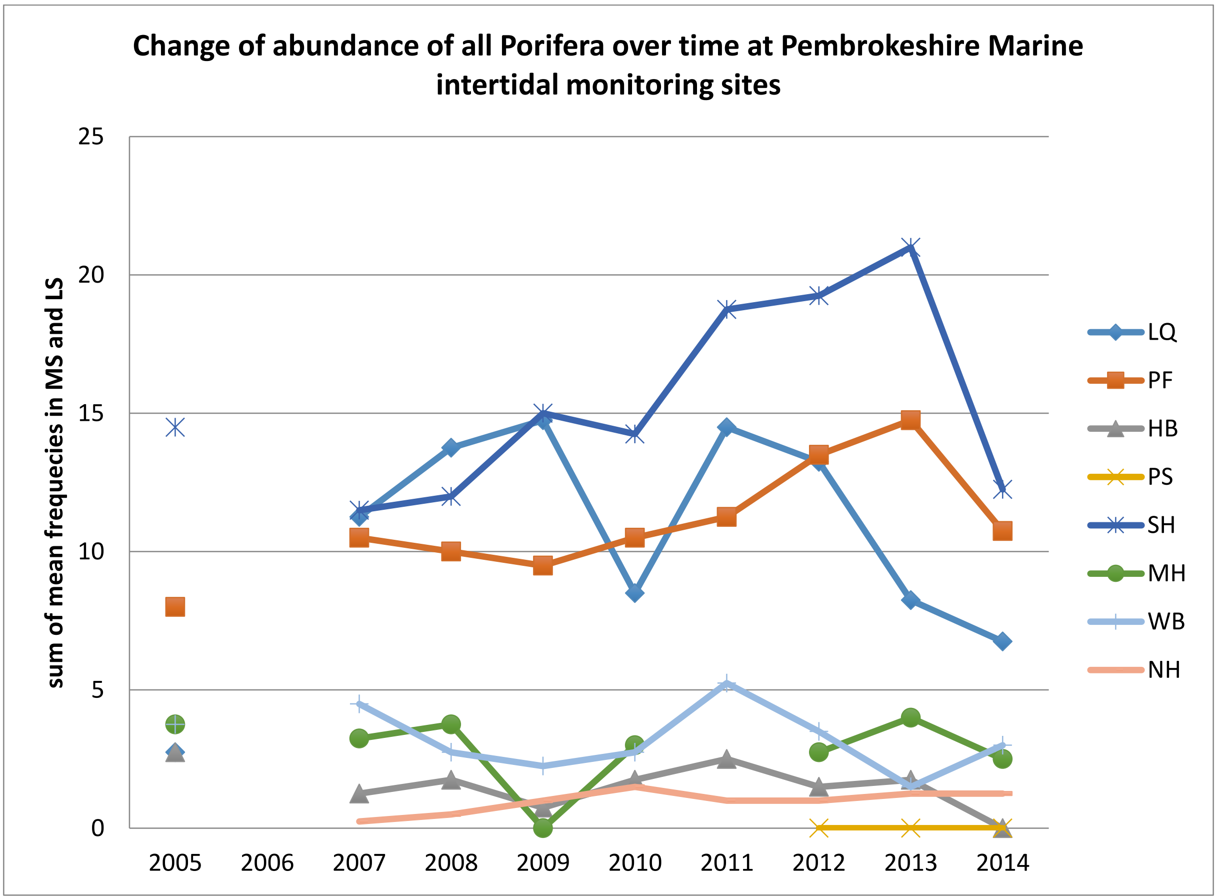

Figure 14 Porifera abundance graph 2005 to 2014

Table 15 Porifera average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	2.75		11.25	13.75	14.75	8.5	14.5	13.25	8.25	6.75
PF	8		10.5	10	9.5	10.5	11.25	13.5	14.75	10.75
HB	2.75		1.25	1.75	0.75	1.75	2.5	1.5	1.75	0
PS								0	0	0
SH	14.5		11.5	12	15	14.25	18.75	19.25	21	12.25
MH	3.75		3.25	3.75	0	3		2.75	4	2.5
WB	3.75		4.5	2.75	2.25	2.75	5.25	3.5	1.5	3
NH			0.25	0.5	1	1.5	1	1	1.25	1.25

3.4. Coelenterata

3.4.1. Hydrozoa

The commonest Hydrozoan occurring in the monitoring quadrats is *Dynamena pumila* but with *Clava multicornis* occurring at Lawrenny Quay. Both these species occur as epiphytes on large brown seaweeds. Although there are fluctuations in the abundance of Hydrozoa over time, the overall trend appears to be a decline over the time of this study. See Figure 15 and Table 16.

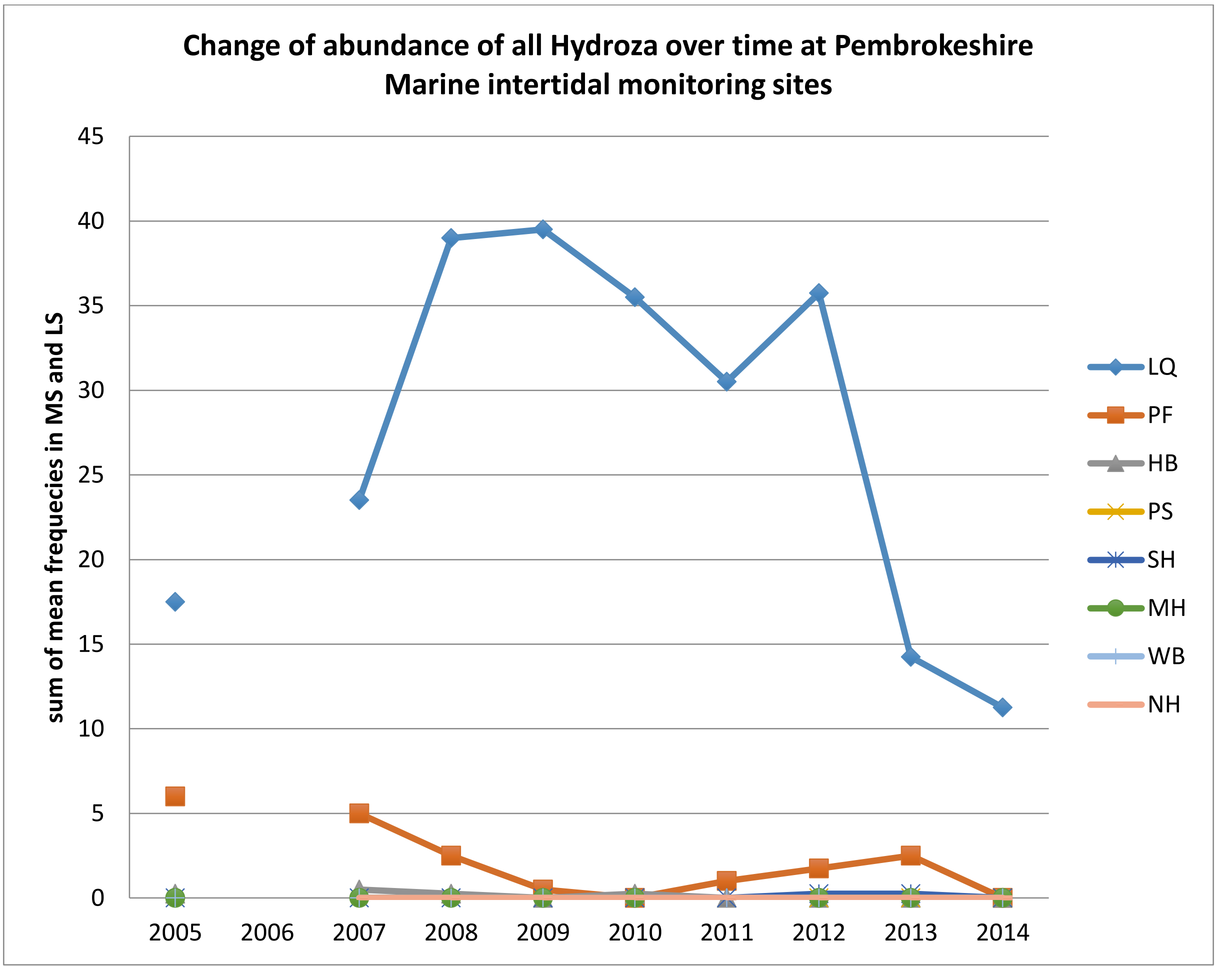

Figure 15 Hydrozoa abundance graph 2005 to 2014

Table 16 Hydrozoa average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	17.5		23.5	39	39.5	35.5	30.5	35.75	14.25	11.25
PF	6		5	2.5	0.5	0	1	1.75	2.5	0
HB	0.25		0.5	0.25	0	0.25	0	0	0	0
PS								0	0	0
SH	0		0	0	0	0	0	0.25	0.25	0
MH	0		0	0	0	0		0	0	0
WB	0		0	0	0	0	0	0	0	0
NH			0	0	0	0	0	0	0	0

3.4.2. Anthozoa

In this study the anthozoa encountered in the monitoring quadrats include *Actinia equina, Aulactinia verrucosa*, *Urticina felina*, *Cereus pedunculatus*, *Sagartia troglodytes* and *Diadumene lineata*. The commonest of these species being *A. equina*, with the exception of Pembroke Ferry where *Diadumene lineata* is the most abundant species.

The patterns of abundance over time varies between shores. At South Hook, there appears to have been a steady decline in abundance since the start of the monitoring in 2005. At Pembroke Ferry there is great variation in the abundance of Anthozoa over time. The other shores show Anthozoa in low abundance with little fluctuation over time. See Figure 16 and Table 17.

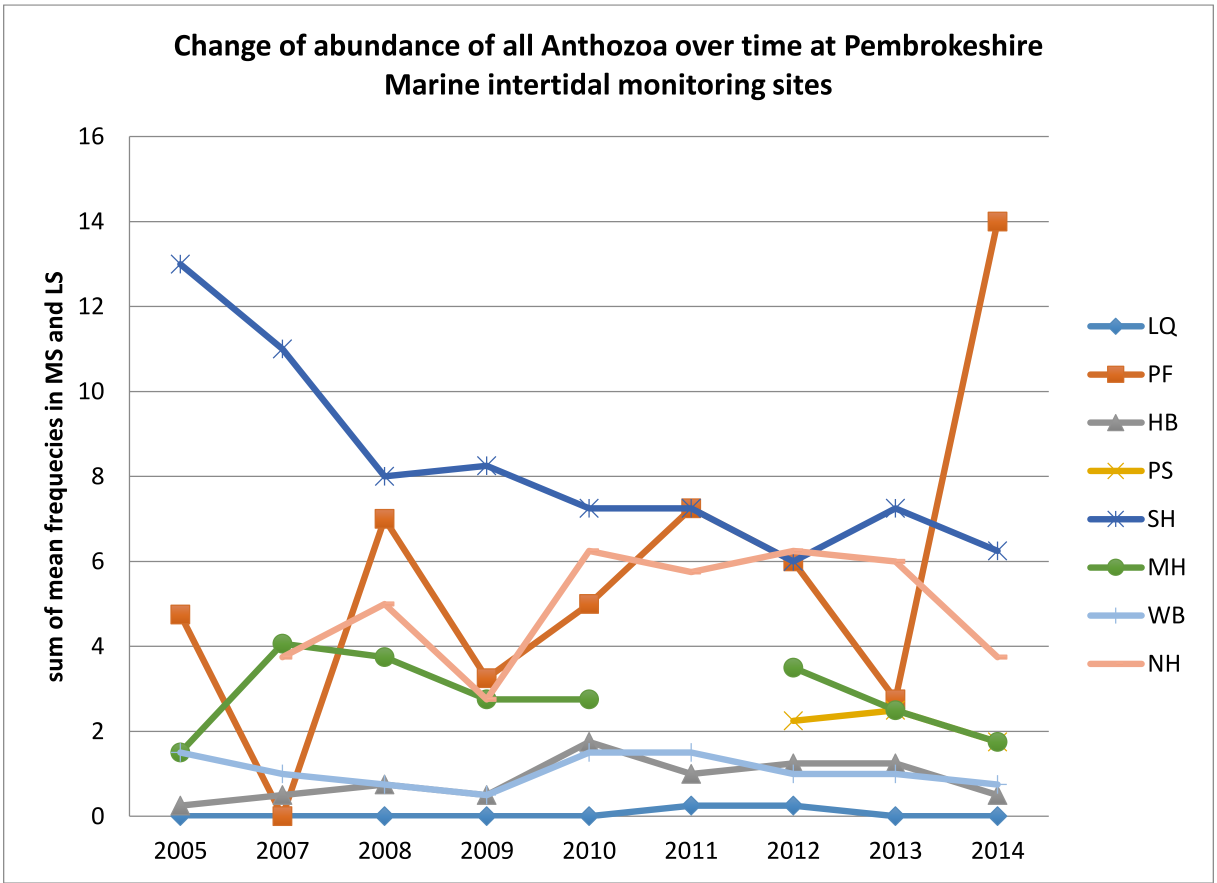

Figure 16 Anthozoa abundance graph 2005 to 2014

Table 17 Anthozoa average frequencies on the shore (US to LS) 2005 to 2014

	2005	2007	2008	2009	2010	2011	2012	2013	2014
LQ	0	0	0	0	0	0.25	0.25	0	0
PF	4.75	0	7	3.25	5	7.25	6	2.75	14
HB	0.25	0.5	0.75	0.5	1.75	1	1.25	1.25	0.5
PS							2.25	2.5	1.75
SH	13	11	8	8.25	7.25	7.25	6	7.25	6.25
MH	1.5	4.0625	3.75	2.75	2.75		3.5	2.5	1.75
WB	1.5	1	0.75	0.5	1.5	1.5	1	1	0.75
NH		3.75	5	2.75	6.25	5.75	6.25	6	3.75

3.5. Polychaeta

3.5.1. Spirorbinae

Several species of Spirorbinae occur on rocky shores, and field identification is problematical. All records here are grouped together under the family group Spirorbinae. According to Nelson-Smith and Gee (1966) the commonest species on Milford Haven shores are *Spirorbis spirorbis,* an epiphyte on fucoid seaweeds, and the rock dwelling *Spirorbis rupestris* and *Janua pagenstecheri. S. rupestris* grows on encrusting Corallinaceae covered rocks, mainly in the lower intertidal.
J. pagenstecheri penetrates high up the Daugleddau, living on stones, in crevices and under rocky overhangs from the lower shore to mean tide level. Spirorbinae are most abundant at Lawrenny Quay, Pembroke Ferry and South Hook and the year to year abundance is rather erratic. There are possible indications of an overall decline in abundance of at Lawrenny Quay and Pembroke Ferry. See Figure 17 and Table 18.

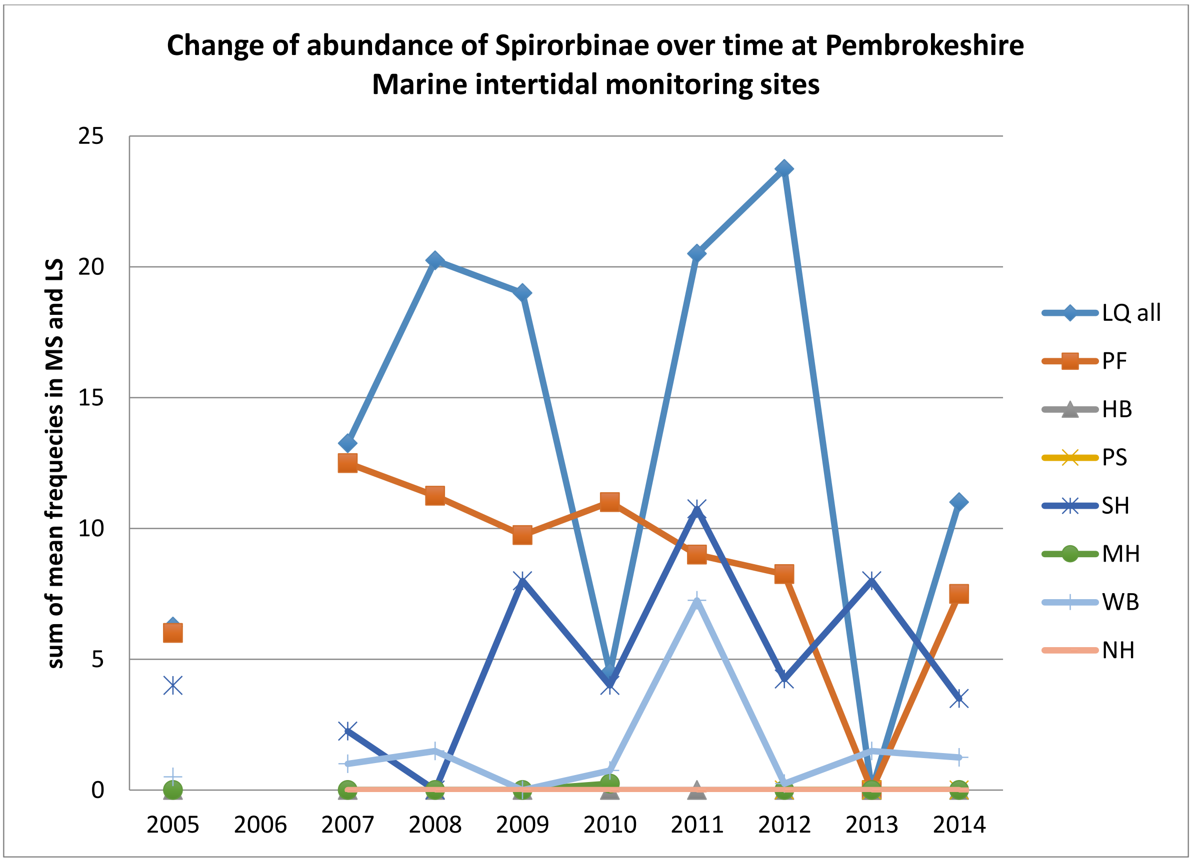

Figure 17 Spirorbinae abundance graph 2005 to 2014

Table 18 Spirorbinae average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ all	6.25		13.25	20.25	19	4.5	20.5	23.75	0	11
PF	6		12.5	11.25	9.75	11	9	8.25	0	7.5
HB	0		0	0	0	0	0	0	0	0
PS								0	0	0
SH	4		2.25	0	8	4	10.75	4.25	8	3.5
MH	0		0	0	0	0.25		0	0	0
WB	0.5		1	1.5	0	0.75	7.25	0.25	1.5	1.25
NH			0	0	0	0	0	0	0	0

3.6. Mollusca

3.6.1. *Mytilus edulis*

The mussel *Mytilus edulis* has been recorded in the quadrats on all shores studied. The largest populations were encountered at the most exposed site at Nolton Haven but this has varied considerably over time. At all sites there seems to have been a general decline in the population with few records in 2014. See Figure 18 and Figure 19.

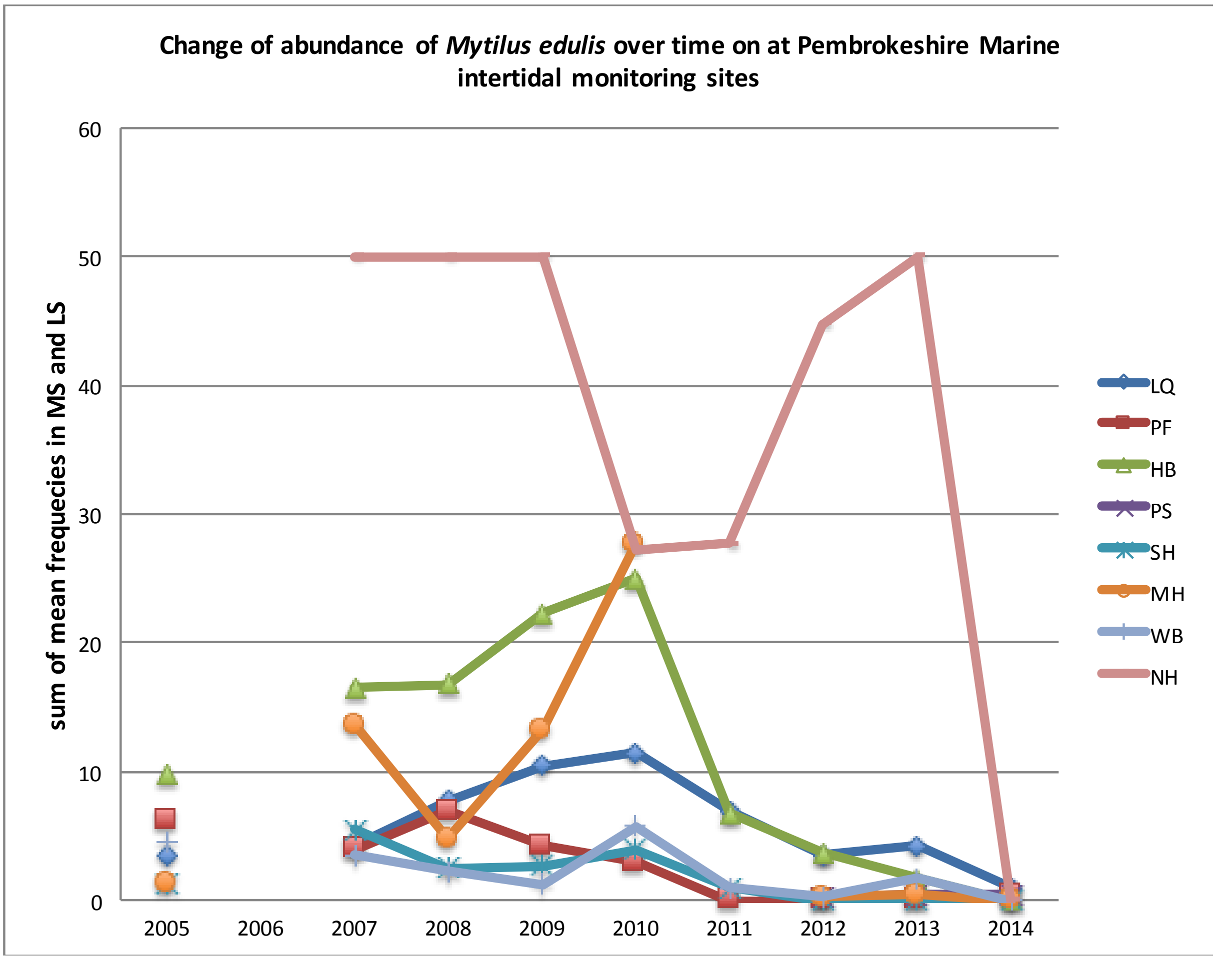

Figure 18 *Mytilus edulis* abundance graph 2005 to 2014

Table 19 *Mytilus edulis* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	3.5		4.25	7.75	10.5	11.5	7	3.5	4.25	1
PF	6.25		4	7	4.25	3	0	0	0	0.5
HB	9.75		16.5	16.75	22.25	25	6.75	3.75	1.75	0
PS								0.25	0.5	0.5
SH	1.25		5.5	2.5	2.75	4	1	0	0	0
MH	1.25		13.625	4.75	13.25	27.75		0.25	0.5	0
WB	4.5		3.5	2.25	1.25	5.75	1	0.25	1.75	0
NH			50	50	50	27.25	27.75	44.75	50	0

3.6.2. *Small gastropods in crevices*

The group of molluscs referred to as ‘small gastropods in crevices’ is comprised mainly of *Littorina saxatilis* with *Melarhaphe neritoides* also occurring in the upper and middle shore (rarely the lower shore) at the more exposed sites. Other small gastropods (such as juvenile *Littorina compressa, Littorina obtusata* or *Littorina fabalis* and *Lacuna pallidula*) may also occur. Counting each species reliably in the field is difficult and so this ‘catch all’ group is recorded. (The presence of the species in each quadrat is recorded but without a frequency). Small gastropods in crevices occur on all the shores studied and are most numerous on the more exposed shores. The abundance of these molluscs fluctuates from year to year but not wildly.

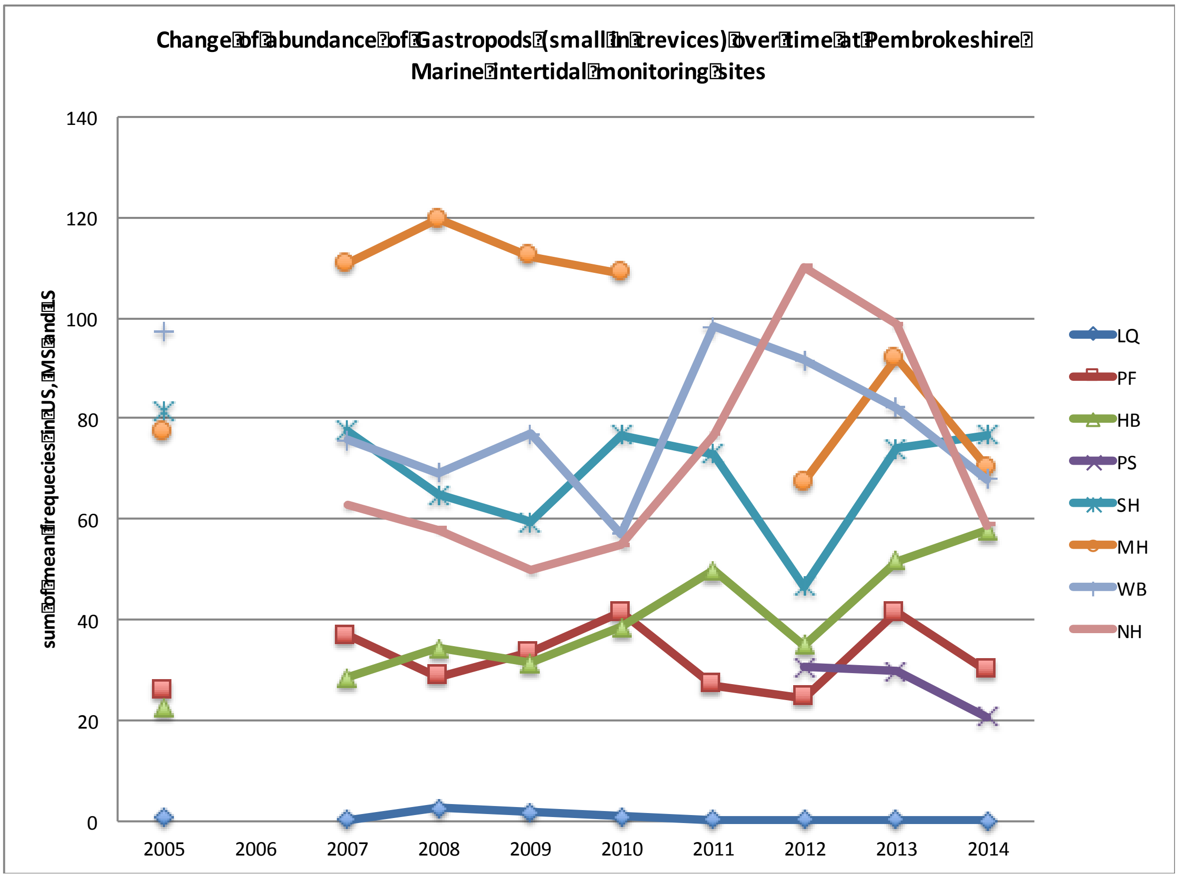

Figure 19 Gastropods in small crevices abundance graph 2005 to 2014

Table 20 Gastropods in small crevices average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	0.75		0.25	2.5	1.75	1	0.25	0.25	0.25	0
PF	25.75		36.75	28.75	33.5	41.5	27	24.5	41.5	30
HB	22.5		28.5	34.25	31.5	38.5	49.75	35	51.75	57.75
PS								30.5	29.75	20.75
SH	81.5		77.5	64.75	59.3	76.75	73	46.75	74	76.75
MH	77.25		110.75	119.5	112.25	109		67.25	92	70.25
WB	97.5		75.75	69.25	77	57	98.25	91.5	82.25	68
NH			62.75	58	49.75	54.75	76.75	110.25	98.75	58.75

3.6.3. *Littorina obtusata / fabalis*

The two species of 'flat periwinkle', *Littorina obtusata* and *Littorina fabalis* (previously *Littorina mariae*) are grouped together in this study due to identification difficulties in some field situations.

These species live primarily on large fucoid seaweeds and so are more common on sheltered shores than exposed. The numbers recorded can be seen to fluctuate from year to year but with no particular rise or decline.

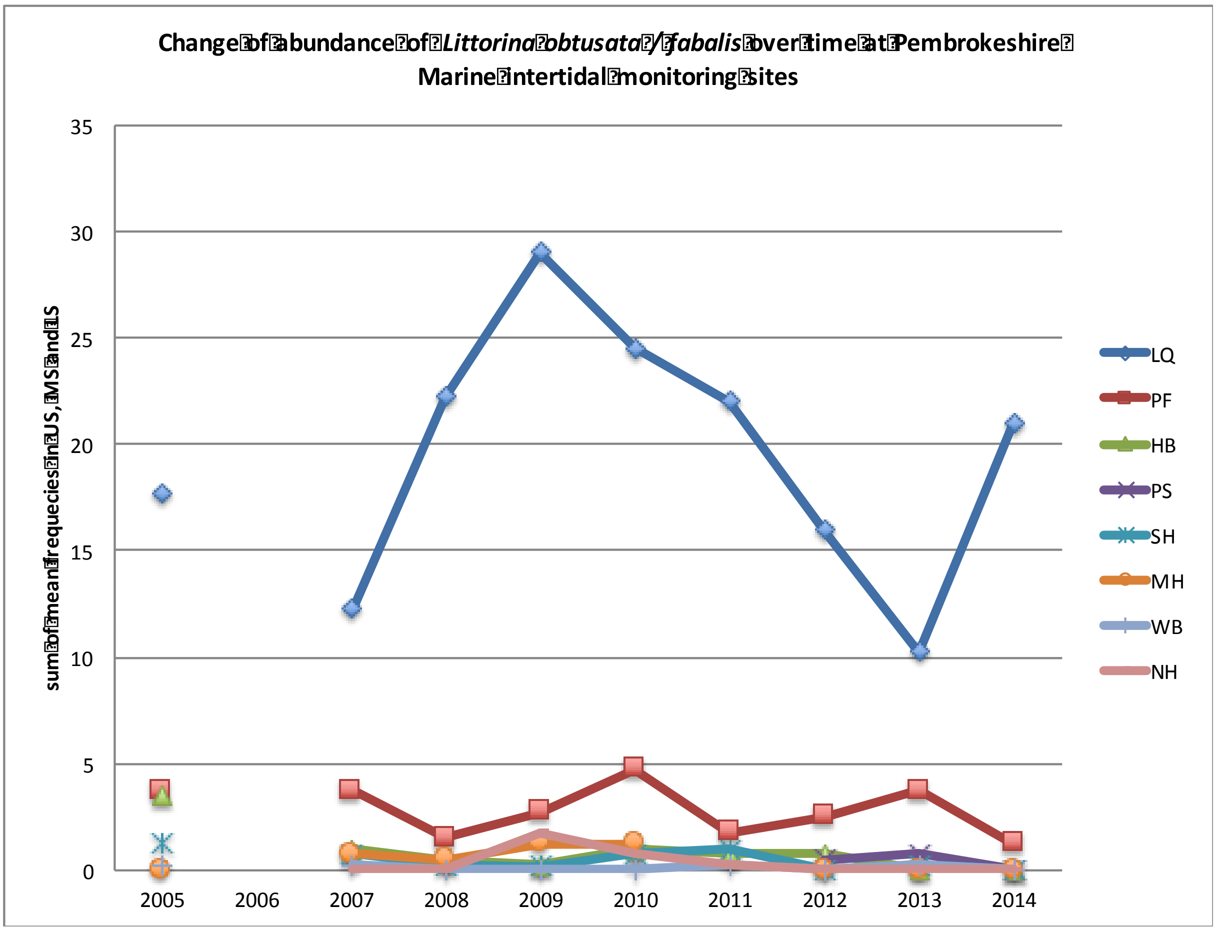

Figure 20 *Littorina obtusata / fabalis* abundance graph 2005 to 2014

Table 21 *Littorina obtusata / fabalis* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	17.75		12.25	22.25	29	24.5	22	16	10.25	21
PF	3.75		3.75	1.5	2.75	4.75	1.75	2.5	3.75	1.25
HB	3.5		1	0.5	0.25	1	0.75	0.75	0	0
PS								0.5	0.75	0
SH	1.25		0.75	0.25	0.2	0.75	1	0	0.25	0
MH	0		0.75	0.5	1.25	1.25		0	0	0
WB	0.25		0.25	0	0	0	0.25	0	0.25	0
NH			0	0	1.75	0.75	0.25	0	0	0

3.6.4. *Crepidula fornicata*

The slipper limpet *Crepidula fornicata* is encountered most commonly in the monitoring quadrats at Hazelbeach on the lower shore cobbles. Here there appears to have been a rise in abundance over the course of this study.

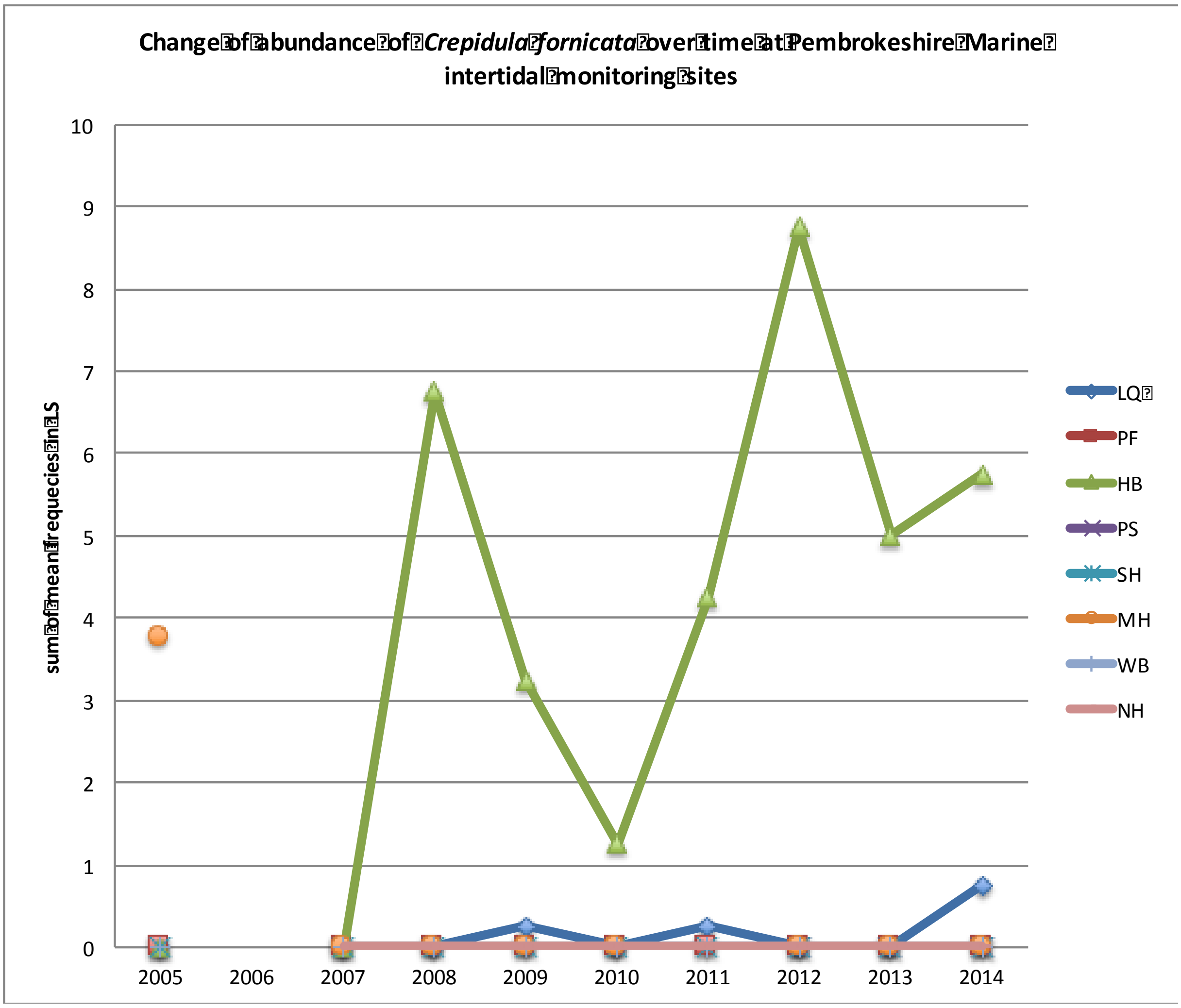

Figure 21 *Crepidula fornicata* abundance graph 2005 to 2014

Table 22 *Crepidula fornicata* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	0		0	0	0.25	0	0.25	0	0	0.75
PF	0		0	0	0	0	0	0	0	0
HB	0		0	6.75	3.25	1.25	4.25	8.75	5	5.75
PS								0	0	0
SH	0		0	0	0	0	0	0	0	0
MH	3.75		0	0	0	0		0	0	0
WB	0		0	0	0	0	0	0	0	0
NH			0	0	0	0	0	0	0	0

3.6.5. *Littorina littorea*

The edible periwinkle *Littorina littorea* is found most commonly at the heavily grazed sheltered sites of Hazelbeach and Pembroke Power Station. Numbers of this species have fluctuated from year to year on all shores but there has been no overall decline or rise in the populations.

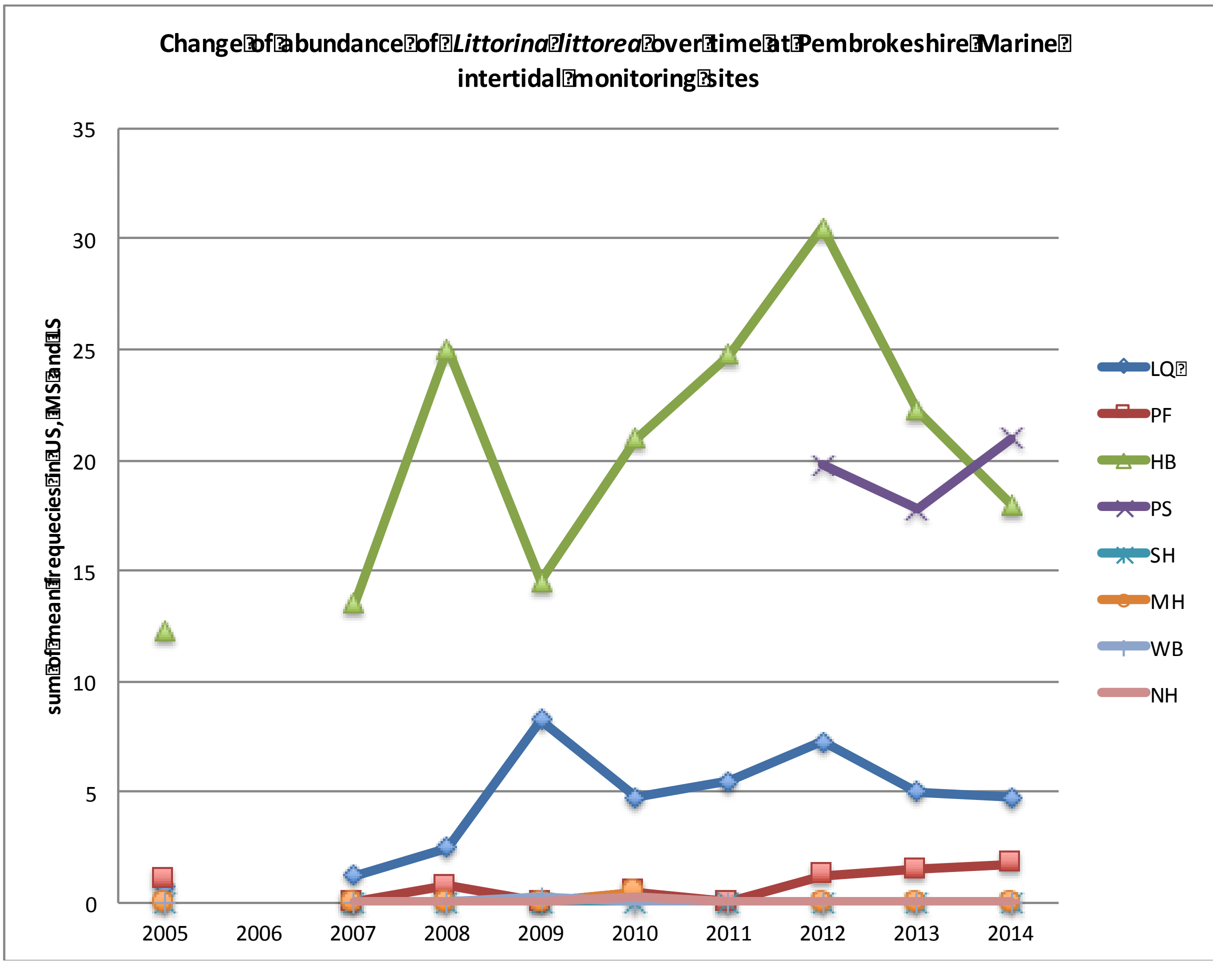

Figure 22 *Littorina littorea* abundance graph 2005 to 2014

Table 23 *Littorina littorea* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	0.75		1.25	2.5	8.25	4.75	5.5	7.25	5	4.75
PF	1		0	0.75	0	0.5	0	1.25	1.5	1.75
HB	12.25		13.5	25	14.5	21	24.75	30.5	22.25	18
PS								19.75	17.75	21
SH	0		0	0	0	0	0	0	0	0
MH	0		0	0	0	0.5		0	0	0
WB	0		0	0	0.25	0	0	0	0	0
NH			0	0	0	0.25	0	0	0	0

3.6.6. *Nucella lapillus*

The dogwhelk *Nucella lapillus* can be found on all shores but is most abundant at Nolton Haven, South Hook and West Angle Bay. Numbers fluctuate from year to year in the monitoring quadrats and there is no evidence of an overall rise or decline of this mobile gastropod at any of the sites.

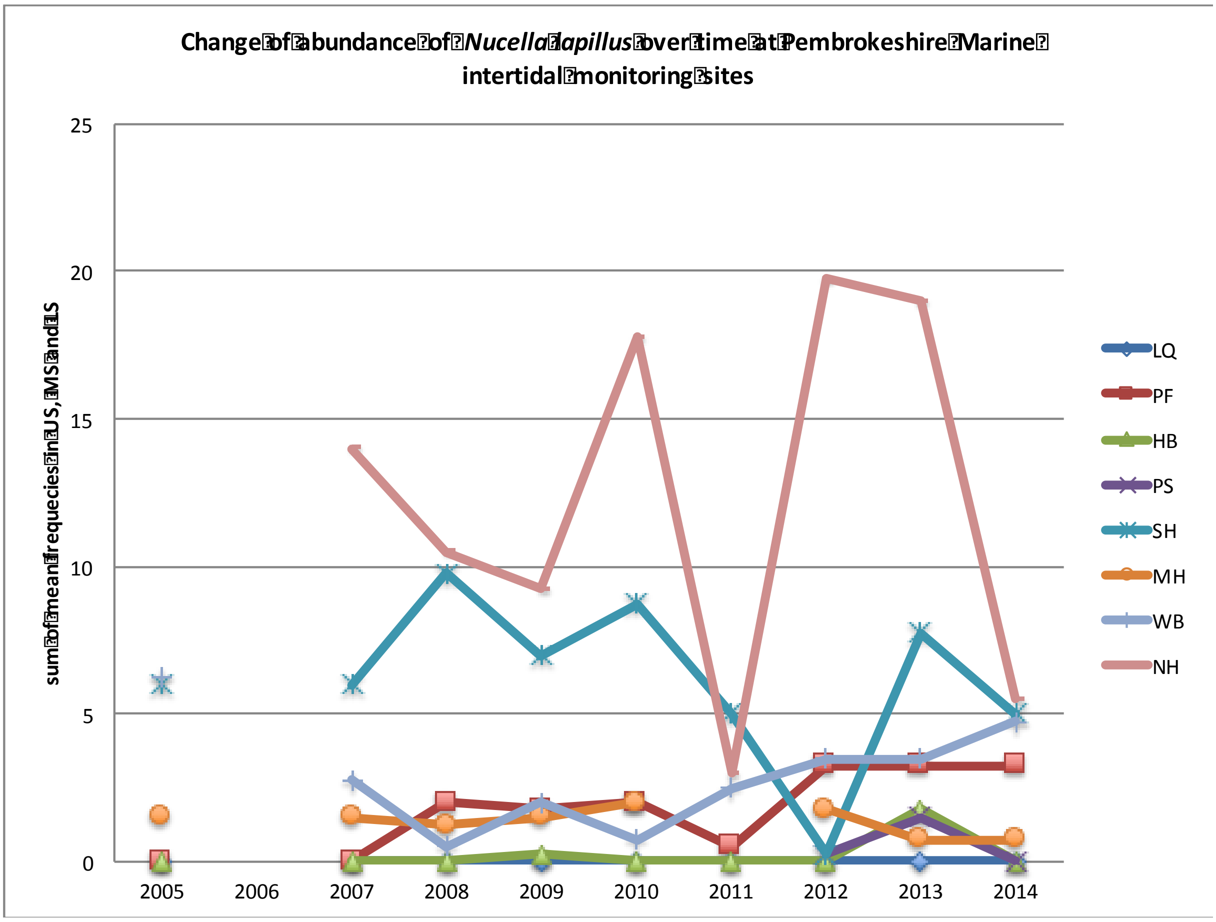

Figure 23 *Nucella lapillus* abundance graph 2005 to 2014

Table 24 *Nucella lapillus* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	0		0	0	0	0	0	0	0	0
PF	0		0	2	1.75	2	0.5	3.25	3.25	3.25
HB	0		0	0	0.25	0	0	0	1.75	0
PS								0.25	1.5	0
SH	6		6	9.75	7	8.75	5	0.25	7.75	5
MH	1.5		1.5	1.25	1.5	2		1.75	0.75	0.75
WB	6.25		2.75	0.5	2	0.75	2.5	3.5	3.5	4.75
NH			14	10.5	9.25	17.75	3	19.75	19	5.5

3.6.7. *Gibbula cineraria*

The grey topshell *Gibbula cineraria* has been recorded in low abundance from the monitoring quadrats on most shores. Generally *G. cineraria* is most frequent on the grazed sheltered shores of Pembroke Ferry and Hazelbeach. The numbers fluctuate from year to year and apart from this there are no obvious trends in the data, although there is some indication of a decline at all sites in recent years.

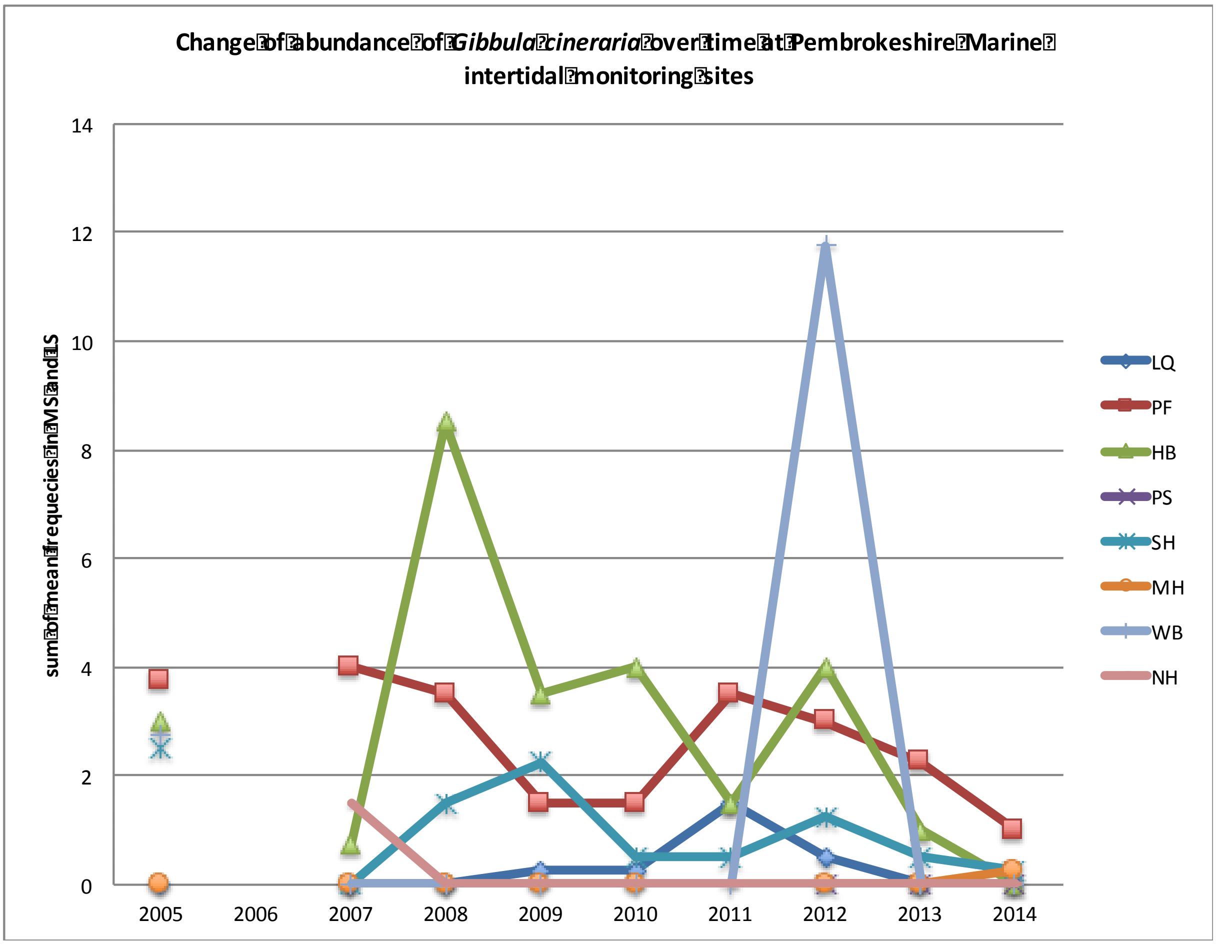

Figure 24 *Gibbula cineraria* abundance graph 2005 to 2014

Table 25 *Gibbula cineraria* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	0		0	0	0.25	0.25	1.5	0.5	0	0
PF	3.75		4	3.5	1.5	1.5	3.5	3	2.25	1
HB	3		0.75	8.5	3.5	4	1.5	4	1	0
PS								0	0	0
SH	2.5		0	1.5	2.25	0.5	0.5	1.25	0.5	0.25
MH	0		0	0	0	0		0	0	0.25
WB	2.75		0	0	0	0	0	11.75	0	0
NH			1.5	0	0	0	0	0	0	0

3.6.8. *Gibbula umbilicalis*

The purple topshell, *Gibbula umbilicalis* has been recorded at all the monitoring sites, most frequently at Hazelbeach, Monk Haven and West Angle Bay. The abundance of *G. umbilicalis* tends to fluctuate from year to year on each shore and no definite trends of change in abundance can be seen in the data set.

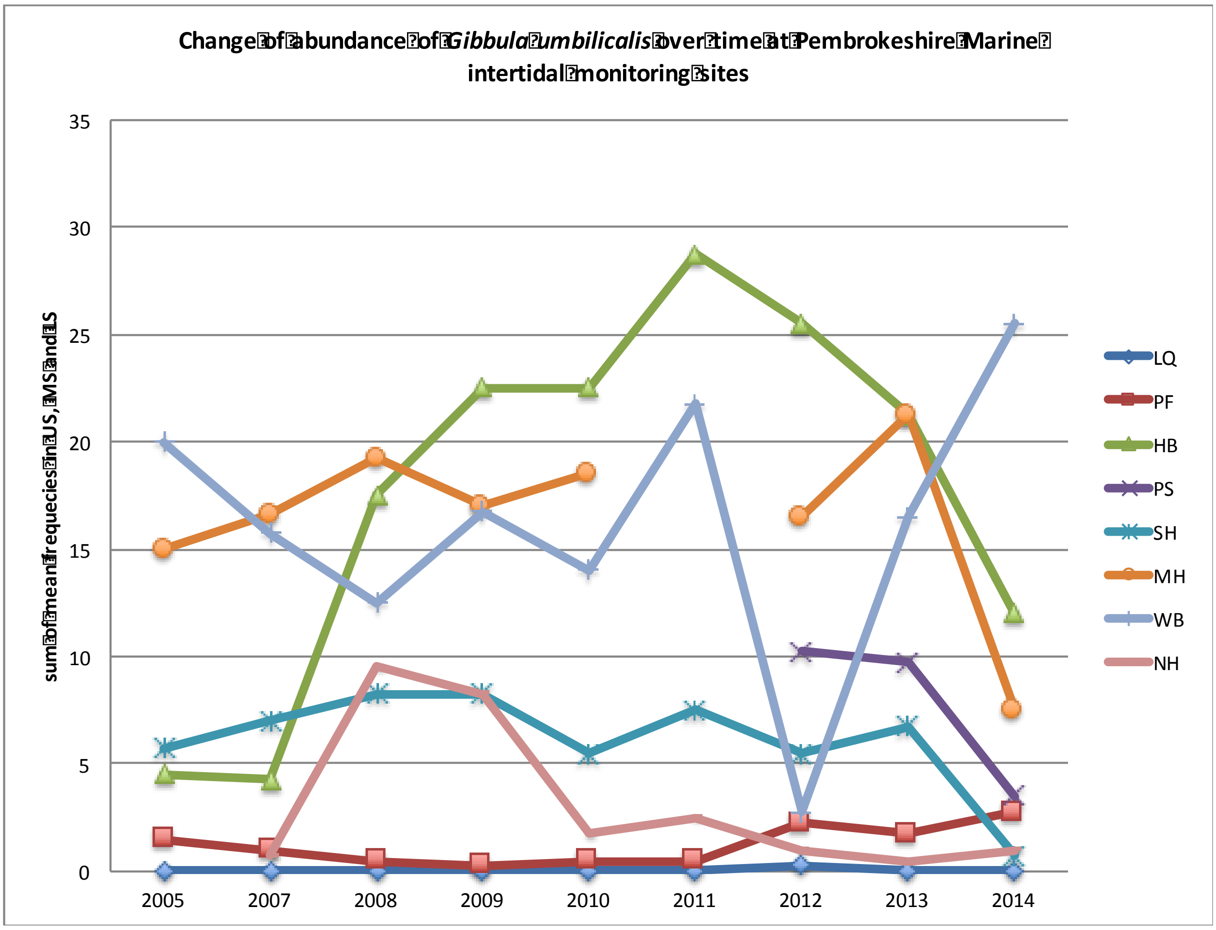

Figure 25 *Gibbula umbilicalis* abundance graph 2005 to 2014

Table 26 *Gibbula umbilicalis* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2007	2008	2009	2010	2011	2012	2013	2014
LQ	0	0	0	0	0	0	0.25	0	0
PF	1.5	1	0.5	0.25	0.5	0.5	2.25	1.75	2.75
HB	4.5	4.25	17.5	22.5	22.5	28.75	25.5	21.25	12
PS							10.25	9.75	3.5
SH	5.75	7	8.25	8.25	5.5	7.5	5.5	6.75	0.75
MH	15	16.625	19.25	17	18.5		16.5	21.25	7.5
WB	20	15.75	12.5	16.75	14	21.75	2.75	16.5	25.5
NH		0.75	9.5	8.25	1.75	2.5	1	0.5	1

3.6.9. *Phorcus lineatus*

The toothed topshell *Phorcus lineatus* (formerly named *Monodonta lineata*) is infrequently recorded on most of the study shores apart from Hazelbeach and Pembroke Power Station. Numbers on these shores fluctuate over time. The data shows a possible trend of increasing numbers at Hazelbeach.

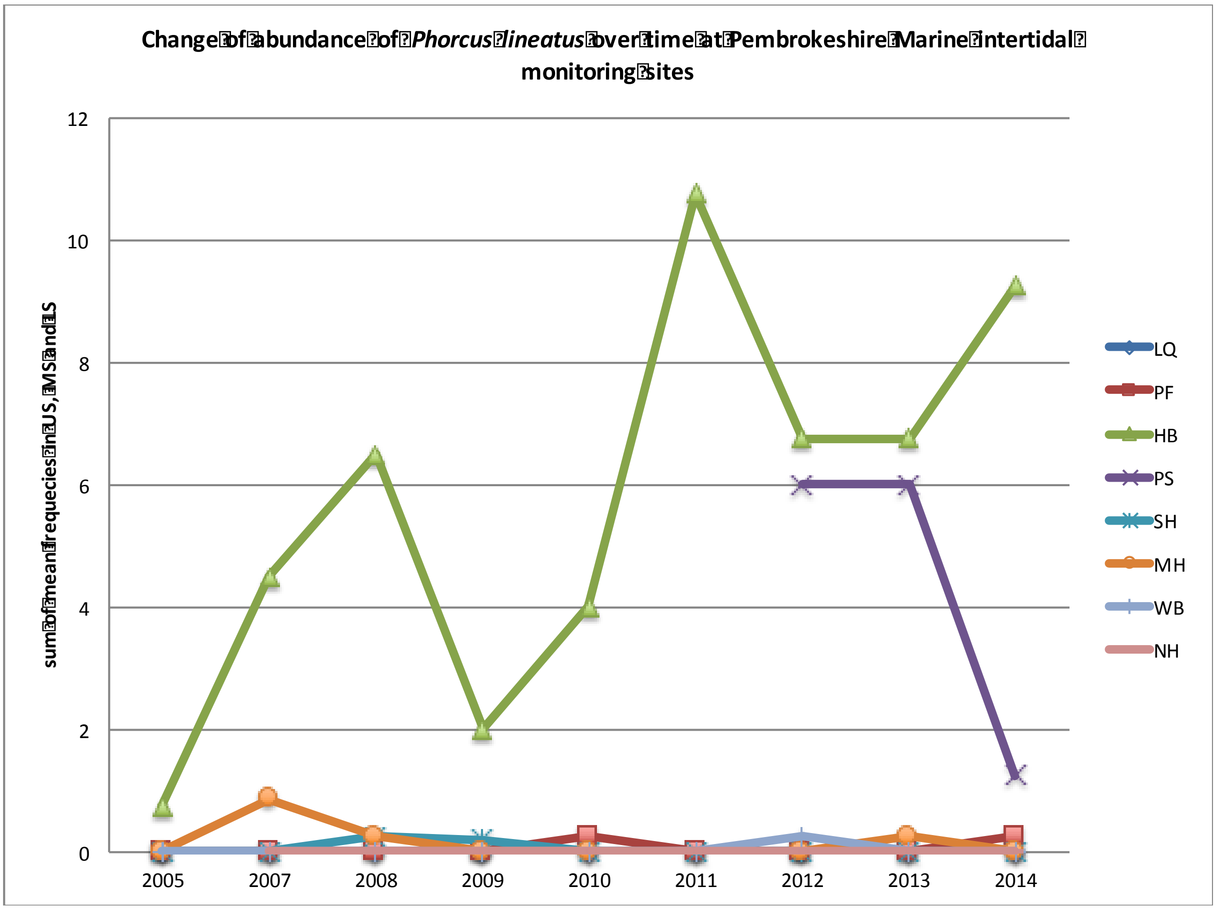

Figure 26 *Phorcus lineatus* abundance graph 2005 to 2014

Table 27 *Phorcus lineatus* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2007	2008	2009	2010	2011	2012	2013	2014
LQ	0	0	0	0	0	0	0	0	0
PF	0	0	0	0	0.25	0	0	0	0.25
HB	0.75	4.5	6.5	2	4	10.75	6.75	6.75	9.25
PS							6	6	1.25
SH	0	0	0.25	0.2	0	0	0	0	0
MH	0	0.875	0.25	0	0		0	0.25	0
WB	0	0	0	0	0	0	0.25	0	0
NH		0	0	0	0	0	0	0	0

3.7. Bryozoa

3.7.1. *Alcyonidium – gelatinosum, mytili and polyoum*

The three species of gelatinous encrusting bryozoa, *Alcyonidium gelatinosum*, *Alcyonidium mytili* and *Alcyonidium polyoum* cannot reliably be separated in the field unless reproductive and they can all be found on shores in the survey area. Because of this, the species have been lumped together for recording purposes. These species of *Alcyonidium* are most common on the sheltered shores of Lawrenny Quay and Pembroke Ferry. Abundance at Lawrenny Quay has fluctuated over the years, whereas the data shows the possibility of a steady decline since 2007 at Pembroke Ferry although frequency has been lower than at Lawrenny Quay in every year since 2007.

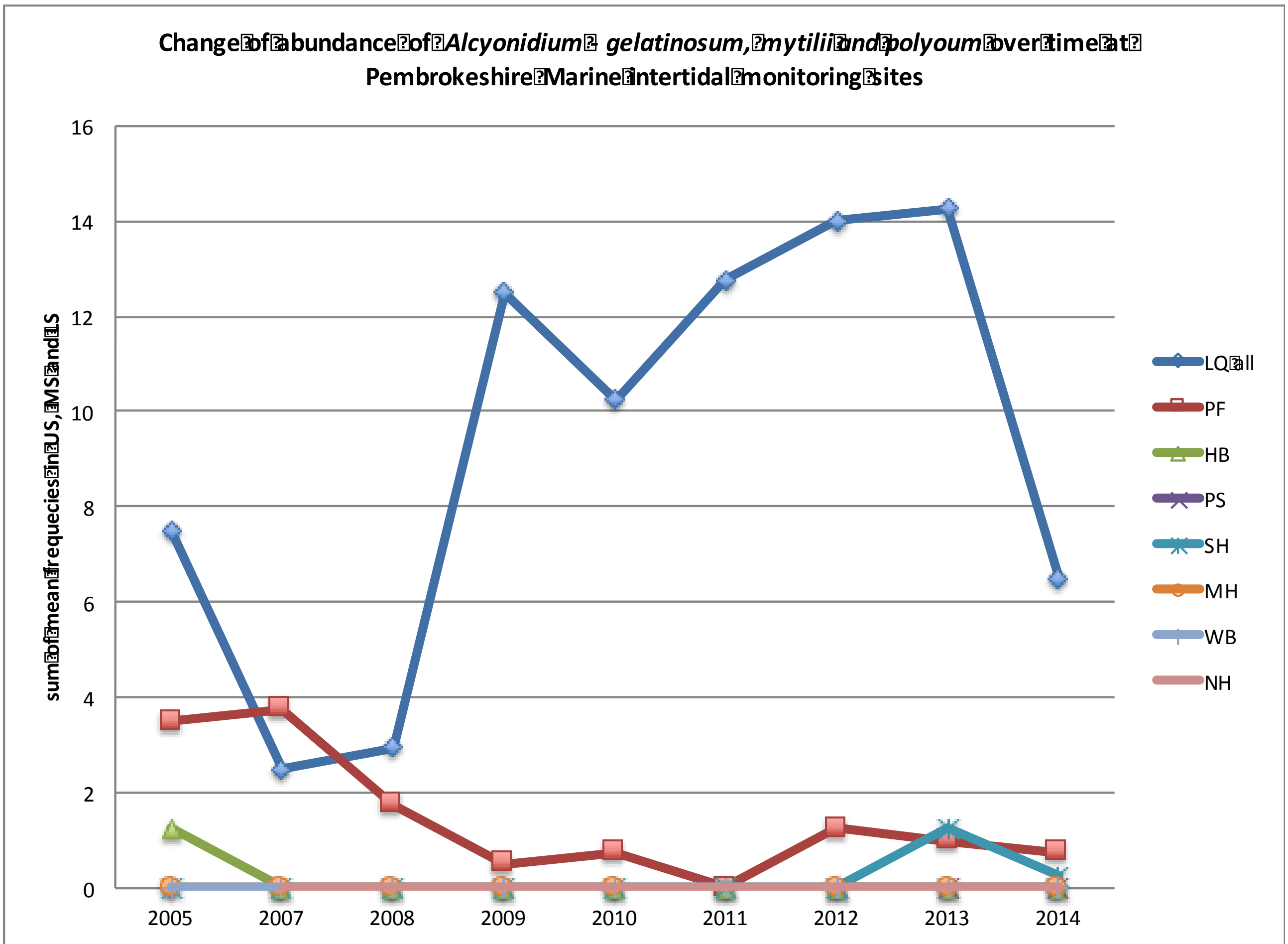

Figure 27 *Alcyonidium - gelatinosum*, *mytili and polyoum* abundance graph 2005 to 2014

Table 28 *Alcyonidium - gelatinosum*, *mytili* and *polyoum* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2007	2008	2009	2010	2011	2012	2013	2014
LQ all	7.5	2.5	2.95	12.5	10.25	12.75	14	14.25	6.5
PF	3.5	3.75	1.75	0.5	0.75	0	1.25	1	0.75
HB	1.25	0	0	0	0	0	0	0	0
PS							0	0	0
SH	0	0	0	0	0	0	0	1.25	0.25
MH	0	0	0	0	0		0	0	0
WB	0	0	0	0	0	0	0	0	0
NH		0	0	0	0	0	0	0	0

3.8. Ascidians

3.8.1. *Corella eumyota*

The non-native ascidian *Corella eumyota* has been recorded at both Lawrenny Quay (since 2010) and South Hook (in 2014). Numbers have been low and at Lawrenny Quay have fluctuated quite widely in the monitoring quadrats.

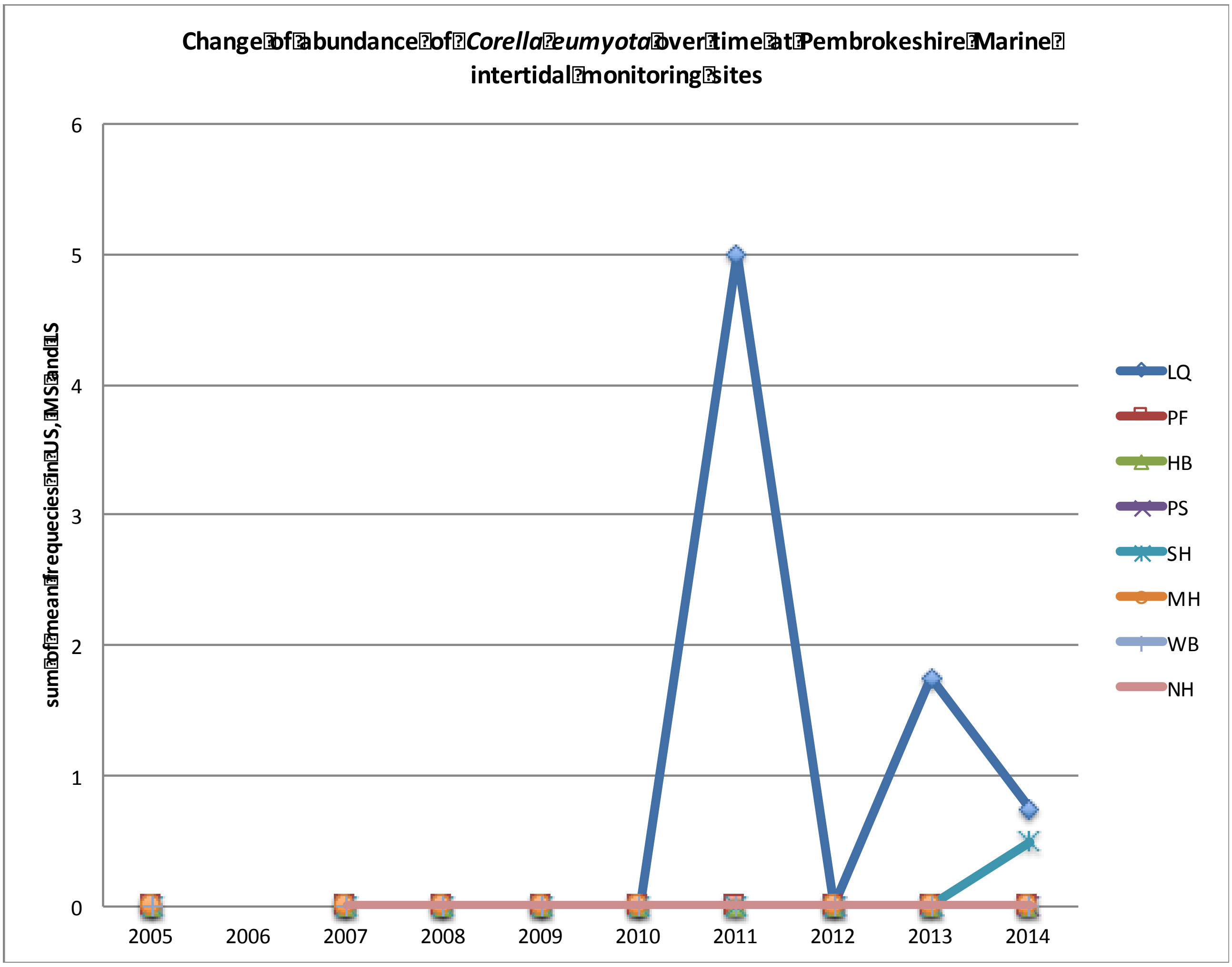

Figure 28 *Corella eumyota* abundance graph 2005 to 2014

Table 29 *Corella eumyota* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	0		0	0	0	0	5	0	1.75	0.75
PF	0		0	0	0	0	0	0	0	0
HB	0		0	0	0	0	0	0	0	0
PS								0	0	0
SH	0		0	0	0	0	0	0	0	0.5
MH	0		0	0	0	0		0	0	0
WB	0		0	0	0	0	0	0	0	0
NH			0	0	0	0	0	0	0	0

3.8.2. *Botrylloides violaceus*

The non-native colonial ascidian *Botrylloides violaceus* has been recorded from Lawrenny Quay and Pembroke Ferry. It was first recorded in the monitoring quadrats at Lawrenny Quay in 2009 and then at Pembroke Ferry in 2011. There are not enough records from the quadrats to ascertain any real trends with this species.

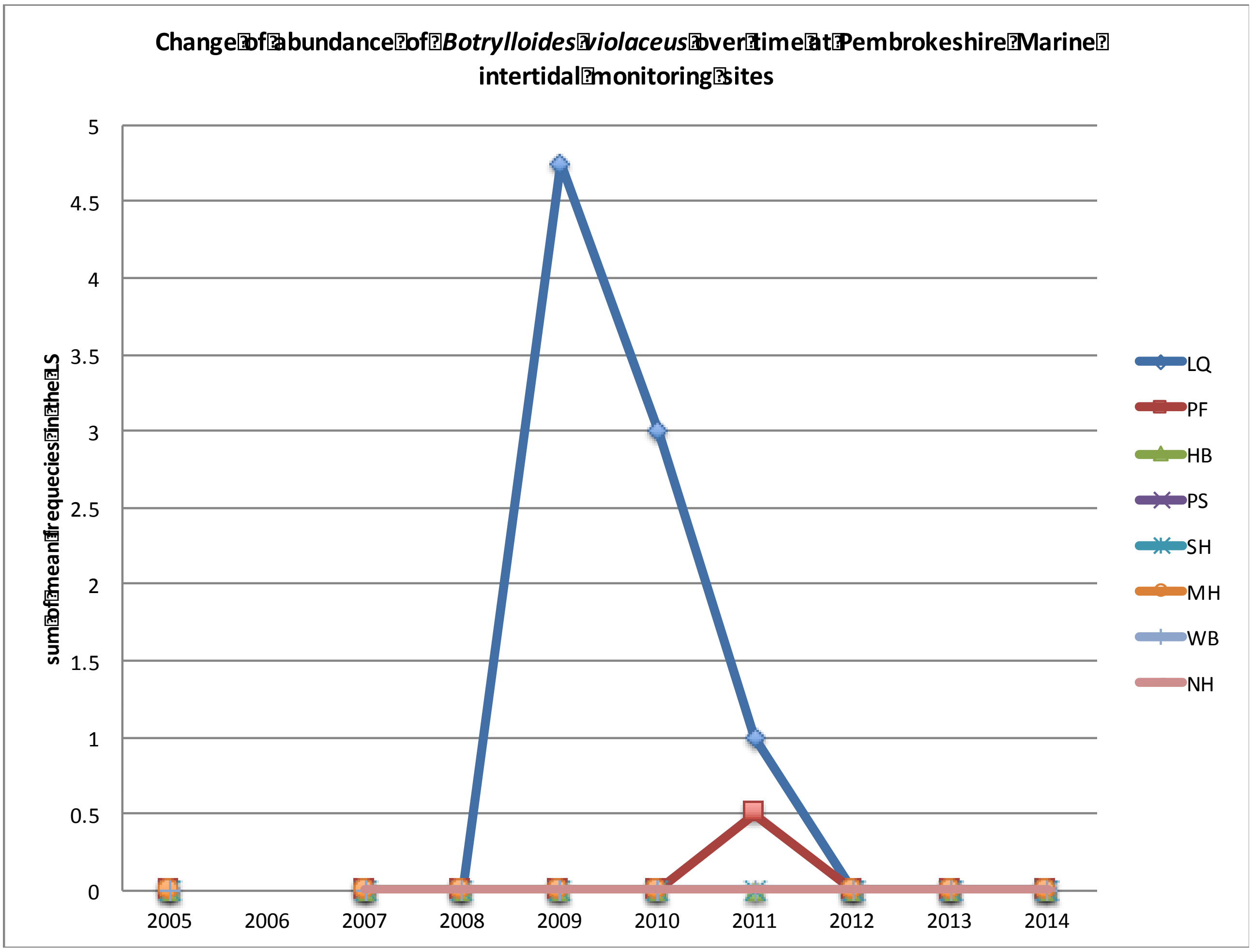

Figure 29 *Botrylloides violaceus* abundance graph 2005 to 2014

Table 30 *Botrylloides violaceus* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	0		0	0	4.75	3	1	0	0	0
PF	0		0	0	0	0	0.5	0	0	0
HB	0		0	0	0	0	0	0	0	0
PS								0	0	0
SH	0		0	0	0	0	0	0	0	0
MH	0		0	0	0	0		0	0	0
WB	0		0	0	0	0	0	0	0	0
NH			0	0	0	0	0	0	0	0

3.9. Barnacles

3.9.1. *Perforatus perforatus*

The volcano barnacle *Perforatus perforatus* has been recorded from the more exposed sites of West Angle Bay, South Hook and Nolton Haven. Significant frequencies have only been recorded from the quadrats at Nolton Haven where abundance has fluctuated.

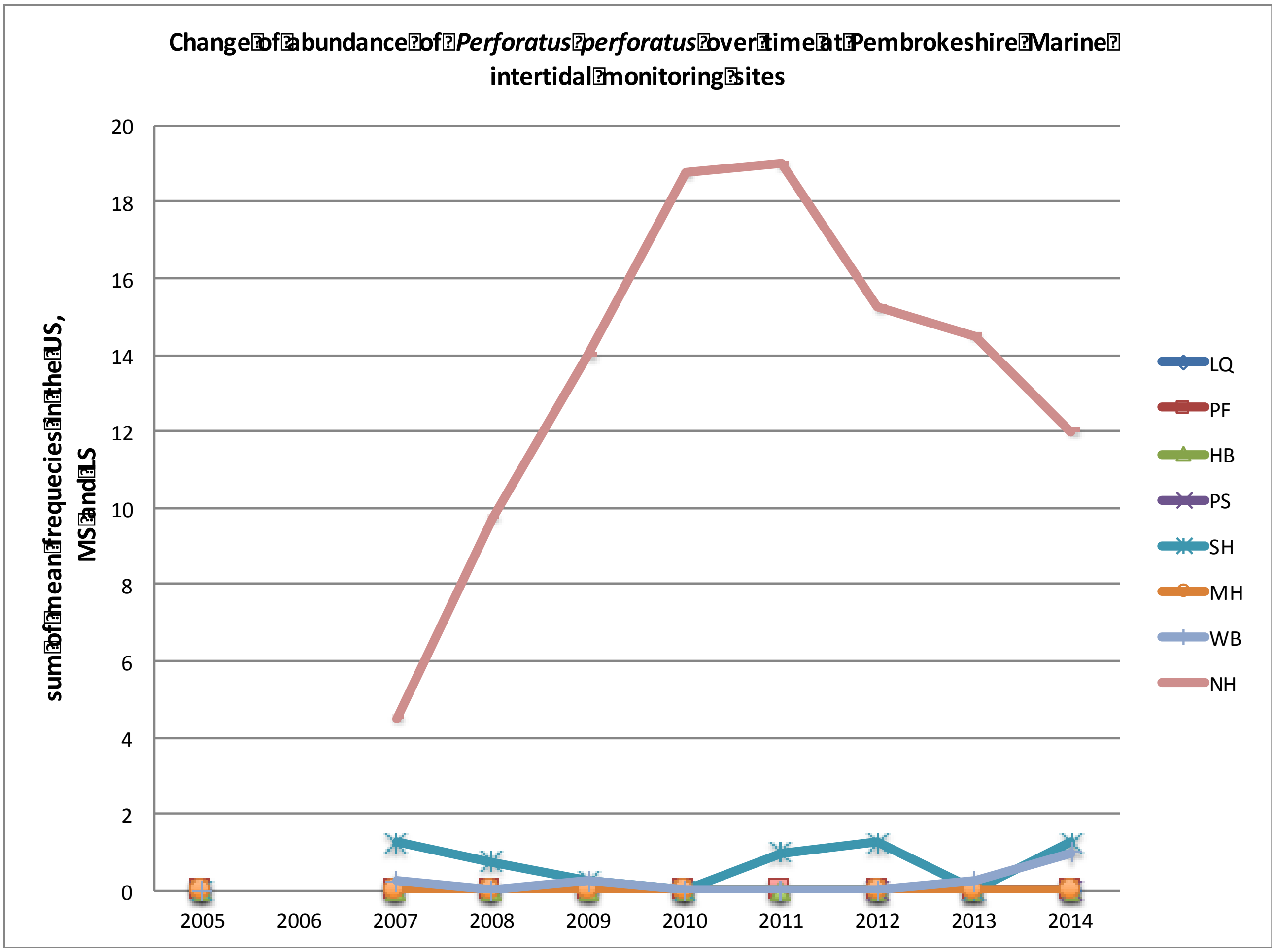

Figure 30 *Perforatus perforatus* abundance graph 2005 to 2014

Table 31 *Perforatus perforatus* average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ	0		0	0	0	0	0	0	0	0
PF	0		0	0	0	0	0	0	0	0
HB	0		0	0	0	0	0	0	0	0
PS								0	0	0
SH	0		1.25	0.75	0.25	0	1	1.25	0	1.25
MH	0		0	0	0	0		0	0	0

3.9.1. *Cirripedia except for Perforatus perforatus*

Cirripedia (barnacles all species) are a feature of all the rocky shores studied and are generally numerous in all quadrats. The data shows that the frequency of occurrence of Cirripedia does not appear to have changed a great deal over time in the monitoring quadrats on the different shores, although there is some evidence of a decline at Hazelbeach and Pembroke Power Station.

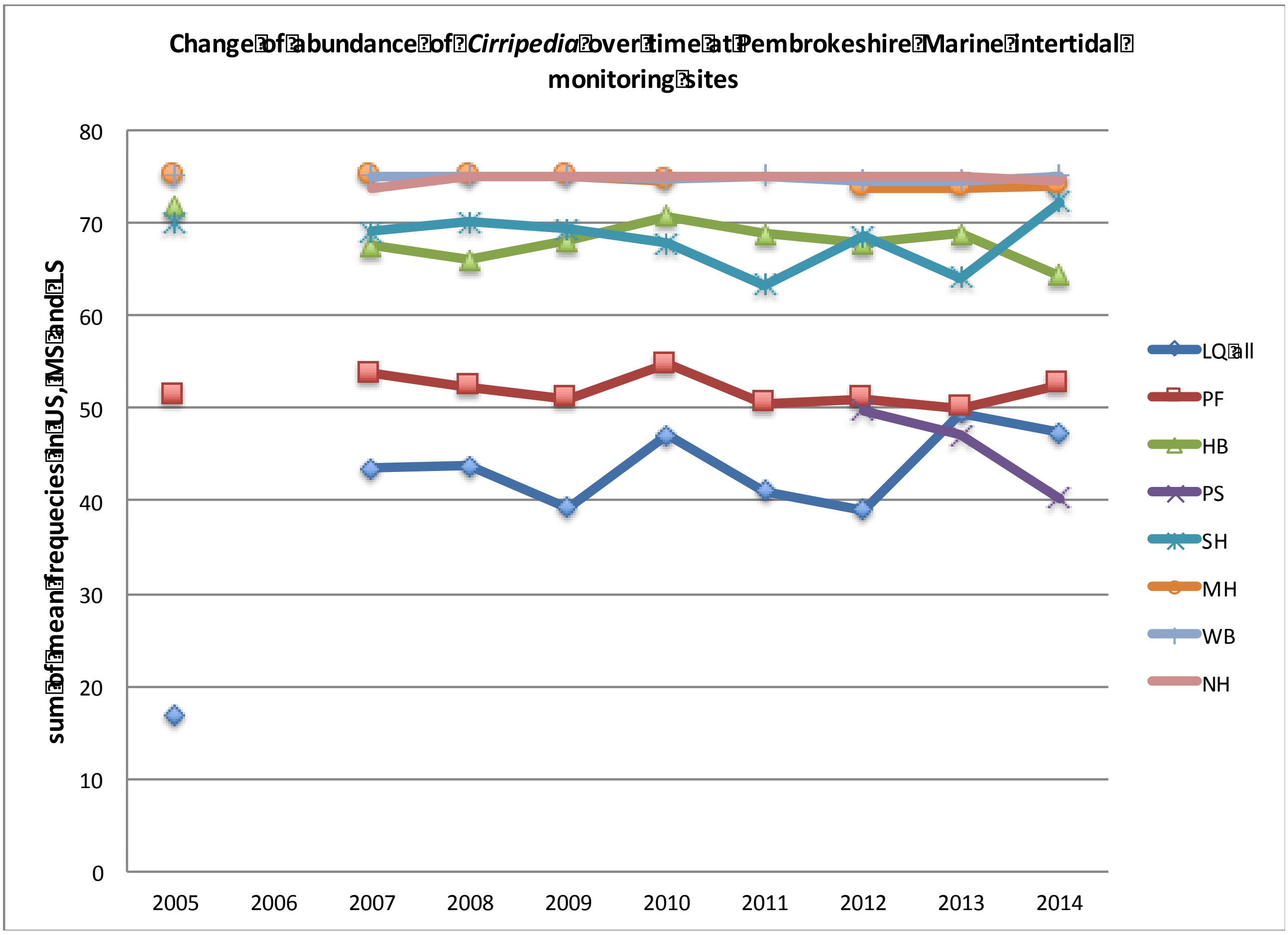

Figure 31 Cirripedia (except for *Perforatus perforatus*) abundance graph 2005 to 2014

Table 32 Cirripedia (except for *Perforatus perforatus*) average frequencies on the shore (US to LS) 2005 to 2014

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LQ all	16.75		43.5	43.75	39.25	47	41	39	49.5	47.25
PF	51.25		53.75	52.25	51	54.75	50.5	51	50	52.5
HB	71.75		67.5	66	68	70.75	68.75	67.75	68.75	64.25
PS								49.75	47	40.25
SH	70		69	70	69.25	67.75	63.25	68.5	64	72.25
MH	75		75	75	75	74.5		73.75	73.75	74
WB	75		75	75	75	74.75	75	74.5	74.5	75
NH			73.75	75	75	75	75	75	75	74.5

4. Discussion

4.1. Brown seaweeds (Phaeophyceae)

4.1.1. Pelvetia canaliculata

The brown alga *Pelvetia canaliculata (Linnaeus) Decaisne et Thuret* lives above MHWN tide level and can tolerate physical stress better than any other intertidal fucoid seaweed, living emersed for up to 8 days during neap tide periods. A study by Dring and Brown (1982) showed that upper intertidal algae appear to recover from desiccation more completely than lower-shore species and Pfetzing, Stengel *et al*. (2000) studied the effects of temperature and emersion on photosynthesis, carbohydrate content and growth of *P. canaliculata*. Pfetzing, Stengel *et al*. (2000) showed that while *P. canaliculata* could survive well when emersed in warm summer temperatures, that growth was suppressed. It may be that the dry and warm summer of 2014 accounts for the apparent decline in this species at most sites.

4.1.2. Fucus spiralis

The general increase in cover of *Fucus spiralis* Linnaeus at the monitoring sites during the time period of this study is of interest. Chapman (1989) studied populations of *F. spiralis* in Nova Scotia, Canada and found the most important regulator of recruitment density in *F. spiralis* was the presence of a canopy of conspecific adults. Kim, Park *et al*. (2011) found that *F. spiralis* germlings always grew faster than those of *P. canaliculata* and did best in mixed cultures, whereas *Pelvetia* did least well when mixed with *F. spiralis* germlings. It would be interesting to further examine intraspecific competition between populations of *F. spiralis* and *P. canaliculata* at the different monitoring sites.

4.1.3. Fucus vesiculosus

The bladder wrack, *Fucus vesiculosus* Linnaeus is known to hybridise, particularly with *Fucus spiralis* (Guiry, 2012) and distinguishing the two species, particularly in the upper shore and upper middle shore at sheltered sites such as Pembroke River can be problematical.

Dring and Brown (1982) showed how it is in the extent of recovery of photosynthesis after desiccation that intertidal brown algae show the clearest correlation with their heights in the zonation pattern on European shores. Chapman (1990) showed that *F. vesiculosus* outcompeted *F. spiralis* in the middle shore and it is normally readily identifiable in this zone. This is especially so in sheltered areas where thalli bear characteristic paired air bladders. The stands of the bladderless form of *F. vesiculosus* known as variety *evesiculosus* (or variety *linearis*) that occur on exposed shores can be difficult to distinguish from other fucoid species, especially when young and under developed. Inconsistent identification between recorders may account for some of the variability in the data noticed in Figure 4 and Table 1.

F. vesiculosus only lives between 2 to 4 years and maybe less on more exposed sites, (Kerser and Larson, 1984) and so variability in the population of this species at different sites over time is expected.

4.1.4. Ascophyllum nodosum

The seaweed *Ascophyllum nodosum* (Linnaeus) Le Jolis dominates middle shore rocky substrata at Lawrenny Quay. It is also present at Pembroke Ferry in much lesser abundance but is scarce on the other monitoring shores. *A. nodosum* is a long lived species where individual fronds continue to grow for 10 to 13 years (Baardseth, 1970) or maybe more. Whereas fronds will be lost or damaged over time by physical means or grazing, *A. nodosum* thalli can be very long lived. It was estimated that they can (theoretically) survive 120 years in Sweden (Aberg, 1992).

Much research has been devoted to *A. nodosum* due to its importance as a sustainable crop. Recent publications include those of Seeley and Schlesinger (2012) and Guiry and Morrison (2013). *A. nodosum* cutting does not occur in Milford Haven but any decline is of concern as it is absent from much of the sheltered shoreline of the Daugleddau, with the shores being barnacle and limpet dominated.

A study of aerial photographs from Strangford Lough, Northern Ireland by Davies, Johnson *et al*. (2007) indicated a decline in cover of sheltered shores by *A. nodosum* over 44 years, resulting in a change to barnacle covered rock. This change was accompanied by increases in limpet densities since the 1980's and an increase in rate of cover by barnacles since 1990. Several studies have shown that high densities of limpets prevent the development of algal canopies due to their grazing activities, e.g. Hawkins and Hartnoll (1983). Davies, Johnson *et al*. (2008) showed that high densities of limpets consumed more *A. nodosum* than low densities.

Davies, Johnson *et al*. (2007) surmised that increases in limpet densities since the 1980's due to a series of mild winters has led to the decline of *A. nodosum*. It is also postulated that climate change may have a role in causing canopy loss, not by direct effects on the growth of fucoids, but by increasing the severity of grazing through changes to limpet populations. Both *Patella vulgata* and *A. nodosum* are known to be strong regulators of rocky shore communities and disruption to either species can lead to major changes throughout the shore.

There is some pressure on the Lawrenny Quay shore due to trampling because of winkle collecting (*Littorina littorea*) but effects of this are unknown. The taking of wide angle photographs of the monitoring site and general abundances in the middle shore in the quadrat area has been undertaken since 2014. This will add contextual information to that of the monitoring quadrats and a more visual record of *Ascophyllum cover* at the site.

Figure 32 View north along east shore of Daugleddau by Lawrenny Quay monitoring site in September 2014 showing patchy distribution of *Ascophyllum* and grazed barnacle and limpet dominated patches. Photograph F. Bunker

4.1.5. Fucus serratus

The saw wrack, *Fucus serratus* Linnaeus dominates the lower shore at Lawrenny Quay and is also conspicuous at Pembroke Ferry. Elsewhere it is present at monitoring sites but in low abundance. The apparent increase in abundance at Lawrenny Quay contrasts with a decrease in abundance at Pembroke Ferry.

In comparison to *Ascophyllum nodosum*, *F. serratus* is a short lived plant surviving 4 to 5 years on sheltered shores but less in exposed situations (Rees, 1932). Over the 10 years of this study it would be expected that plants would die and be recruited and that the population would fluctuate.

A study by Malm and Kautsky (2003) showed that *F. serratus* was unable to regenerate vegetatively from *holdfasts*, whereas *F. vesiculosus* sprouted from only traces of holdfasts.

Creed, Norton *et al*. (1996) studied the recruitment of *F. serratus* and found mortality to be initially high (70% in 1 month), falling considerably over time. It was concluded that *F. serratus* behaved like most higher plants with respect to changing population structure and that a "seed bank" develops in an algal population with thousands of young plants remaining undeveloped (< 1mm high after a year), until there is opportunity for growth.

The fluctuating abundances of *F. serratus* in this study would seem to concur with our knowledge of the population dynamics of this species.

It was found in a study in the Baltic Sea (Isæus, Malm *et al*., 2004) that both filamentous algae and sediment negatively affect the settlement ability of *F. serratus* eggs and zygotes and the subsequent survival of the germlings, with sediment having the strongest effect. It was concluded that the prior existence of an adult *F. serratus* may allow for continuing recruitment of juveniles, while colonization of new areas unaffected by the sweeping effect of larger individuals was deterred under silted conditions. The lower shore rock encountered at several sites in 2014 was very silty (including Lawrenny Quay and Pembroke Ferry). If this trend were to continue it may be that settlement of *F. serratus* plants could be deterred at these sites.

4.1.6. Laminaria digitata

There has been much recent work undertaken on kelp beds and effects of anthropogenic factors including climate change (e.g. Wernberg, Thomsen *et al*. (2010) and Yesson, Bush *et al*. (2015)) with warnings of global decline.

The only kelp recorded in any quantity in the Pembrokeshire Marine SAC monitoring quadrats was *Laminaria digitata* (Hudson) J.V.Lamouroux at Lawrenny Quay and was absent from the site in 2014. The quadrats at other sites are generally vertical and too high up the shore to be suitable for *L. digitata.*

A study by Bartsch, Vogt *et al*. (2013) showed that high temperatures inhibited reproduction of *L. digitata*. This study surmised that high sub-lethal temperature stress will at first decrease population density due to a lowered reproductive efficiency and reduced growth rates, then following periodic lethal damage will eventually become extinct. Such a decreasing resilience of kelp beds has already been observed along a natural temperature gradient off western Australia (Wernberg, Thomsen *et al*., 2010). Some monitoring of the abundance of *L. digitata* outside of the quadrats at the different monitoring sites would be useful. Yesson, Bush *et al*. (2015) emphasises the lack of historic quantitative data concerning populations of large brown seaweeds.

4.2. Red Seaweeds

4.2.1. Bostrychia scorpioides

The scorpion-tailed saltmarsh weed, *Bostrychia scorpioides* (Hudson) Montagne occurs at the sheltered sites of Lawrenny Quay and Pembroke Ferry where it is found in the upper shore forming a low lying turf with *Catenella caespitosa*. *B. scorpioides* is ideally suited to this habitat, being tolerant of lowered salinities (Maggs and Hommersand, 1993) and having an increased capacity for photosynthesis when emersed (Mercado and Niell, 2000).

Production of gametangia in *B.* scorpioides is only known to occur at high temperatures, with British records of gametangial plants all being from southern England (Van Reine and Sluiman, 1980).

It would be of interest to check for the occurrence of gametangia in *B. scorpioides* over time at the Milford Haven monitoring sites.

4.2.2. Catenella caespitosa

Creeping chain weed *Catenella caespitosa* (Withering) L.M.Irvine occurs in a wider range of habitats than *Bostrychia scorpioides* but like *B. scorpioides* it is essentially an upper shore species. Although the populations seem to fluctuate over time at the different sites, it is probably normal for this species.

Unlike *B. scorpioides*, production of gametangia is not restricted geographically in British populations (Prud'homme van Reine, Sluiman *et al*., 1983).

4.2.3. Corallinaceae

Although it is not within the scope of this study to monitor changes in the abundance of different species of Corallinaceae at the different sites, these seaweeds as a group are considered to be important as they are considered especially sensitive to the warming, acidification and sea level rise caused by CO_2 emissions. Brodie, Williamson *et al*. (2014) state how the combined impacts of seawater warming, ocean acidification, and increased storminess may replace structurally diverse seaweed canopies with associated calcified and non-calcified flora with simple habitats dominated by non-calcified, turf-forming seaweeds.

4.2.4. *'Corallina'* spp.

The effects of climate change predicted for crustose Corallinaceae are likely to be similar for erect forms such as the '*Corallina'* spp. and so changes in abundance for this group of species is important to study.

The different species comprising this group, *Corallina officinalis* Linnaeus*, Corallina caespitosa* R.H.Walker, J.Brodie & L.M.Irvine and *Ellisolandia elongata* (J.Ellis & Solander) K.R.Hind & G.W.Saunders[1] can be tricky to identify in the field, especially when specimens are not intact or fully formed and this is often the case in the monitoring quadrats. The recording of these different species is of interest to this monitoring study, especially as they each have their own distinctive geographical distribution, with *E. elongata* being a southern species with a limited distribution in Britain and Ireland (Brodie, Walker *et al*., 2013).

Recording protocols instituted in 2012 include the recording of the different species present as well as the collective grouping, where specimens can be accurately identified. This is not always the case and so obtaining quantitative information for the different species within the monitoring quadrats is problematical.

4.2.5. Chondrus crispus

Irish moss *Chondrus crispus* Stackhouse is a common species around Pembrokeshire and is found on the open coast as well as sheltered locations. Out of the monitoring stations it is most abundant in the lower shore of the sheltered sites of Lawrenny Quay and Pembroke Ferry.

A study by Lindgren, Pavia *et al*. (2003) studied grazing of *C. crispus* by the common shore molluscs *Littorina littorea*, *Lacuna vincta* and the crustaceans *Idotea granulosa* and *Gammarus locusta.* The results showed that all four mesoherbivore species were capable of consuming both adult and juvenile tissue. However, none of the herbivores showed a significant preference for a specific stage of adult fronds. For juvenile fronds, it was found that *I. granulosa* significantly preferred gametophytes to tetrasporophytes and there was a tendency for *L. littorea* to consume more of juvenile tetrasporophytes than gametophytes. This suggests that grazing could have an influence on the ploidy ratio of *C. crispus*. It would be of

[1] *Elisolander elongata* was formerly known as *Corallina elongata*, see Hind, K.R. and Saunders, G.W. 2013. A Molecular Phylogenetic Study of the Tribe Corallineae (Corallinales, Rhodophyta) with an Assessment of Genus-Level Taxonomic Features and Descriptions of Novel Genera. *Journal of Phycology* 49(1) 103-114.

interest to determine the abundance of gametophyte and tetrasporophyte fronds at the monitoring sites.

4.2.6. Mastocarpus stellatus

The grape-pip weed, *Mastocarpus stellatus* (Stackhouse) Guiry population mainly occurs on the lower shore. The variability in abundance seen at Hazelbeach (compared to other study shores) is most likely due to the mobile nature of the lower shore substratum. This species is common in Milford Haven and is worthy of more research.

Guiry and West (1983) showed *M. stellatus* to have a complex reproductive biology. They identified two main types of life history in the N. Atlantic. The first was a heteromorphic life history where, following fertilization, foliose male and female gametophyte plants produced carpospores which developed as a crustose sporophyte phase known as '*Petrocelis'*. The other main type of life history involved female foliose gametophytes, which, in the apparent absence of males produced carpospores that developed into more foliose plants (without the '*Petrocelis*' phase. Guiry and West (1983) found a few cultured plants appeared to have a mix of these reproductive modes. Also there were indications that some gametophytes may be monecious.

Guiry and West (1983) showed a difference in the biogeographic pattern of life history types in *Mastocarpus stellatus*, with sexual plants found exclusively in the south (Spain, Portugal), almost exclusively asexual plants in Scotland, Denmark and Iceland, and mixed populations in France, Britain and Ireland.

Their results indicated two almost non-interbreeding and geographically separated populations. There was a southern breeding group in Spain, Portugal and northern Brittany and a northern breeding group in Britain, Ireland and northern Brittany. Both breeding groups were found at the same site in Brittany (at St. Michel en Gre`ve).

Zuccarello, Schidlo *et al*. (2005) used molecular markers to confirm the findings of Guiry and West (1983) and carried out further sampling in some populations. Using organellar markers they showed that the breeding groups have different plastid and mitochondria haplotypes and appear to be distributed along a north–south gradient.

Populations in southern England and northern France (Brittany) generally had mixed northern and southern breeding groups, as was shown by Guiry and West (1983). Results also showed that most asexual plants had a plastid haplotype corresponding to the northern breeding group and a mitochondrial haplotype corresponding to the southern breeding group. It was postulated that these asexual plants had inherited these different organelles from the two breeding groups and emphasised the high levels of genetic variation in marine algae in Brittany.

The possibility that distribution of sexual and asexual plants could reflect climatic change is raised by Zuccarello, Schidlo *et al*. (2005). It would be of interest to study the populations of *M. stellatus* at the shore monitoring sites described here to determine the reproductive types present and any changes that may occur over time.

4.3. Sponges

4.3.1. Porifera

Both of the common sponges at the monitoring sites, *Hymeniacidon perlevis* (Montagu, 1814), and *Halichondria panicea* (Pallas, 1766) were described by Burton (1949) to change shape and size over periods of several months in a study based on the south coast of England. He found that increase in size and fusion of adjacent individuals occurred during the summer months, and regression and fragmentation occurred during winter.

Burton (1949) estimated the longevity of *H. perlevis* to be approximately 2 years and *H. panicea* up to three years. However a study by Stone (1970) considered *H. perlevis* lived much longer and described an annual cycle of growth and regression with growth taking place during the summer and regression, causing size decrease and fragmentation in the winter. Stone (1970) also noted that dehydration and emersion is an important factor limiting the distribution and abundance of *H. perlevis* on the shore and Burton (1949) noted that factors including grazing by nudibranchs and damage by crabs could affect the size and shape of individual colonies.

There was an apparent decline of sponges in 2014 (as shown in Figure 14). The reason for this is unclear.

4.4. Coelenterata

4.4.1. Hydrozoa

The commonest hydrozoan encountered in the monitoring quadrats is *Dynamena pumila* (Linnaeus, 1758).

Henry (2002) studied rocky shores of the northwest Atlantic over a four year period and described how physical factors affect the intertidal zonation and seasonality of abundance, morphology, and fertility of the thecate hydroid *Dynamena pumila* (Linnaeus, 1758). The first objective of this paper was to report seasonal changes in the small (i.e., vertical zonation) and large scale (i.e., horizontal zonation) distribution patterns of *D. pumila* over gradients of desiccation stress, wave exposure, and seasonal changes. The second objective was to link seasonal changes with changes in size and fertility under natural conditions in order to explain changes of zonation patterns for *D. pumila* over time.

The habitat for *D. pumila* at Lawrenny Quay and Pembroke Ferry is typical for that described by Henry (2002), where it frequently colonises *Ascophyllum nodosum* with colonies usually found on the algal holdfasts (although they occasionally extend up-wards over the stipes). Because of this, the finding of Henry (2002) are relevant to this study.

Henry (2002) reviews various studies relating to *D. pumila* and describes how zonation patterns of *D. pumila* are set by desiccation at upper shore levels and by larval preferences in lower intertidal zones. Orlov (1997) describes how the lower distribution limits of *D. pumila* may be set by larval preferences for settling in zones where macro-algal assemblages provide the thickest canopy. Evidence for this came from observations that *D. pumila* larvae are attracted to surficial microbial films that cover rocky shore macroalgae. Henry (2002) describes how the size and reproductive state of colonies are controlled by water temperature, current velocities, food supply, and competition with other epifauna. In general, *D. pumila* colonies are known to be larger and more often sexually mature at lower shore levels in warm seasons, where there is an abundant supply of high quality food to growing and sexually reproductive hydroids.

Physical factors which may modify zonation patterns and seasonality of *D. pumila* assemblages are reported by Henry (2002), again by reviewing the work of other scientists on this species. It is reported that smaller and denser assemblages of hydrocauli are found on shores with higher degrees of wave action. Also, combined changes in water temperature and food supplies are said to modify the distribution and seasonality of *D. pumila*.

4.4.2. Anthozoa

The patterns of abundance over time varies between shores. At South Hook, there appears to have been a steady decline in abundance since the start of the monitoring in 2005. At Pembroke Ferry there is great variation in the abundance of Anthozoa over time. The other shores show Anthozoa in low abundance with little fluctuation over time.

The steady decline of Anthozoa at South Hook is of interest. The majority of the anemones at this site are the species *Actinia equina* (Linnaeus, 1758) with most occurring on the lower shore. A study by (Rees, 1985)(cited Brace and Quicke (1986) noted that *A. equina* is thought to live for many tens of years. Changes in the population within the quadrats may be due to movements of the anemones rather than a decline in the population. *A. equina* is known as a highly mobile species and Rostron and Rostron (1978) noted that *A. equina* seem to migrate in and out of pools at different times of the year.

The commonest anemone at Pembroke Ferry is *Diadumene lineata* (Verrill, 1869). This is a non-native species originating from the West Pacific which was probably introduced via the import of oysters or by ships and appeared in the Atlantic in the late 19th century (Manuel, 1988). At Pembroke Ferry, small individuals of *D. lineata* are found living in rock crevices in the middle and lower shore. It is probable that the variation in numbers recorded is due to the difficulty in seeing the animals due to their small size and cryptic habit.

4.5. Polychaeta

4.5.1. Spirorbinae

It was discussed in section 3.5.1 that there were three main species, making up the littoral Spirorbinae; *Spirorbis spirorbis* (Linnaeus, 1758), *Spirorbis rupestris* Gee & Knight-Jones, 1962 and *Janua pagenstecheri* (Quatrefages, 1866). The erratic patterns of abundance seen with this group of species is probably due to irregular recruitment. The commonest of these species on sheltered shores is *S. spirorbis* which colonises *F. serratus* (and a to a lesser extent *F. vesiculosus*, Knight-Jones and Knight-Jones (1977)). An apparent decline of *S. spirorbis* at Pembroke Ferry could be linked with a decline of *F. serratus* at this site.

4.6. Mollusca

4.6.1. *Mytilus edulis*

McGrorty and Goss-Custard (1993) studied the population dynamics of 12 individual mussel beds in the Exe in southern England, ranging from the mouth to the upper reaches of the estuary. They found that the main settlement of mussels occurred in March but that there was also settlement in between March and September. The high densities of recruitment occurred on beds where adult density was already high. Low recruitment tended to be associated with substratum muddiness and distance up the estuary. The density-dependent relationships were found to result in a temporal and spatial compensation in the pattern of settlement and mortality between beds. Also, it was found that density-dependent losses or recruitment of summer settling larvae reduced the variation in spat recruitment over the whole estuary between years and, therefore, acted as a compensatory process over time.

Indications from the results shown in section 3.6.1 are that there has been an overall decrease in the recruitment of *M. edulis* within Milford Haven over the time of the study with populations declining at all sites.

On the open coast at Nolton Haven, the population has varied markedly over time. A decline in the population was noted in 2010 (Bunker and Brazier, 2013) and this was followed by a recovery. In 2014 there was a dramatic fall in recruitment. It could be that the severe winter storms of 2014 impacted the mussel communities, particularly on the open coast and with mobilisation of sediments and silting within Milford Haven. It is noteworthy that there are also indications of a decline in *M. edulis* on the study shores around Skomer in recent years (Mark Burton pers. comm.).

A study by McGrath and King (1991) of *M. edulis* populations on twenty three exposed shores around the Irish coast found that direct settlement of larvae occurred in mussel colonised areas in both the middle and lower shore on all but 5 of the shores. Reasons for the recruitment failures were not determined.

4.6.2. Small gastropods in crevices

Rough periwinkles, often referred to as the *L. saxatilis* complex are very varied in shell form with regards to shell size, thickness and colouration. The different forms of rough periwinkles were regarded as several separate species (Fretter and Graham, 1980), including a small form known as *Littorina neglecta* which inhabits dead barnacle shells. As a result of genetic studies, rough periwinkles are now known to comprise of just three species, *Littorina saxatilis* (Olivi, 1792), *Littorina arcana* Hannaford-Ellis, 1978 and *Littorina compressa* Jeffreys, 1865 (Reid, 1996). *L. neglecta* is now known to be an ecotype of *L. saxatilis*.

The shells of adult *L. compressa* can be relatively easily distinguished and have been recognised from the upper shore of the sheltered sites of Lawrenny Quay, Pembroke Ferry and Hazelbeach. Distinguishing *L. saxatilis* and *L. arcana* is more problematical and requires examination of the anatomy of the sexual organs. The majority of the rough periwinkles encountered on the study shores can fairly safely be assumed to be *L. saxatilis* as *L. arcana* is characteristic of exposed vertical rock on the open coast (Mill and Grahame, 1990).

As well as *L. saxatilis,* the grape-pip periwinkle *Melarhaphe neritoides* (Linnaeus, 1758) occurs at the more exposed sites. The two species can be difficult to distinguish when hidden in crevices and dead barnacle shells.

The genetic studies of rough periwinkles has provided a good illustration of emerging speciation through ecological rather than geographical separation (Galindo and Grahame, 2014). The monitoring of the different ecotypes and species over the whole set of the Pembrokeshire Marine SAC sites would prove interesting but is beyond the scope of the current work program. This leaves this study with the unsatisfactory scenario of monitoring one of the most common animals at the study sites as a complex of species. There are few published data on longevity in *L. saxatilis.* Hughes (1995) gives a maximum of about four years. Any failure in recruitment might well be picked up by the current data collection method.

4.6.3. Littorina obtusata / fabalis

Difficulties with distinguishing the flat periwinkle species *Littorina obtusata* (Linnaeus, 1758) and *Littorina fabalis* (Turton, 1825) reliably in the field occur mainly on moderately to exposed shores and with juveniles.

A study of these species in Milford Haven by Williams (1990) shows a distinct niche separation between these species on fucoid dominated shores (see Figure 33). *L. obtusata* feeds almost exclusively on *Ascophyllum nodosum* in the middle shore, whereas *L. fabalis* is confined to the lower shore where it feeds on epiphytes of *Fucus serratus*. On Williams's study shore (Sawdern Point, Angle Bay), the colour of *L. obtusata* shells were invariably green and *L. fabalis* yellow.

On more exposed shores, Williams (1990) found flat periwinkles only occurring where there was some algal cover. At exposed sites both species were mainly of the reticulated colour form and there was a less distinct zonation of the species. Nevertheless, *L. obtusata* tended to be on plants of *A. nodosum* or *F. vesiculosus* whereas *L. fabalis* occurred on *F. serratus* in the lower shore.

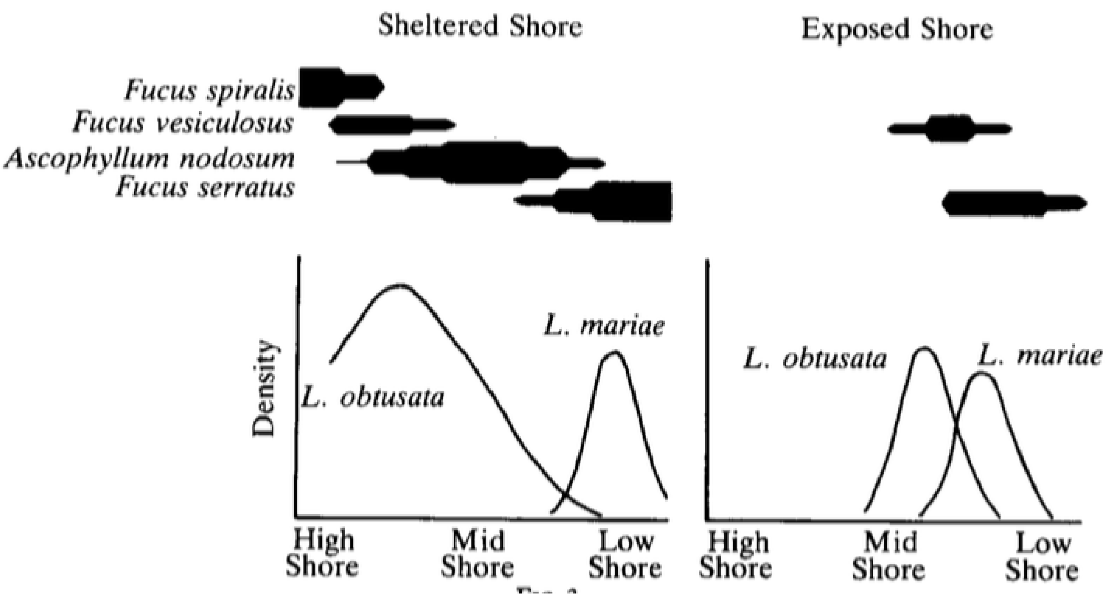

Figure 33. Vertical zonation of *L. obtusata* and *L. fabalis* (formerly known as *L. mariae*). From (Williams, 1990) compiled using several sources.

The two flat periwinkles have very different life histories (Williams, 1990). Whereas *L. obtusata* is a perennial species, living up to 4 years, *L. fabalis* is an annual species, with few individuals surviving more than one year.

Given the distinct ecology of these two similar looking species, it is suggested that on the fucoid covered shores of Lawrenny Quay and Pembroke Ferry, the two species are recorded separately in the field as well as there being a score for 'flat periwinkles' (or *Littorina obtusata / fabalis*). This would be in line with the approach taken with respect to recording the barnacle species.

4.6.4. *Crepidula fornicata*

The slipper limpet *Crepidula fornicata* (Linnaeus, 1758) is an invasive non-native species and abundant (and probably spreading) in Milford Haven. This species is generally confined to the bottom of the lower shore and the subtidal. It doesn't feature in any abundance at the shore monitoring sites because they are too high up the shore. An exception to this is the lower shore at Hazelbeach, where *C. fornicata* occurs on cobbles on an almost flat and so damp area of lower shore.

Here there has been an apparent increase in abundance over the time of the study. This is in line with general observations by divers in Milford Haven (Bunker unpublished and Bunker (2011).

4.6.5. *Littorina littorea*

Large populations of the edible periwinkle, *Littorina littorea* (Linnaeus, 1758) graze the rocky shores at Hazelbeach and Pembroke Power Station and together with other molluscs, result in a low abundance of macroalgae at these sites. *L. littorea* is a herbivore which feeds on diatoms, algal sporelings, vegetable detritus and larger seaweeds and may also ingest animal detritus (Moore, 1980). Individuals are known to be capable of living in excess of 20 years (Woodward, 1913).

Chapman and Johnson (1990) reviewed how intertidal and subtidal algal assemblages are maintained in the NW Atlantic (where many of the dominant intertidal species are the same or similar to the UK). They concluded that intertidal seaweed beds were maintained by carnivory of whelks reducing filter feeder populations, and by herbivorous periwinkles which reduce ephemeral algal populations. Also, that through most of the intertidal zone, disturbance, both biological and physical will dictate which species shall compete and the equilibrium conditions subsequently obtained. Periwinkles such as *L. littorea* were reported to eat mainly ephemeral algae and fucoid sporelings but rarely adult fucoids. The preferential grazing of ephemeral algae, enabled fucoid sporelings to settle and grow.

In the NW Atlantic, *L. littorea* is considered to be the most important grazer in the intertidal zone while in Europe, limpets are generally considered to be the most important grazing species (Norton, Hawkins *et al*., 1990). This is not always the case. A study in Heligoland by Janke (1990) carried out field experiments in the US, MS and LS examining competition between competitors for space *(Mytilus edulis* and macroalgae), herbivores (*Littorina* spp.) and predators (mainly *Carcinus maenas*). The US (occupied by *Littorina* spp. and *Enteromorpha* spp.*)* showed that a natural density of herbivores could not prevent algal settlement and had only little influence on algal growth. Instead, abiotic factors e.g. storms, decreased the stock of the green algae. The mid and lower intertidal were found to be influenced to a high degree by biological interactions. Herbivory by *L. littorea* and competition for space between mussels and macroalgae were the main determinants of community structure in the MS, whereas predation (mainly by *Carcinus maenas*) became significantly important in the lower intertidal.

Carlson, Shulman *et al*. (2006) reported that *L. littorea* may achieve relatively higher densities at more rugose sites because these sites provide (1) more damp, shaded areas in which snails can escape thermal and desiccation stress; (2) more crevices that serve as refuges from predators; and/or (3) greater surface area or more attractive surfaces for recruitment. The shores of both Hazelbeach and Pembroke

Power Station are formed of very pitted sandstone rock and this may well be a major factor accounting for the large populations at these site.

Based on the studies cited above, it is surmised that the dense populations of both *L. littorea* and *Patella* spp. at Hazelbeach and Pembroke Power Station prevent seaweed populations becoming established (especially in the middle shore) of these sites. The yearly fluctuations in abundance seen particularly at Hazelbeach are probably due to several factors including the fact that *L. littorea* is a mobile species and will move in or out of the quadrats over time. Also, in hot dry conditions, *L. littorea* will tend to seek refuge in crevices, etc. (Moore, 1980).

4.6.6. Nucella lapillus

The biology and ecology of the dogwhelk *Nucella lapillus* (Linnaeus, 1758) is summarised in Crothers (1985) and Fretter (1985). During these Pembrokeshire Marine SAC intertidal monitoring studies, *N. lapillus* was recorded at highest frequencies at the exposed shores of South Hook and Nolton Haven and at both sites the abundance varied quite markedly from year to year (see Section 3.6.6). It is most likely that this is due to the mobile nature of this species. Dogwhelks tend to form aggregations when breeding or sheltering from bad weather (Burrows and Hughes, 1989; Fretter, 1985). Whether or not *N. lapillus* aggregations are recorded in the quadrats will depend on their movements at the time as well as availability of suitable microhabitats. The monitoring quadrats are situated where possible on flat rock, avoiding crevices and overhangs and would not tend to attract dogwhelk aggregations.

Dogwhelks are estimated to live for between 5 and 6 years (Fretter, 1985) and so it is unlikely that mortality will account for any observed year on year variation. Animals of different size have been observed in the quadrats and on occasion, egg cases are present indicating breeding populations. Dogwhelks are not recorded in large numbers at the sheltered sites in Milford Haven, which is typical for this species (Fretter, 1985).

N. lapillus feeds primarily on barnacles and mussels and tend to stick to the same food source until it is in short supply, only then will they change to another prey species. Fretter (1985) notes that this can have a profound effect on the shore ecology. This point is illustrated well by Crothers (1985) in a photograph of the shore west of Mioness where selective predation of *Nucella lapillus* seems to have restricted distribution of *Semibalanus balanoides* to a narrow band near high water mark. Even amongst barnacles, *N. lapillus* shows preference for prey species. In Milford Haven, the favourite prey of *N. lapillus* is considered to be the barnacle *Semibalanus balanoides* (which it prefers to other barnacle species) whereas in SW England it has been shown to be the mussel *Mytilus edulis* (Crothers, 1985). It is possible that the decline of *Mytilus edulis* highlighted in Sections 3.6.6 and 4.6.6 could be partly due to predation by *N. lapillus*.

4.6.7. Gibbula cineraria

The grey topshell, *Gibbula cineraria* (Linnaeus, 1758) is found almost exclusively on the lower shore and is described in detail by Fretter and Graham (1977). This species is said to prefer gently sloping, rather than steep shores and does not thrive where there is dense seaweed cover or mud. The decline of this species at Lawrenny Quay in 2014 may be linked with the increase of mud deposited on the shore during this year but there also appears to be a decline on other study shores in recent years (not linked with mud). *G. cineraria* disperses via a planktonic phase and it could be that sites become re-populated over time. Underwood (1972) postulated that temperature stimulates spawning in *G. cineraria* and following studies in Plymouth, he concluded that conditions are not sufficiently stable in southern Britain for successful spawning of *G. cineraria* to occur every year. It may be that a decline of *G. cineraria* populations on the Milford Haven study shores could be associated with unfavourable temperature regimes over recent years.

As *G. cineraria* is primarily a sublittoral species, it would be of interest to scrutinise information on distribution and abundance at subtidal monitoring sites in Pembrokeshire Marine SAC. It must be remembered that *G. cineraria* is a mobile species and fluctuations in abundance can result from movement in and out of the fixed quadrat positions from year to year.

4.6.8. Gibbula umbilicalis

The purple topshell *Gibbula umbilicalis* (da Costa, 1778) is a southern species and since the mid 1980’s has been documented as extending its northern range due to of the onset of global climate warming (Mieszkowska, Milligan *et al*., 2013).

G. umbilicalis occurs mainly in the middle and lower shore (higher in pools) and is tolerant of 75% emersion. Breeding takes place is spring and early summer with settlement in the autumn after a brief planktonic phase (Fretter and Graham, 1977).

On the monitoring shores, *G. umbilicalis* is commonest at Hazelbeach, Monk Haven and West Angle Bay. The abundance can be seen to vary over time, sometimes quite markedly but there are no obvious patterns observable in the data (see section 3.6.8). Kendall and Lewis (1986) commented that studies in Aberaeron showed how severe winters can adversely affect juveniles. There have been no particularly harsh winters since this monitoring program commenced but in future years this could affect the populations. Kendall and Lewis (1986) also noted how sedimentation deters settlement of larvae and following the sedimentation at West Angle Bay in 2014 it will be of interest to see whether this affects the population in coming years. The longevity of adults in this area is not known but Lewis (1986) reports that this varies with latitude. *G. umbilicalis* can live 8 to 12 years in N. Scotland but only two years in Portugal. As this species may live for a number of years, it could be a few years before population numbers obviously decrease.

4.6.9. Phorcus lineatus

The toothed topshell, *Phorcus lineatus* (da Costa, 1778), is a southern species and like *Gibbula umbilicalis* has extended its northern range since the mid 1980’s which is considered to be due to global climate warming (Mieszkowska, Milligan *et al*., 2013).

P. lineatus occurs between the lower shore and mean high water neaps (Fretter and Graham, 1977). In some populations *P. lineatus* has been shown to migrate up the shore in summer and down in winter but this is not always the case (as discussed in Crothers (2001)).

Breeding occurs in summer with a brief planktonic stage of 4 to 5 days (Fretter and Graham, 1977). *P. lineatus* is vulnerable to temperature fluctuations. Whereas a warm summer seems to benefit recruitment of this species, a cold winter can adversely affect populations (Crothers, 1998).

P. lineatus is most numerous at Hazelbeach and Pembroke Power Station monitoring sites but no distinct changes in abundance can be seen from the monitoring data (see section 3.6.9).

The subject of longevity of adults at West Angle Bay was reported in Kendall (1987) to be a maximum of 11 years.

4.7. Bryozoa

4.7.1. Alcyonidium gelatinosum, mytili and polyoum

Alcyonidium species are mainly found at the two most sheltered study sites, Lawrenny Quay and Pembroke Ferry. They are most abundant at Lawrenny Quay where they are mainly found on the lower shore growing on *Fucus serratus*. The recorded abundance has varied from year to year quite markedly at Lawrenny Quay with a distinct decline noted in 2014, which also occurred at Pembroke Ferry. 2014 was a relatively hot and dry summer compared to previous years which may not be favourable for soft bodied invertebrates like *Alcyonidium* spp.

The littoral species of *Alcyonidium* are discussed and described in Ryland and Porter (2006). Five species of *Alcyonidium* are found commonly on rocky shores; *Alcyonidium diaphanum*, Alcyonidium *gelatinosum*, *Alcyonidium hirsutum*, *Alcyonidium mytili* and *Alcyonidium polyoum*.

A. diaphanum and *A. hirsutum* are distinctive (and are recorded separately in this study) but the other three species are easily confused unless in breeding condition. *A. mytili* is oviparous, whereas *A. gelatinosum* and *A. polyoum* are larviparous.

A. gelatinosum and *A. polyoum* can be distinguished morphologically, for example, by gut shape, tentacle number, but these are not good field characteristics.

In the field, breeding season is the main distinguishing characteristic, as *A. gelatinosum* is a winter breeder (like *A. hirsutum*) and *A. polyoum* reproduces in summer or autumn. With *A. gelatinosum*, embryos are white, pink or red, and occur in clusters of 3 to 4 in autumn to early spring. In *A. polyoum*, embryos are buff and occur clusters of 6 to 7 and are visible clusters (April to September or September to December) depending on location.

A. gelatinosum and *A. hirsutum* are described by Ryland and Porter (2006) as being by far the most widespread and abundant species on rocky shores.

It would be of interest to undertake a detailed study of the *Alcyonidium* in Milford Haven to establish exactly which species are present at the monitoring sites and in what abundance.

4.8. Ascidians

4.8.1. Corella eumyota

Collin, Oakley *et al*. (2010) report the southern hemisphere ascidian *Corella eumyota* Traustedt, 1882, first record in the northern hemisphere in Brittany, France, in 2002. Since then, it has been recorded in Spain, Ireland, the south coast of England and south Wales. Bishop, Wood *et al*. (2015) states records of *C. eumyota* from Fleetwood on the northwest coast of England and on the east coast as far north as Sunderland. *Corella eumyota* has also been recorded on the west coast of Scotland (Beveridge *et al*. 2011).

Whereas *C. eumyota* was initially thought of as a species colonising artificial habitats such as marinas (Collin, Oakley *et al*., 2010), it is now know to occur on natural and semi-natural shores (Bishop, Wood *et al*. (2015) and this study).

C. eumyota was first recorded at Lawrenny Quay in 2011 and since then there has been a record from South Hook in 2014. It may be more widespread in Pembrokeshire Marine SAC but most of the lower shore monitoring stations are too high up the shore to detect this species. The spread of this species in the British Isles has been rapid.

4.8.2. Botrylloides violaceus

Botrylloides violaceus Oka, 1927 was first recognised in the UK from a marina in Plymouth in May 2004 by G. Lambert and C. Lambert (Bishop, Wood *et al*., 2015). Following this first sighting, a 2004 rapid assessment survey (RAS) of marinas of the south coast of England (Arenas, Bishop *et al*., 2006) showed *B. violaceus* to be widespread on the south coast (and to be present in a variety of colour forms). This suggested that *B.* violaceus had been present for some time, presumably being overlooked through confusion with the (putatively) native species *Botrylloides leachii* (Savigny, 1816).

During the 2004 RAS, an additional *Botrylloides* species, recognisable by its distinctive two-colour pattern (in contrast to the predominantly single-coloured appearance of *B. violaceus* colonies) and presumed to be non-native, was noted, but not included in Arenas *et al*. (2006) because of uncertainty over its identity.

Bishop, Wood *et al*. (2015) referred to this entity as *Botrylloides diegensis* Ritter and Forsyth, 1917. During investigations of *B. violaceus* collected from both sides of the English Channel, specimens resembling *B. violaceus* in general external appearance were encountered but, based on DNA sequencing, were conspecific with the distinctive colour morph of *B. diegensis*. This shows that these two species could easily be confused and clear morphological distinctions (apart from those of the seasonally brooded larvae) were not available.

Bishop, Wood *et al*. (2015) reports the presence of *B. violaceus* only where its identity has been confirmed by DNA analysis or by the presence of the distinctive embryos. In *B. violaceus* the embryos are very large, the larvae are pink-purple in colour and brooded in the colonial tunic after the regression of the maternal zooid. The larvae of *B. diegensis* are much smaller and are brooded alongside the abdomen of the maternal zooid, and have about 8 vascular ampullae compared to more than 20 in *B. violaceus*. Similarly, Bishop, Wood *et al*. (2015) only recorded *B. diegensis* where confirmed by DNA analysis or by the occurrence of the distinctive colour morphs.

B. violaceus was first recorded from Lawrenny Quay in 2008 and from Pembroke Ferry in 2010. *B. diegensis* has not been recorded but due to the possible confusion of the two species as outlined above, it is recommended that regular collections of *Botrylloides* species be collected to check identifications. The graphs shown in Figure 29 (section 3.8.2) imply that *B. violaceus* was not present after 2012. This may be so for the monitoring quadrats but this species is common on the lower shore below the level of the quadrats.

4.9. Barnacles

Barnacles are the commonest animals on most of the study shores and yet are the most problematic to identify and count.

Frequency, which is the primary measure of abundance in this project is not suitable for comparing cover or proportions of the different species. For example, *Semibalanus balanoides* may be in all 25 squares of a gridded quadrat but in ones and two's whereas *Austrominius modestus* may also be in all squares but be very abundant or *vice versa*. For this reason, four different strategies have been adopted for recording barnacles, each with a different purpose:

1. To determine the total frequency of all Cirripedia species together (i.e. total barnacles except *Perforatus perforatus*) in the quadrats.

2. To record the percentage cover of all Cirripedia (except *P. perforatus*) in 5 randomly selected 20 cm x 20 cm squares in each quadrat.

3. To record barnacle proportions using photographic means. Multiple 5 x 5 cm quadrats were photographed at each shore level for later analysis. (It isn't in the scope of this contract to analyse the photographs but a recent initiative by NRW has enabled the photographs to be analysed and the results of this will be available in the near future).

4. To attempt to record frequencies of each separate species in the 1 m^2 quadrats. It is difficult to accurately score frequencies from large 1 m^2 quadrats. This is especially so where barnacles are dense (Hazelbeach and West Angle Bay) and at South Hook where quadrat positions in the middle shore are difficult to access and at Lawrenny Quay where the rock is covered in silt and fucoid mats dominate the quadrats. In fine weather, barnacle identification is easier than in inclement weather. Between recorder errors are another factor that must be considered as experienced field workers may differ in the way that they record the different species.

With the exception of *Perforatus perforatus*, barnacle frequencies have been rather inconsistently recorded over the duration of this project with data missing from some years. Better QA in recent years has led to better recording from the 1 m^2 quadrats but the frequency data on individual species to date is fairly piecemeal and for this reason has not been included here.

4.9.1. *Perforatus perforatus*

The volcano barnacle *Perforatus perforatus* (Bruguière, 1789) is a southern species towards its northern distribution limits in the British Isles, occurring predominantly in south west England and south Wales. This is a large and conspicuous species confined to the lower shore (and shallow subtidal) where it can out-compete *Semibalanus balanoides* and *Austrominius modestus* (Rainbow, 1984). *P. perforatus* is readily identifiable and doesn't present the same challenges of identifying and counting that can bedevil the other barnacle species.

P. perforatus is an open coast species and in this set of Pembrokeshire Marine SAC monitoring sites, it is found at greatest abundance at Nolton Haven (and also the rockpool monitoring site of Pen-y-holt). It also occurs in significant numbers at monitoring sites at South Haven, North Haven and Martins Haven in the Skomer MCZ (Mark Burton personal communication).

In Milford Haven *P. perforatus* occurs in small numbers at shores near the entrance to the waterway at South Hook and West Angle Bay. This concurs with similar patterns seen by the author in drowned river valleys elsewhere and documented for the Ria del Arosa in Spain (Macho, Vázquez *et al*., 2010).

P. perforatus in known to be particularly susceptible to mortality in cold winters. Moyes and Nelson-Smith (1964) relate a total demise of *P. perforatus* in south Wales during the severe winter of 1962-63. Herbert, Hawkins *et al*. (2003) published on the range extension and reproduction of *B. perforatus* in the eastern English

Channel. They concluded that range extension is probably induced by a series of warm summers (as happened in the 1990's) and that extreme cold weather (such as occurred in 1962 and 1963) can trim back ranges with recovery taking many years.

Although this species is relatively uncommon at the monitoring sites, it is nevertheless a good species to indicate effects of climate fluctuations on these shores. Out of the shores considered here, *P. perforatus* is most abundant at Nolton Haven (see Section 3.9.1). It must be borne in mind that the lower shore at Nolton Haven is sand scoured and fluctuations in the population may be more due to this than other factors.

4.9.2. Cirripedia except for *Perforatus perforatus*

Four barnacle species comprise the majority of barnacles encountered on the study shores and include:

The acorn barnacle, *Semibalanus balanoides* (Linnaeus, 1767)

Poli's stellate barnacle, *Chthamalus stellatus* (Poli, 1791)

Montagu's stellate barnacle Chthamalus montagui Southward, 1976

The Australasian barnacle, *Austrominius modestus* (Darwin, 1854)

A fifth species, *Balanus crenatus* Bruguière, 1789 is confined to the extreme lower shore and subtidal (where it dominates) and is rarely encountered in the quadrats.

Each barnacle species thrives in a particular set of conditions and the distribution and abundance is governed by a host of both abiotic and biotic factors (see Rainbow (1984) and Mieszkowska, Burrows *et al*. (2014) for useful summaries).

The results shown in section 3.9.1 are more or less as would be expected, where the more exposed shores have the highest abundance of barnacles and the more sheltered shores the least. The graphs in Figure 31 show the barnacle populations remaining fairly constant over time, except for a decline in abundance noticeable at Pembroke Power Station since 2011 and Hazelbeach since 2013. This apparent decline is of interest and warrants further investigation as these are the nearest sites to the Pembroke Power Station outfall that came on-stream in 2011.

Personal observation backed up by those of John Archer-Thomson (ex Dale Fort Field Centre) is that barnacle populations in Milford Haven have shown a general decrease since the 1980's. John Archer-Thomson postulates that this is correlated with an increase in the dogwhelk populations (*Nucella lapillus*) following a ban on the use of TBT antifouling paints on boats which suppressed dogwhelk populations by causing imposex (Spence, Bryan *et al*., 1990). The ban on use of TBT paints by the UK government came into force on boats less than 25 m in length in 1987 and was followed by a total ban in 2008. Recovery of dogwhelk populations following the ban has been well documented in a number of studies e.g. Bray, McVean *et al*. (2012).

The general pattern of barnacle species distribution in Milford Haven is for *A. modestus* to dominate in the upper, more estuarine and sheltered reaches of the waterway (Lawrenny Quay and Pembroke Ferry). *A. modestus* together with *S. balanoides* form the main complement of barnacles on shores in the middle of the waterway (such as Hazelbeach and Pembroke Power Station). These two species are joined by the *Chthamalus* species on the more exposed shores near the entrance to Milford Haven (South Hook, Monk Haven and West Angle Bay) and the open coast (Nolton Haven and Pen-y-Holt).

There is a wealth of published literature on the biology and ecology of the different barnacle species and a knowledge of this helps towards an understanding of the distribution and abundance of the different species, how they vary over time and their importance to monitoring.

The acorn barnacle *Semibalanus balanoides* is a northern species and is the dominant barnacle species on the open coast in the north of the British Isles. Its range extends from Spitsbergen and the White Sea in the North Sea to northern Spain in the south (Fischer-Pietee and Pregnant, 1956 cited Flowerdew and Crisp (1975)). The southernmost populations of *S. balanoides* have contracted in recent years and Wethey and Woodin (2008) reported it from only a single location in North Spain (the Ria de Arosa). *S. balanoides* can live up to 10 years (Mieszkowska, Burrows *et al*., 2014).

Semibalanus balanoides competes directly with the *Chthamalus* species for space on the rocky shore. *S. balanoides* will aggressively outcompete *Chthamalus* when in contact by smothering, undercutting or crushing individuals (Connell, 1961). Whereas *S. balanoides* cyprid larvae settle in spring and early summer, those of *Chthamalus* spp. settle in later summer and early autumn (Southward and Crisp (1956); (Barnes, 1989)). This strategy enables the cyprid larvae of *Chthamalus* spp. to become established on rock unoccupied by *S. balanoides*. *Chthamalus* spp. (particularly *C. montagui*) can withstand higher temperatures than *S. balanoides* allowing it to establish higher up the shore and so avoid competition. The effects of various abiotic and biotic factors and how they influence the distribution of these species are reviewed in Rainbow (1984).

Studies on the sibling *Chthamalus montagui* and *Chthamalus stellatus* show them to have considerable overlap in their vertical distributions on the shore. Crisp, Southward *et al*. (1981) suggest that these sibling species have evolved separately with *C. montagui* originating from circum-boreal and *C. stellatus* from tropical / sub-tropical Atlantic stock. *C. montagui* is normally commoner in embayed situations and *C. stellatus* on more wave exposed sites (and often more numerous lower down the shore). The *Chthamalus* species are considered to be ‘southern’ with temperature being an important factor limiting their distribution to the warmer coasts of the Britain and Ireland. *Chthamalus* spp. are found down the west coast of France and on Portuguese, Spanish and north African coasts and in the Mediterranean (Crisp, Southward *et al*., 1981). *Chthamalus* spp. typically live between two and 5 years (Mieszkowska, Burrows *et al*., 2014).

The importance of temperature to the distribution and abundance of *Chthamalus* spp. and *Semibalanus* over time on study shores in south west England was highlighted in a classic study by Southward and Crisp (1954). This study correlated the settlement of both species over 9 years and correlated success of both species with temperature with *Chthamalus* spp. favouring warm years and *Semibalanus* colder years.

Mieszkowska, Leaper *et al*. (2005) showed via the MarClim project, how intertidal barnacles are ideal for investigating climatic influence on population dynamics. The *Chthamalus* species and *S. balanoides* all reach the edges of their biogeographical distributions around Britain and Ireland and populations at range edges are known to be most sensitive to fluctuations in the environment. 35 years of historical quantitative data was collected by Alan Southward and Denis Crisp. This work was then continued by Steve Hawkins in 1997 and the data were analysed using advanced statistical techniques. The analyses show a negative effect of warm springs on the survival of *Semibalanus balanoides* with the consequence that *Chthamalus* species had less competition and were are able to thrive. Although the biogeographic range of *S. balanoides* in Britain had not changed, this species was less abundant in the 2000s than during the cooler climatic periods of the 1960s and 1970s in south west England and by contrast, the *Chthamalus* spp. were more abundant. Work carried out by Pippa Moore in Plymouth showed that there had been little or no settlement of *S. balanoides* on shores studied around Plymouth in the early 2000's (Moore, 2005).

Poloczanska, Hawkins *et al*. (2008) used the same long term data sets of populations of barnacles in south west England (see Mieszkowska, Leaper *et al*. (2005)) to predict barnacle population abundance over the next century taking into account interaction between *S. balanoides* and the *Chthamalus* spp. Under all the emission scenarios investigated, *S. balanoides* was predicted to virtually disappear from south west England by 2050. Studies on the East Coast of north America (Jones, Southward *et al*., 2012) have shown the range of *S. balanoides* to have retreated 350 km northwards between 1963 and 2007.

The value of long term data sets in providing essential information to enable informed predictions for the future e.g. as a consequence of climate change is eloquently discussed by Hawkins, Firth *et al*. (2013). The paucity of such data sets is also emphasized and underlines the importance of the data collected in this study and the desirability to work up the data on individual barnacle species.

Mieszkowska, Burrows *et al*. (2014) investigated the long-term data sets showing the changes of *Chthamalus* and *Semibalanus* populations in south west England in relation to climatic fluctuations including local sea surface temperature (SST), the North Atlantic Oscillation (NAO) and the Atlantic Multidecadal Oscillation (AMO) to determine which exerts the strongest influences on barnacle abundance and relative dominance. It was concluded that there were strong links with the AMO. Mieszkowska, Burrows *et al*. (2014) showed how barnacles are 'sensitive and easily sampled indicators of oscillations occurring across several trophic levels in the wider coastal marine environment' and their value as a monitoring tool is emphasized.

The final intertidal barnacle to consider here is the non-native species *Austrominius modestus*. This species is an introduction from Australasia that was first recorded in Chichester Harbour and the River Crouch in 1945 (Bishop, 1947 cited Crisp (1958)). Its spread around Britain and Ireland has been well documented (Crisp, 1958; Rainbow, 1984). *A. modestus* was first recorded in Milford Haven in 1951 by Bassindale and Barrett (1957) from Dale Roads. Since then it has spread throughout the shores of the Milford Haven waterway and now dominates the upper reaches of the waterway and is dominant at the monitoring sites at Lawrenny Quay, Pembroke Ferry, Hazelbeach and Pembroke Power Station.

A. modestus is present at all sites towards the entrance to Milford Haven and on the open coast at Nolton Haven but does not dominate. *A. modestus* is most successful in sheltered and estuarine waterways with silty conditions where it outcompetes native species (Crisp, 1958). It is *S. balanoides* that is usually displaced by *A. modestus*. *Chthamalus* species tend to occur mainly towards the mouth of inlets and on the open coast (except in the south west of England) rather than up estuaries (Crisp, 1958).

Crisp (1958) gives several reasons, which account for the success of *A. modestus*. Whereas *S. balanoides* produces one annual brood of embryos which are released in the spring, *A. modestus* produces multiple broods over the summer (when conditions are suitable) and so many more larvae. The cyprid larvae of *A. modestus* are aggressive in their settlement behaviour and where there is no available rock space, they will settle directly onto the shell plates of other barnacles. *A. modestus* shows a greater tolerance to siltation than our native species and to lower salinities than *S. balanoides*. The feeding rate and so growth rate of *A. modestus* is also greater than *S. balanoides*. In waterways where *A. modestus* becomes established it soon becomes the dominant barnacle in the upper reaches. Crisp (1958) suggests that *A. modestus* can replace *Balanus improvisus* in low salinity situations. A useful summary of the ecological requirements of *A. modestus* compared with native species is given in Table 33.

Table 33 Ecological requirements of *A. modestus* (previously *Elminius modestus*) compared with the native species taken from (Crisp, 1958)

ECOLOGICAL REQUIREMENTS OF *ELMINIUS*, COMPARED WITH THE NATIVE SPECIES

Species ...	*Elminius modestus*	*Balanus balanoides*	*Balanus improvisus*	*Balanus crenatus*	*Balanus perforatus*	*Chthamalu stellatus*
Season of settlement ...	May–Oct.	Mar.–Apr.	May–Sept.	Apr.–May	Aug.–Sept.	July–Sept.
Tidal levels occupied ...	M.H.W. to below L.W.S.	H.W.N. to L.W.S.	L.W.N. sub-littoral	L.W.N. sub-littoral	L.W.N. sub-littoral	H.W.S. to M.T.L. (sometime to L.W.N.)
Tolerance of low salinity	+++	+	+++	+	+	−
Tolerance of silt	++	+	+++	+	++	+
Tolerance of low temperatures (below zero)	++	+++	+++	++	−	+
Tolerance of high temperatures (above 20° C)	+++	−	++	−	++	++++
Tolerance of desiccation	+++	++	−	−	+	++++
Resistance to mechanical damage	+	++	+++	+++	++++	++++
Mean rate of cirral beat at 20° C as beats per 10 sec (Southward, 1955*b*, 1957)	17–18	5–6	*ca.* 9	*ca.* 10	*ca.* 7	*ca.* 6

Results of studies in the Ria del Arosa in Spain led to conclude that vertical migration behaviour of larvae act to retain the larvae of *A. modestus* in the upper parts of the estuary and that this is an important factor in allowing it to establish as a dominant species. Whereas *A. modestus* larvae were mainly found in the highest density in the inner part of the estuary, the converse was true of *C. montagui* and reflected the distribution and abundance of these species in the Ria del Arosa.

A. modestus has both expanded its range in recent years and its dominance in sites where it was already established. Witte, Buschbaum *et al*. (2010) relate a recent expansion of the population at the Island of Sylte off the west coast of Denmark. *A. modestus* has been there since 1955 but always in low numbers until 2007 when the population has expanded and overtaken *S. balanoides* to become the dominant barnacle. Witte, Buschbaum *et al*. (2010) refer to *A. modestus* as a non-native 'sleeper' species, which has remained present in low numbers until a series of mild winters and warm summers have allowed it to expand.

Gomes-Filho, Hawkins *et al*. (2010) report on barnacle surveys along the shores of the Plym and the Yealm Estuaries in Devon where they found *A. modestus* to be the dominant species and comparison with data from previous decades showed an increase in abundance at the expense of native species, particularly *S. balanoides*. Here both the decline in abundance of *S. balanoides* in the south-west and the favourable condition inside the estuaries are thought to have contributed to the expansion of *A. modestus* populations.

Gallagher, Davenport *et al*. (2015) reports how *A. modestus* was first found on the Isle of Cumbrae in 1955 and that despite an increase in numbers since that time, *S. balanoides* is still the dominant species at the monitoring sites. Whether this will change over time if the climate changes at this northerly location remains to be seen. The abundance of *A. modestus* at the Pembrokeshire Marine SAC monitoring sites should be followed with interest.

4.10. Summary

Fluctuations in the populations of shore species over time are to be expected. Mieszkowska (2013) summarises the results of surveys of 43 shore sites studied in 2012 in Wales (36 in north Wales and seven in south Wales). These included 32 sites studied over an 11 year time series. It was concluded that the community composition at the majority of sites did not show major changes in abundance over 11 years. Also that increases in warm water species abundances and decreases in cold-water species abundances were only sufficient to drive small shifts in the SACFOR category at each and that this did not cause a significant alteration in overall rocky shore community structure. Mieszkowska (2013) surmised that at shores where community composition had altered across the time-series this was often due to cyclical fluctuations in macroalgae corresponding to ‘interaction between lifecycle dynamics and environmental temperature or a pulse recruitment event of an invertebrate (e.g. *Mytilus* spp.) that has subsequently declined to lower abundances or disappeared again from the site’.

This report examines how records of selected species have varied over time.

The focus on individual species described in this report has attempted to link apparent changes in abundance over time with our current knowledge of the ecology of the selected species. There are big holes in our knowledge concerning the ecology of many of our common shore species but it is considered useful to speculate on why observed changes occur and provide possible targets for future autecological study.

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Appendix 1 Data Archive

Data outputs associated with this project are archived at Project Number 199, Media Number 556 (for 2004 – 2010 data) and 1221 (for 2007-2010 data) on server–based storage at Natural Resources Wales.

http://libcat.naturalresources.wales (English)

http://catllyfr.cyfoethnaturiol.cymru (Welsh)

The data archive contains:

[A] The final report in Microsoft Word and Adobe PDF formats.

[B] Spreadsheets of site and species data: Pembs Quadrat Data 2011 v5 MR.xls
Pembs Marine 2012 QA and Wormed.xlsx
Pembs Marine 2013 data_qa_wormed_noaverages.xlsx
Pembs Marine 2014 bedrock with QA v2.xlsx

[C] A full set of images produced in jpg format.

[D] Species data are held in Marine Recorder.

Metadata for this project is publicly accessible through Natural Resources Wales' Library Catalogue http://libcat.naturalresources.wales/webview/ by searching 'Dataset Titles'

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